# การพัฒนาเส้นใยพีแอลเอ/พีอีโออิเล็กโตรสปันแบบสององค์ประกอบชนิดข้างเคียงข้าง

นายสุทธิพันธุ์ ภวสุปรีย์

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ปีการศึกษา 2555

# DEVELOPMENT OF SIDE-BY-SIDE PLA/PEO BICOMPONENT ELECTROSPUN FIBER

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A Dissertation Submitted in Partial Fulfillment of the Requirements

for the Degree of Doctor of Philosophy Program in Nanoscience and Technology

(Interdisciplinary Program)

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| Thesis Title | DEVELOPMENT OF SIDE-BY-SIDE PLA/PEO BICOMPONENT ELECTROSPUN FIBER |
| By | Mr. Suttipan Pavasupree |
| Field of Study | Nanoscience and Technology |
| Thesis Advisor | Ratthapol Rangkupan, Ph.D. |
| Thesis Co-advisor | Associate Professor Kawee Srikulkit, Ph.D. |

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สุทธิพันธุ์ ภวสุปรีย์ : การพัฒนาเส้นใยพีแอลเอ/พีอีโออิเล็กโตรสปันแบบสององค์ประกอบชนิดข้างเคียงข้าง. (DEVELOPMENT OF SIDE-BY-SIDE PLA/PEO BICOMPONENT ELECTROSPUN FIBER) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: อ.ดร.รัฐพล รังกุพันธุ์, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม : รศ. ดร.กาวี ศรีกูลกิจ, 180 หน้า.

การวิจัยนี้ได้แบ่งออกเป็น3ส่วน ส่วนแรกคือการศึกษาปัจจัยในการขึ้นรูปที่มีผลต่อลักษณะเส้นใยโพลิแลคติกเอซิดโดยกระบวนการปั่นเส้นใยแบบไฟฟ้าสถิต ผลการทดลองพบว่าการลดความเข้มข้นของสารละลายทำให้ขนาดเส้นใยลดลง เมื่อเพิ่มอัตราส่วนของไดเม็ทธิลฟอร์มาร์ไมด์ในสารละลายส่งผลให้ขนาดเส้นใยเล็กลงและเกิดเส้นใยที่มีบีท การเพิ่มความต่างศักดิ์ทางไฟฟ้าส่งผลกระทบ2อย่างคือเพิ่มและลดขนาดเส้นใย อัตราการไหลของโพลิเมอร์และระยะห่างระหว่างหัวเข็มกับฉากรับเส้นใยมีผลเพียงเล็กน้อยต่อขนาดของเส้นใย ส่วนที่2 คือการศึกษาปัจจัยในการขึ้นรูปเส้นใยอิเล็กโตรสปันแบบสององค์ประกอบแบบข้างเคียงข้าง ด้วยกระบวนการปั่นเส้นใยแบบไฟฟ้าสถิตแบบหัวเข็มร่วมกัน โดยใช้โพลิแลคติกเอซิดกับโพลิเอทิลีนออกไซด์เป็นโพลิเมอร์ต้นแบบในการศึกษา จากผลการทดลองพบว่าพื้นผิวของเส้นใยสามารถควบคุมด้วยระบบตัวทำละลายของโพลิแลคติกเอซิด ซึ่งประกอบด้วยผิวรูพรุนกับผิวเรียบ ขนาดเส้นใยเพิ่มขึ้นเมื่อเพิ่มความเข้มข้นของโพลิเอทิลีนออกไซด์ ซึ่งส่วนประกอบของเส้นใย ลักษณะเส้นใย และขนาดเส้นใยสามารถควบคุมได้ด้วยอัตราราส่วนการไหลของโพลิแลคติกเอซิดกับโพลิเอทิลีนออกไซด์ ในขณะที่ความต่างศักย์ทางไฟฟ้ามีผลเพียงเล็กน้อยต่อขนาดเส้นใย สุดท้ายนี้เมื่อละลายเนื้อของโพลิเอทิลีนออกไซด์ออก จะได้โครงสร้างเส้นใยรูปตัวซี ส่วนที่3 ได้ทำการศึกษาความเป็นไปได้ในการใช้งานด้านการกรองของโพลิแลคติกเอซิดโครงสร้างรูปตัวซี โดยใช้โพลิแลคติกเอซิดโครงสร้างรูปตัวซีไปปรับปรุงประสิทธิภาพการกรองของแผ่นกรองทั่วไปที่ใช้ทำหน้ากาก ผลการทดลองแสดงถึงโพลิแลคติกเอซิดโครงสร้างรูปตัวซีมีการกักเก็บอนุภาคการกรองที่สูงกว่าและยังมีประสิทธิภาพ การกรองสูงกว่าแผ่นกรองทั่วไป23เปอร์เซ็นต์

สาขาวิชา วิทยาศาสตร์นาโนและเทคโนโลยี ลายมือชื่อนิสิต ..........

ปีการศึกษา 2555 ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก ..........

ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์ร่วม ..........

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SUTTIPAN PAVASUPREE: DEVELOPMENT OF SIDE-BY-SIDE PLA/PEO BICOMPONENT ELECTROSPUN FIBER. ADVISOR : RATTHAPOL RANGKUPAN, Ph.D., CO-ADIVISOR : ASSOC.PROF. KAWEE SRIKULKIT , Ph.D., 180 pp.

This research can be divided into 3 main parts. The first part, the investigation of processing parameters effect on morphology and formation of poly(lactic acid) (PLA) fiber in electrospinning process. We found the fiber size decreased with decreasing concentration. High DMF ratio solvent also tended to yield smaller fibers and smoother surface. Increasing applied voltage showed both effect of increased and decreased on fiber size. The flow rate and gap distance had a small effect on fiber size. In the second part, the apparatus for electrospinning of bicomponent fiber with side by side geometry was developed. Effect of key processing parameters on fiber formation of bicomponent electrospinning were studied in detail, using PLA and poly(ethylene oxide) (PEO) as polymer model system. The surface of fiber can control by PLA solvent system which consist of porous surface and smooth surface. The fiber size increased with increasing PEO concentration. The compositions and fiber formation can control by flow rate ratio, while an applied voltage showed minor impact on the fiber size. Finally, After PEO phase removal, the C-shape ultrafine fiber was generated. In the final part, we demonstrated potential use of C-shape PLA electrospun fiber derived from PLA-PEO bicomponent fiber in filtration application. The C shape PLA fabric was used to improve filtration efficiency of a conventional filter media used in ordinary personal mask. The result showed that the C-shape modified filter media had higher filtration particulate loadings, while also improved filtration efficiency of the media by 23% compared to the conventional one.

Field of Study: Nanoscience and Technology ........ Student's Signature ..............................

Academic Year: 2012 .............................. Advisor's Signature ..............................

Co-advisor's Signature ..............................

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# CHAPTER I

# INTRODUCTION

## 1.1 Introduction

Electrospinning process is a simple and versatile method suitable for fabrication continuous polymer fibers with diameter in the range of nanometer to micrometers. Typical electrospun fiber mat consists of ultrafine to nanometer scale fiber with smaller pores size, higher specific surface area and higher porosity than a conventional fabric. It can be used for various applications such as filtration, tissue engineering, scaffolds and sensor etc.

Until recently, most electrospun fibers were prepared from a solution of homopolymer or polymer blend without clear distinction between each phase These monocomponent and blended electrospun fibers are extremely useful for many applications, such as PLA-PEO hybrid scaffolds for drug delivery application that were electrospun from polymer blend by Honarbakhsh, S., and Pourrdeyhimi [1]. Given such benefit from ordinary electrospun fiber, fibers made of two or more components with different property could offer even more advantages. Recent development in this field led to a new processing technique which can produce electrospun fibers composed of two or more that components co-existed throughout the length of the fiber. These so called bicomponent/multicomponent electrospun fibers offer researchers opportunities to enhance fiber property, produce novel fibrous structure and improve the functionality of nanofiber.

Newly developed nanofiber structure from bicomponent electrospinning process include size-by-size [2], core-shell [3,4] and hollow fiber [5] geometry. Utilization potential of the bicomponent electrospun fiber is very promising especially for applications [6] such as filtrations, tissue engineering [7], scaffolds [8], encapsulation [9], and drug delivery [10], since it can be use

- To protect and minimize degradation of unstable inner component from harsh or degrading environment.
- To allow control over delivery kinetic of drugs in multiple stages release or to be incorporated with incompatible drugs by using 2 different matrix.
- To tailor mechanical property [11], surface functionality or degradation behavior of nanostructure such as those used in tissue engineering application.
- To use advantage properties of each materials which high efficiency
- To use as a template to create other novel geometry structure.
- To create non-electrospinnable materials

Research for bicomponent electrospinning process had been focused mostly with core-shell structure from both application and processing stand point. Research for bicompoment electrospinning process with side-by-side geometry, on the other hand, had been carried out in much lesser number. Most of them were emphasized on application development aspect as presented in the following context. Lacks of sufficient understanding on how each processing parameter in side-by-side bicomponent electrospinning affects fiber formation, fiber property and overall processability leaves room for our exploration of the domain. We expected that our finding would contribute to a better understanding of how to control, manipulate and prepare bicomponent electrospun fibers with tailored geometry and functionality that suitable specifically for each application in the future.

In the later part of this study, we had demonstrated potential use of nylon 6 electrospun nanofibers and PLA/PEO side by side electrospun fibers as a filtration efficiency enhancer for typical filter media used in personal mask. The health hazardous is depending on particles size, concentration, shape and composition of air pollutant. The particle in the air composes of from large size to smaller size. Indoor air pollutant can be prevent by using the human respiratory system, it have a standard guideline, accommodate larger than 0.3 μm of the particles size. The cigarette smoke is problem in indoor air quality (IQA). The aerosol particulate matter of smoke have a researches which have particle size from 0.01 to 1 μm. [12,13] Then the small particle can pass through the human respiratory system. The advantage of electrospun fiber for filtration application arise from have a small fiber size, small pore size and high surface area. These properties were support for filtration**.** Then the electrospun fibers expect increasing the filtration efficiency properties.

**1.2 Objectives**

1. To investigate effect of processing parameters, i.e. solvent system, solution concentration, solution flow rate, applied voltage and gap distance on morphology and characteristics of poly(lactic acid) (PLA) electrospun fiber.
2. To develop an apparatus for bicomponents electrospinning with side by side geometry.
3. To prepare and characterize PLA/poly(ethylene oxide) (PEO) bicomponents electrospun fiber with side by side geometry.
4. To investigate effect of processing parameters, i.e. PLA solvent system, PEO concentration, solution flow rate ratio and applied voltage on the formation and morphology of obtained bicomponents fibers.
5. To demonstrated potential use and of nylon 6 electrospun nanofibers and PLA/PEO side by side electrospun fibers as a filtration efficiency enhancer for typical filter media used in personal mask.

## 1.3 Scope

In this research, we will investigate the effects of processing parameter, i.e. solvent system, solution concentration/viscosity/conductivity/flow rate, applied voltage and spinneret design on morphology and formation of fiber obtained from single and side-by-side electrospinning. The emphasis of bicomponents fiber preparation will be put on the side-by-side electrospinning process. PLA and PEO are selected as polymer pair model for the study because of their good spinnability, relatively uniform fiber formation, different hydrophilicity and potential use in biomedical application. In addition the modification of filter with Nylon6 nanofibers and C-shape PLA fiber were investigated for air filtration application.

# CHAPTER II

# THEORY AND LITERATURE REVIEW

## 2.1 Electrospinning process

### 2.1.1 Introduction to electrospinning process

Typical electrospinning process set up consists of a polymer solution reservoir connected to a fine spinneret, a stationary or rotating fiber collector and a high voltage power supply with its high voltage line connect to the spinneret, and its counter electrode connect to the collector. Flow rate of the solution is usually controlled by syringe or metering pump to improve fiber size uniformity. Figure2.1 shows schematic diagram of a typical set up of elctrospinning process.

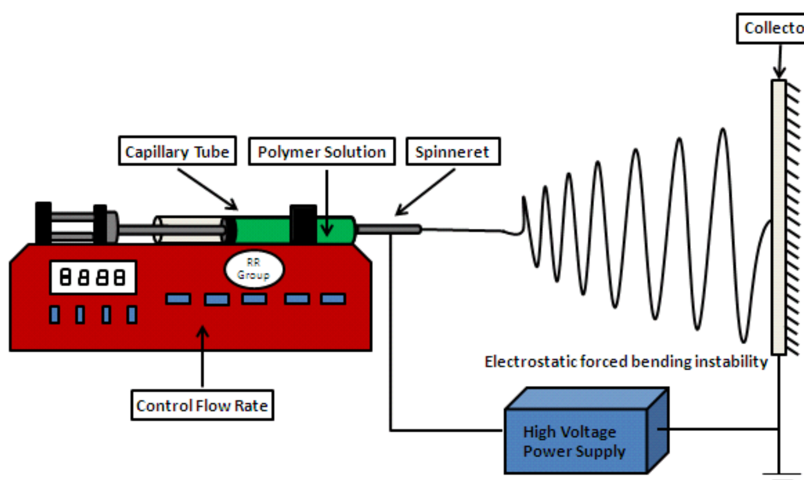



Figure 2.1 Schematic diagram of typical set up of elctrospinning process.

In the process initial step, polymer solution forms a droplet at the tip of the spinneret. Under applied electric field, the droplet is deformed into a conical shape, or so called Taylor's cone, by electrostatic repulsion force from induced surface charges. When the charge repulsion overcomes surface tension of polymer solution, a charged jet initiates from the apex of the

Taylor's cone. As the emitted jet travels from the spinneret to the collector, it elongate many times via electrically driven bending stability making the jet thinner and thinner. At the same time, solvent evaporation stiffen the jet making it more and more difficult to stretch until the jet fully solidifies and forms the fiber. Figure2.1 shows schematic of electrospinning process.

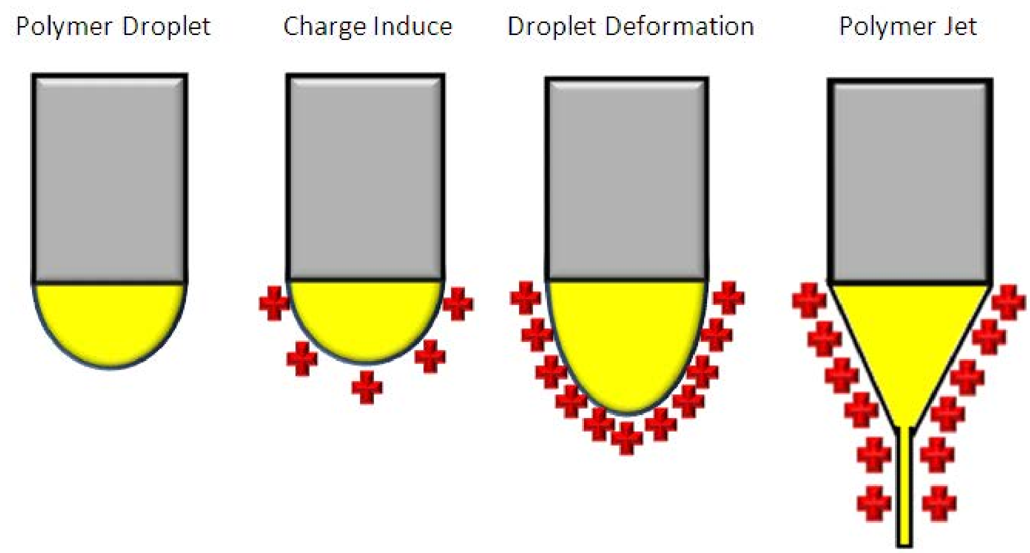



Figure 2.2 Schematic of electrospinning process.

### 2.1.2 Electrospinning parameters

Processing parameter in the process that influence morphology and spinning behavior of the include 3 main parameters. The first is materials parameter such as molecular weight of polymer, solvent type, concentration, viscosity, surface tension and conductivity of polymer solution. The second is processing parameters such as applied voltage, distance between spinneret and collector, solution flow rate of polymer and collector speed. The third is environment parameters such as room temperature and humidity.[14-21] Among these parameters, solution viscosity and applied voltage are the most critical parameters that govern fiber formation.

#### 2.1.2.1 Materials parameters

##### 2.1.2.1.1 Solution viscosity

The solution viscosity is important parameter influencing on the morphology and fiber formation. The difference of solution viscosity can be eletrospun is different such as morphology (bead on the fiber and fiber without bead) and fiber size (small to large). The bead formation on the fiber decreased with increasing solution viscosity. The fibers size increased with increasing solution viscosity.

##### 2.1.2.1.2 Solution conductivity

Solution conductivity means a measure of solution property to conduct an electric current. In the elctrospinning process, the polymer solution requires the transfer of charge on the solution surface then the solution conductivity is essential for electrospinning technique. The solution conductivity is effect of elongation in polymer solution jet which influence on morphology and fibers formation. Higher conductivity is easier the transfer of charge on the surface. The polymer solution of zero conductivity cannot produce electrospun fibers. The fiber size decreased with increased solution conductivity.

##### 2.1.2.1.3 Solution concentration

The polymer solution need to adequate chain entanglement to produce continuous uniform fibers. The polymer solution concentration is influence on morphology and fibers formation. Increasing polymer solution concentration is results in higher polymer chain entanglement in the solution which tend to increasing fibers size. Low polymer solution concentration result in bead formation on the fibers.

##### 2.1.2.1.4 Molecular weight

Molecular weight has effect on the solution properties such as viscosity, surface tension and conductivity. Increasing molecular weight also tend to increased chain entanglement.

#### 2.1.2.1.5 Surface tension

Surface tension is opposite force of charge repulsion force or coulomb repulsion force. The polymer jet will occur, when the charge repulsion force overcome surface tension.

#### 2.1.2.1.6 Volatility

Volatility is the evaporation of solvent from the polymer jet that the fibers will from the fibers on collector. During the process of electrospinning, the solvent will evaporation from the fibers on collector. If not, the wet fibers will generate on the collector.

### 2.1.2.2 Processing parameters

#### 2.1.2.2.1 Applied voltage

The applied voltage (V), (kV) induces the charge on the surface polymer jet. The polymer solution will eject from the tip to collector when charge repulsion overcome surface tension. The applied voltage is importance parameter on morphology and fibers formation. The applied voltage increased tends to increasing charge repulsion.

#### 2.1.2.2.2 Solution flow rate

The polymer solution flow rate is pumped into the spinneret to continuous of Taylor's cone. The feed rate is importance parameter on morphology and fibers formation. Ideally, the feed rate must balance between input and output from the spinneret, there can produce uniform fiber. At lower and higher feed rate influence Taylor's cone and polymer jet that effect on fiber formation.

#### 2.1.2.2.3 Gap distance

The gap distance (d) is the distance between the tip of spinneret and the surface of collector. It defines time for evaporation of the solvent on the polymer jet and influence on strength of electric field.

#### 2.1.2.3 Environmental parameters

The majority research of electrospinning carried out in the air but it can control environment which spinning in the chamber. The environmental parameters have a many things such as room temperature, humidity, gaseous environmental etc. these are influence on morphology and fiber formation. Example high room temperature tends to high evaporation rate. However environmental parameters are difficult set up in laboratory experiments.

### 2.1.3 Application of electrospun fibers

The electrospinning can produce a nonwoven and widely fiber from micrometer to nanometer range scale. The electospun fiber has small fibers, small pore size and high surface area, that showed in figure2.3. These unique characteristics are support for advanced application**.** The potential of electrospun fiber can be used in application area: Filtrations, Wound healing, control release, sensor and tissue engineering scaffolds etc [22-27].

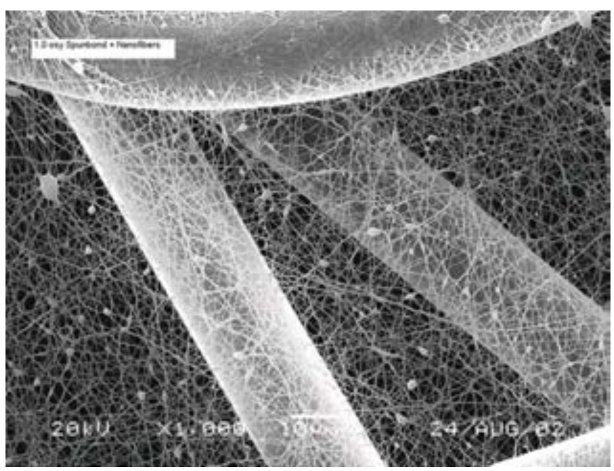



Figure 2.3 SEM image showed nanofiber on microfiber [27].

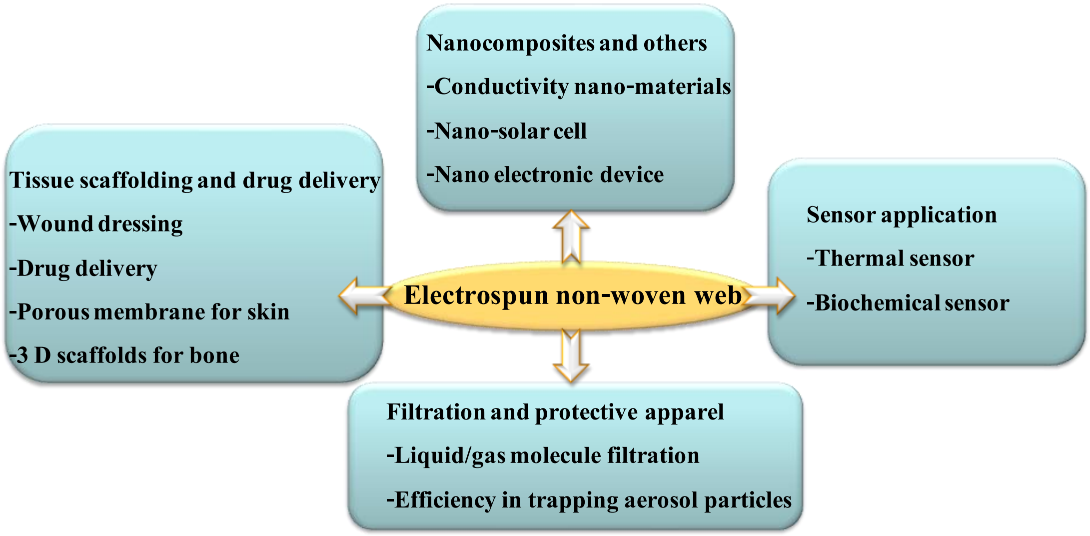



Figure 2.4 Applications of electrospun non-woven web.

## 2.2 Co-electrospinning process

### 2.2.1 Introduction to co-electrospinning process

Bicomponent electrospinning have emerged for preparing ultrafine fibers. Conceptually, the principle of the process is similar to that of the regular electrospinning process, to be called single electrospinng process hereafter, but using different spinneret design with two polymer solutions. For example, the spinneret used in co-axial electrospinning setup contains inner capillary inside outer capillary. Polymer A and B, which must be an appropriate polymer/solvent pairs, are fed through inner and outer core, respectively. Under a right solution and processing condition, one can prepare a bicomponent electrospun fiber with a core-shell geometry where polymer A, a core, surrounded by polymer B, a shell. Employing the same strategy with different spinneret geometry, one can also produce side-by-side fiber. Figure 2.5 shows schematic diagram of typical set up of bi-component electrospinning. Figure 2.6 shows a simplified cross section drawing of side-by-side and co-axial spinneret.

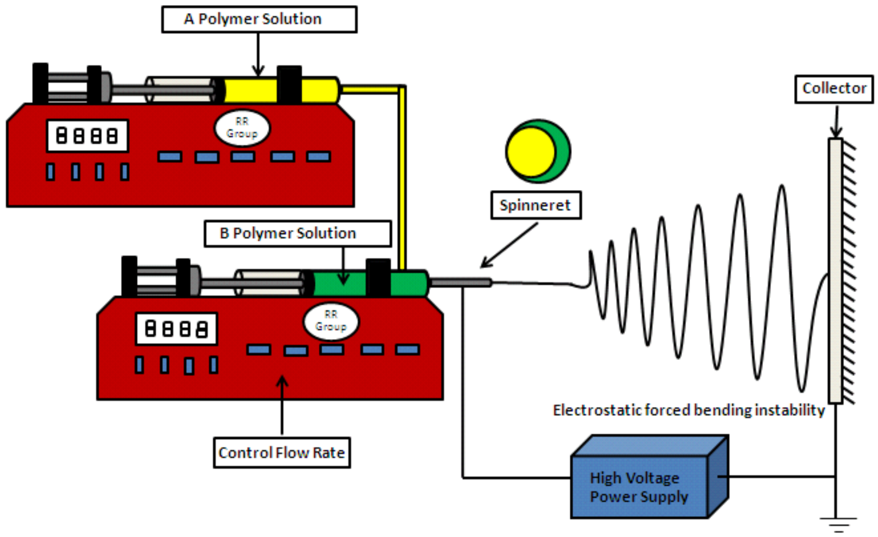



Figure 2.5 Schematic diagram of typical set up of bi-component electrospinning.


Figure 2.6 Schematic of spinneret design (a) side-by-side spinneret, (b) co-axial spinneret.

The process of side-by-side electrospinning is similar the process of electrospinning. Figure 2.7 shows the co-electrospinning process of side-by-side. The polymer droplet form 2 polymer that polymerA and PolymerB (half-half). When the charge repulsion overcome surface tension polymer jet is generate. Finally, the side-by-side electrospun fibers are collected by collector.

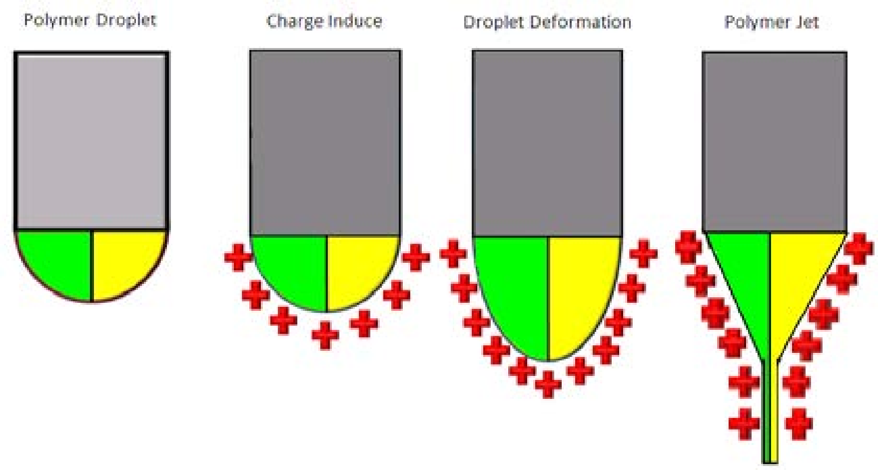



Figure 2.7 Schematic of co-electrospinning process (side-by-side electrospinning).

The process of co-axial electrospinning is similar the process of electrospinning and side-by-side electrospinning. Figure 2.8 shows the co-electrospinning process of co-axial electrospinning. In the process of co-axial electrospinning, the droplet is form core solution and shell solution, the shell solution deformed by charge repulsion and shearing of the core solution via “viscous dragging”  This causes the core liquid to deform into the conical shape and cause to co-axial jet. Finally, The core-shell electrospun fibers are drop on collector.

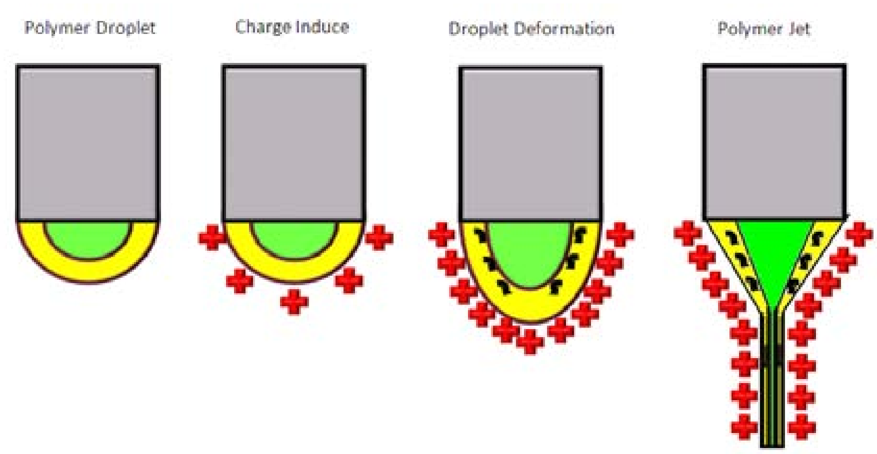



Figure 2.8 Schematic of co-electrospinning process (co-axial electrospinning).

### 2.2.2 Co-electrospinning parameters

The process of co-electrospinning is similar the electrospinning. The quality of bicomponent electrospun fiber can control by condition [28]. The review of effect of parameter on bicomponent fiber is given below.

S.Yan et al. reported a successful preparation of poly(L-lactide-co-3-caprolactone) [PLLACL] coaxial electrospun nanofibers for the application in nerve tissue engineering. They found the diameter fiber increased with increasing of polymer concentration [29].

Y. Z. Zhang et al. investigated co-axial electrospinning of (fluorescein isothiocyanate-conjugated bovine serum albumin)-encapsulated poly($\varepsilon$-caprolactone) nanofibers for sustained release application, and found that increasing flow rate of the core led to larger fiber diameter [30].

Y. Zhang et al. investigated polycaprolactone (PCL)-r-gelatin core-shell electrospun nanofibers. They found the diameter fiber increased with increasing polymer concentration [31].

H. Fong et al. investigated beaded nanofibers formed during electrospinning. They found the diameter decreased with increasing charge density, but the diameter increased with decreasing surface tension [32].

Zhao, P. et al. prepared PCL-gelatin (core-shell) electrospun fiber. They found the fiber size increased with increasing flow rate [33].

Gupta, P. and Wilkes produced PVC and PVDF with morphology of side-by-side bicomponent electrospun fiber. The results didn't show the clearly structure and fiber formation [2].

Even though several studies on bicomponent electrospinning process of various polymer systems had been reported, fundamental understanding of the process is still lacking. A better understanding of how each parameter plays role in the bicomponent fiber formation would lead to a better process control, and an ability to manipulate and fabricate fiber of desired structure and property.

**2.2.3 Application of bicomponent electrospun fiber**

The bicomponent electrospun fiber have a many different morphologies, such as fibers, bead on the fibers, side-by-side, core-shell, and hollow fibers etc. we can control the morphology and fiber formation by control the condition of the process. While the side-by-side, core-shell and hollow fiber can produced by co-electrospinning (side-by-side and co-axial electrospinning). Bicomponent electrospun fiber can be use more function and advance applications.

He, C. L. et. al. prepared the poly(L-lactic acid)(PLLA) and tetracycline hydrochloride (TCH) with core-shell structure by coaxial-electrospinning for potential controlled drug delivery applications.[34]

Li, D. et al. prepared the poly[2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene (MEH-PPV) and poly(3-hexylthiopene) (PHT) which cannot produced by electrospinning due to limited solubility. This bicomponent fiber showed conductivity properties for use in electronic and semiconductor applications.[35]

Liu, Z. et al. fabricated the $TiO_2/SnO_2$ with side-by-side electrospun nanofiber by co-electrospinning technique which $TiO_2$ and $SnO_2$ are exposed to the surface. This morphology showed high efficiency photocatalytic.[36]

Xu, F. et. al. fabricated the $TiO_2/SnO_2$ with side-by-side electrospun nanofiber by dual-opposite-spinneret electrospinning technique which can using in photocatalytic applications.[37]

Chen, S. et al. created the polymeric nanospring structure by off-centered, co-axial and side-by-side electrospinning. Since the different of the shrinking thermoelastic and the rigidity stiff component, the nanospring was generated. The results showed higher elongation, a higher toughness and a higher modulus properties.[38]

Srivastava, Y. et. al. created novel conducting and nonconducting with side-by-side morphology have been electrospun using a microfluidic device source.[39]

**2.3 Filtration application**

Filtration is defined as a separation of solid particles from a fluid, which they are a part of by passage the fluid through a membrane or filter that retains the solids on or within itself (shows in figure2.9). The membrane is called a filter medium, and the equipment assembly that holds the medium and provides space for the accumulated solids is called a filter. The objective of filtration is to expel or remove solid particles may be to purify the fluid by clarification or to recover clean, fluid-free particles, or both. The fluid may be a gas or a liquid.

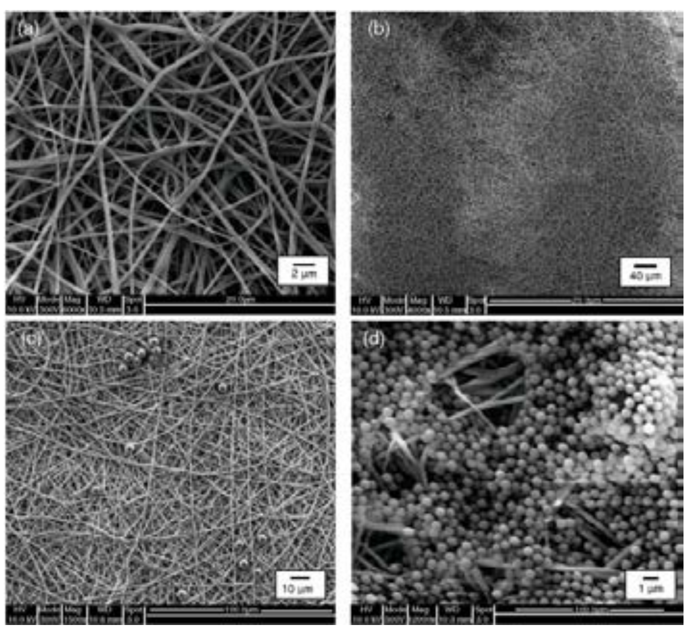



Figure 2.9 FESEM image of PVDF membrane: (a) before separation,

(b) after 10 μm (c) after 5 μm, and (d) after 1 μm separation. [40]

In general, the efficiency filtration has been many parameters which including aerosol particle size, filtration velocity (based on flow rate and available surface area) and several filter parameters including the pore size, fiber diameter, thickness and porosity. The mechanisms of filtration have 4 types

Inertial impaction, This mechanism occurs when the particle is large and deviates from the air stream around the fiber and collides with the fiber.

Interception, This mechanism occurs when a small and particle moves with the air stream through the fibers, the particle attached to the fibers, leaves the air stream and attaches itself to the fibers by Van der Waals force.

Diffusion, This mechanism occurs when very small particle. Air molecules influence to these small particles move through the fibers. The small particles collide with the air molecules and move without Brownian movement. When the particles contact with the fibers and stay attached.

Electrostatic attraction, This mechanism occurs when made of dielectric materials that have a significant microscopic bipolar charge on the fibers. Charged particles are attracted to oppositely charged fibers by the Coulombic force. Neutral particles are collected by the polarization force induced by local electric fields within the filter.

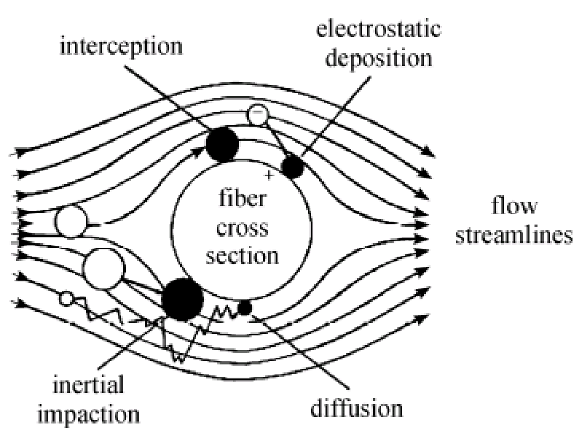



Figure 2.10 The particle deposition mechanism on fiber [41].

## 2.4 Materials

### 2.4.1 Poly(lactic acid) (PLA)

PLA is a thermoplastic aliphatic polyester, biodegradable, non-toxic derived from renewable resources such as corn starch, tapioca roots, chips or starch or sugarcane. It can be widely processed by extrusion, injection molding, film & sheet casting, and spinning and electrospinning, providing access to a wide range of materials which have a good mechanical strength, high Young's modulus and good processing to produce product. It has a glass transition temperature (Tg) around 55 to 59°C and a melting point (Tm) around 150-160 °C.

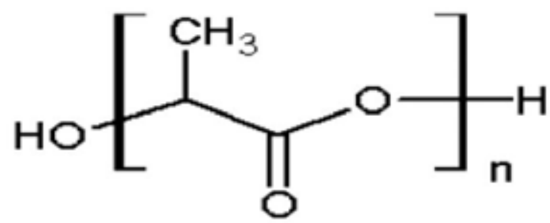


Figure2.11 The structure of poly(lactic acid).

### 2.4.2 Poly(ethylene oxide) (PEO)

PEO has been widely used in electrospinning technique. It is biocompatible, non-ionic linear homopolymer of ethylene oxide and using a many solvent (easy to prepare polymer solution), which can be used in many biomedical applications such as matrix system for controlled release, drug delivery and tissue engineering. The properties of PEO has melt temperature($T_m$) around 65 $^{o}$C, glass transition temperature (Tg) around -73$^{o}$C.

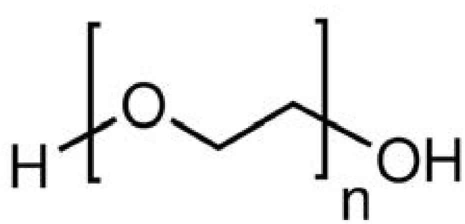


Figure2.12 The structure of poly(ethylene oxide)

### 2.4.3 Nylon6

Nylon 6 is a widely used and commercial engineering plastic and synthetic fiber. It can be widely processed by extrusion, injection molding, film & sheet casting, and spinning and electrospinning. Nylon6 is semi-crystalline polymers, the amide group -(-CO-NH-)- provides hydrogen bonding between polyamide chains, giving properties high strength at high temperatures, toughness at low temperatures, stiffness, wear and abrasion resistance, low friction coefficient, good chemical resistance, glass transition temperature(Tg)= 47$^{o}$C and melting temperature(Tm)= 220$^{o}$C.

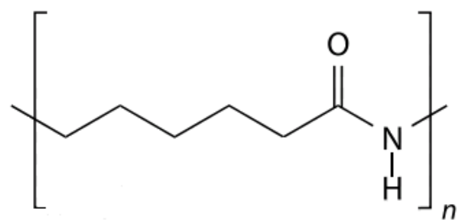



Figure 2.13 The structure of nylon 6.

# CHAPTER III

# MATERIALS AND METHODS

## 3.1 Preparation of PLA electrospun fiber by electrospinning.

In this part, I investigated the effect of processing parameters on morphology and characteristics of polylactic acid (PLA) electrospun fiber.

### 3.1.1 Materials

#### 3.1.1.1 Polymers

Poly(lactic acid) (PLA) (grade 2002D) from Naturework (USA), was purchased through local vendor in Thailand.

#### 3.1.1.2 Solvents

Chloroform ($CHCl_3$) (analytical reagent A.R.) from Lab-Scan (Thailand) and N,N-Dimethylformamide (DMF) (purity$\geq$99.8%,) from Carlo Erba (Italy ).

### 3.1.2 Solution preparation

PLA was dissolved in 100/0, 75/25, 50/50, 25/75, 00/100 w/v mixture of $CHCl_3$/DMF with stir 12hr at 40$^{o}$C. PLA concentration will be varied from 3-20 %w/v, (depend on solvent systems)

### 3.1.3 Experimental setup

Effect of solvent system and concentration were studied by PLA was dissolved in 100/0, 75/25, 50/50, 25/75, 00/100 w/v mixture of $CHCl_3$/DMF. PLA solution concentration was varied from 3-20 %w/v, (depend on solvent systems). Applied voltage, gap distance and solution flow rate were fixed at 15kv, 15cm and 0.5 ml/hr.

For experiment setup of effect of solution flow rate, applied voltage, and gap distance were studied by PLA was dissolved in 100/0, 75/25, 50/50, 25/75, 00/100 w/v mixture of $CHCl_3$/DMF with concentration of 8, 8, 12, 14 and 18% w/v. respectively. Following the condition is below.

Effect of solution flow rate, applied voltage and gap distance were fixed at 15kV and 15cm. The solution flow rate was varied from 0.25-1.0 ml/hr.

Effect of applied voltage, gap distance was fixed at 15cm. the applied voltage was varied from 10-25 kV with investigated solution flow rate at 0.5 and 1.0 ml/hr.

Effect of gap distance, applied voltage and solution flow rate were fixed at 15kV and 0.5 ml/hr, The gap distance was varied from 5-20 cm.

All experiment setup, The polymer solution was put in a 5 ml syringe, which connected to the 21 gauge needle and control flow rate by syringe pump, New Era Pump Systems, Inc. model NE-300. The positive lead of a High voltage supplied (SL300) was purchased from Spellman by applying the voltage of 15 kV. Aluminum foil was covered on stationary collector with collecting the fiber of 15 minutes.

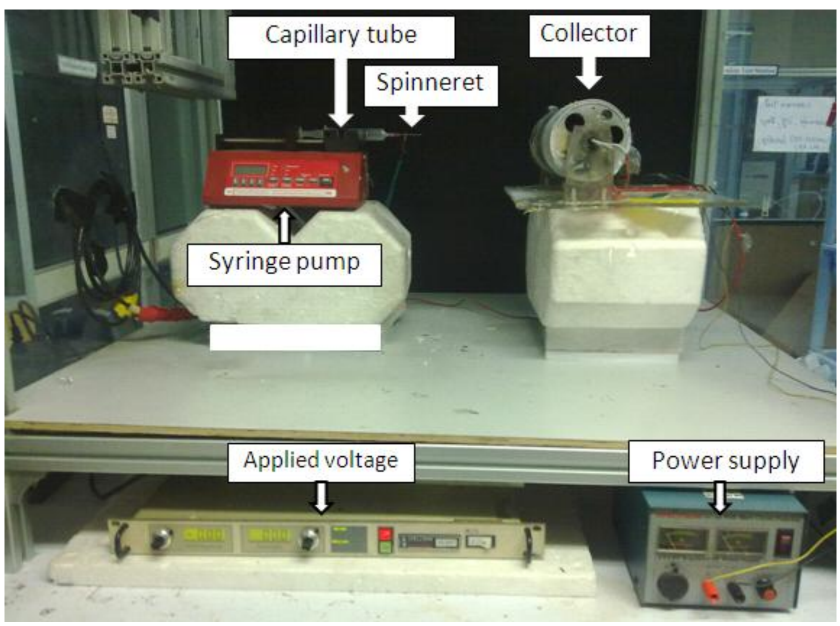



Figure3.1 Experimental set up of electrospinning.

### 3.1.4 Characterization

#### 3.1.4.1 Solution properties

##### 3.1.4.1.1 Viscosity

A viscometer is an instrument for measure the viscosity of a fluid. Viscosity is the measure of the internal friction of a fluid (or polymer solution). The friction is shear force which shearing occurs when the fluid is moved or distributed [42]. The viscosity of PLA solution was measured at 29±2°C using a viscometer, Brookfield model LVDV-II as showed in figure 3.2.

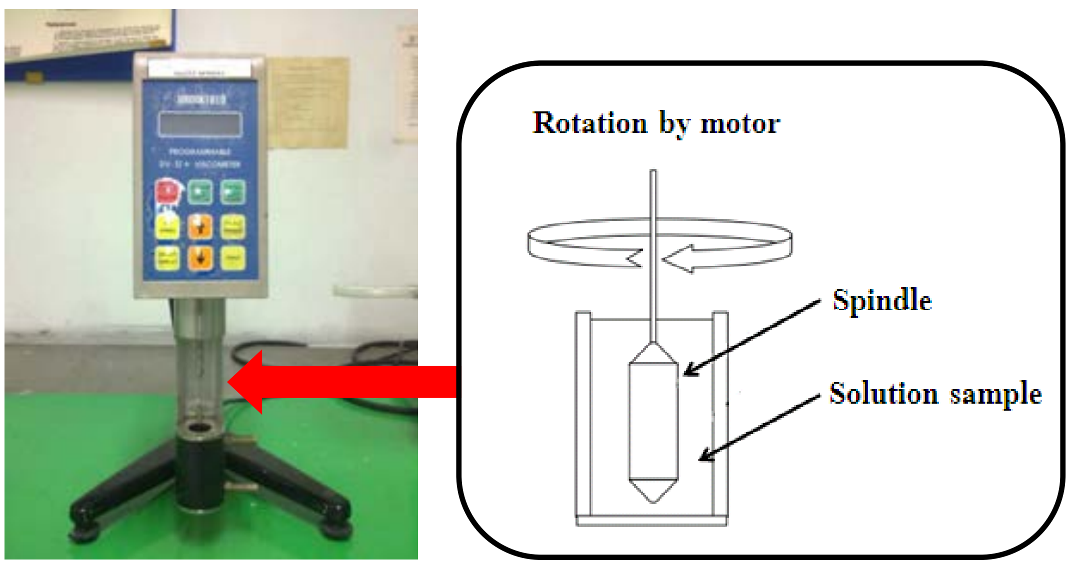



Figure 3.2 Rotational viscometer.

##### 3.1.4.1.2 Conductivity

Electrolytic conductivity is a measure of the ability of a solution to conduct or transfer a current which must be carried by ions. The conductivity measurement evaluates from all ions present in the solutions contribute to the current flowing through the sensor [43]. The conductivity of PLA solution was measured by using a viscometer, EUTECH instruments model CON 501 as showed in figure3.3. The measurement was carried out at 29±2°C.

Figure 3.3 Conductivity meters instrument.

**3.1.4.2 Fiber characterization**

**3.1.4.2.1 Scanning Electron Microscope (SEM)**

A scanning electron microscope (SEM) is an imaging technique to produce high resolution images of a surface sample by scanning it with a focused electrons beam on the surface sample (a type of electron microscope). The electrons interact with electrons in the sample, producing various signals that can be detected and show the surface sample image. Specimens should be conduct electricity (if not need to coat the sample with gold or carbon) and dry. In the process, the specimens were observed in vacuum environment.

The morphology of PLA electrospun fiber was observed by scanning electron microscope (SEM), Philips series XL 30 CP, as showed in figure3.4, which the sample was coated by gold. The average diameter for each sample was calculated from at least 50 individual fibers in SEM images.

Figure 3.4 Scanning electron microscope (SEM).

## 3.2 Preparation of PLA-PEO bicomponent electrospun fiber by co-electrospinning

In this part, I developed apparatus for side by side electrospinning and investigated effect of processing parameters on the formation and morphology of PLA-PEO bicomponent electrospun fiber.

### 3.2.1 Materials

#### 3.2.1.1 Polymers

Poly(lactic acid) (PLA) (grade 2002D) from Naturework (USA), was purchased through local vendor in Thailand. Polyethylene oxide (Mw 400,000) from Sigma-Aldrich (USA).

#### 3.2.1.2 Solvents

Chloroform ($CHCl_3$) (analytical reagent A.R.) from Lab-Scan (Thailand) and N,N-Dimethylformamide (DMF) (purity$\geq$99.8%,) from Carlo Erba (Italy ) were used as received.

### 3.2.2 Solutions preparation

PLA was dissolved in 75/25, 50/50, 25/75, 00/100 w/v mixture of $CHCl_3$/DMF with the concentration 8, 12,16 and 19%w/v, respectively, which stir 12hr at 40$^{o}$C. PEO was dissolved in $CHCl_3$ with the concentration 1, 3 and 5 %w/v.

### 3.2.3 Experimental setup

Figure3.2 showed schematic diagram of a co-electrospinning apparatus used in this study. Appropriated amount of polymer solution A (PLA have use 2 system that PLA 8%w/v in ($CHCl_3$:DMF/75:25) and PLA 19% w/v in DMF) and polymer solution B (1, 3 and 5% w/v of PEO in $CHCl_3$) were loaded in disposable syringe. Both solutions were delivered through an in-house made spinneret with a simplified side-by-side configuration, depicted cross-section view in figure 3.5 Combined solutions flow rate, controlled by 2 separate syringe pumps (New Era Pump Systems, model NE-300) was kept constant at 1.0 ml/hr, while the solution flow rate ratio between solution A and B was varied from 1.0:0.0 to 0.0:1.0 ml/hr. Electrical potential difference of 10-25 kV was established between the spinneret and a stationary fiber collector plate using a high voltage power supplied (Spellman, model SL300P) with positive polarity. The spinneret-collector distance was kept constant 20 cm for all experiment.

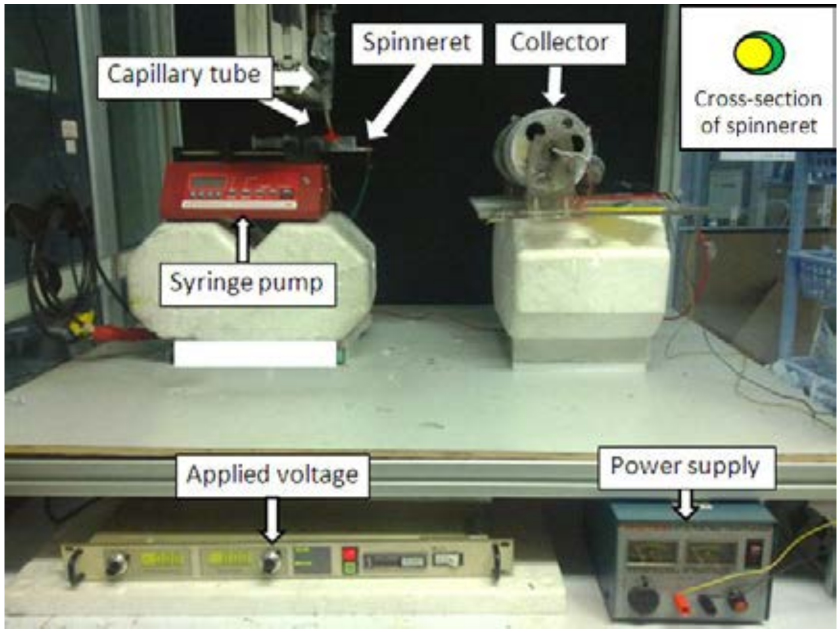



Figure 3.5 Experimental set up of co-electrospinning.

### 3.2.4 Characterization

#### 3.2.4.1 Solution properties

##### 3.2.4.1.1 Viscosity

The viscosity of PLA solution was measured at 29±2°C using a viscometer, Brookfield model LVDV-II.

##### 3.2.4.1.2 Conductivity

The conductivity of PLA solution was measured by using a viscometer, EUTECH instruments model CON 501. The measurement was carried out at 29±2°C.

#### 3.2.4.2 Fiber characterization

##### 3.2.4.2.1 Scanning Electron Microscope (SEM)

The morphology of PLA electrospun fiber was observed by scanning electron microscope (SEM), Philips series XL 30 CP which the sample was coated by gold. The average diameter for each sample was calculated at least 50 individual fibers from SEM images.

#### 3.2.4.2.2 Fourier Transform Infrared Spectroscopy (FTIR)

FTIR is an infrared spectroscopy which is technique for characterization in organic chemistry. IR radiation is passed through a sample that some of the infrared radiation absorbed by the sample and IR transmitted by passed through the sample. The FTIR can use the unique collection of absorption and transmission bands to confirm the identity of pure and specific impurities compound. The composition of bicomponent electrospun fibers were studied by fourier transform infrared spectroscopy (FTIR), Perkin-Elmer IR-ATR as showed in figure 3.6.

Figure 3.6 Fourier Transform Infrared Spectroscopy (FTIR).

#### 3.2.4.2.3 Thermal gravimetric analysis (TGA)

TGA is a technique of thermal analysis which determine thermal stability of the materials. Conceptual fundamental of TGA is the determination of a mass change of the materials associated with an increase in temperature (with constant heating rate) or as a function of time (with constant temperature). The mass change could be a result of thermal decomposition of the materials or a loss of volatile phase in the material. In case that the materials of interest composed of more than one phase, and each phase has different thermal stability such as different thermal degradation temperature. The composition and weight fraction of bicomponent electrospun fibers was studied by Thermal gravimetric analysis (TGA).

Figure 3.7 Thermal gravimetric (TGA)

**3.2.4.2.4 Contact angle measurement**

The contact angle is measure the angle through the liquid, concerning the interaction of a liquid/vapor interface converge a solid surface. Figure3.8 shows contact angle measurement.

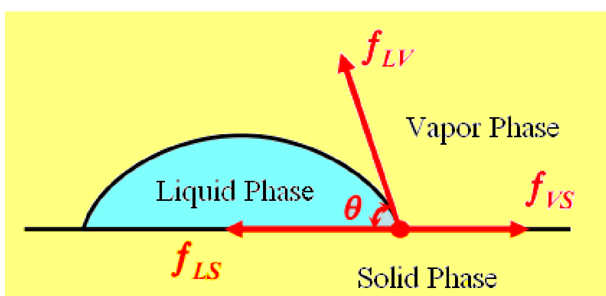



Figure 3.8 Schematic diagram of the contact angle and interfacial tensions of the three phases.

The contact angle was calculated by using the following equation [44].

$$\mathrm{Cos}\theta = \frac{\gamma_s - \gamma_{sl}}{\gamma_l} \qquad 3.1$$

$\gamma s$ = Surface energy of the solid

$\gamma l$ = Surface tension of the liquid

$\gamma sl$ = The interfacial tension between the solid and the liquid

In the experimental, the water and glycerol droplet contact angle on PLA-PEO bicomponent media was measure by a simplify contact angle machine that show in figure3.9.

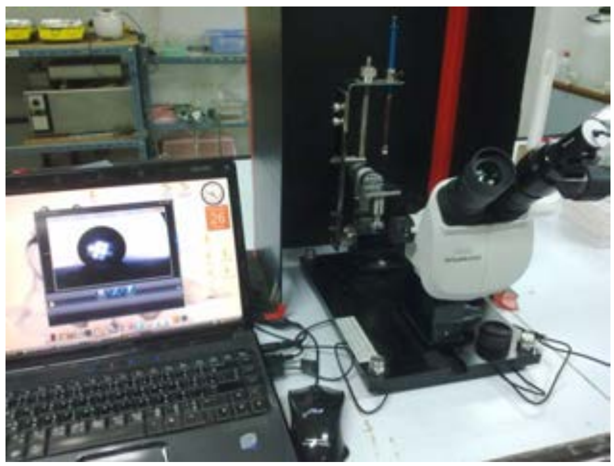


Figure3.9 Contact angle instrument.

## 3.3 Air filtration testing

### 3.3.1 Materials

#### 3.3.1.1 Polymers

Nylon6, Mw=22,000 was purchased through local vendor in Thailand. Formic acid 99% from Carlo Erba (Italy).

Spunbond media form polypropylene (PP) and melt blown media form polypropylene (PP) are the commercial grade. Smooth surface of PLA-PEO bicomponent electrospun fiber was dissolved in distilled water for 24 hr. to remove PEO phase.

#### 3.3.1.2 Solvents

Formic acid 99% from Carlo Erba (Italy).

### 3.3.2 Solution preparation

Nylon6 was dissolved in formic acid with the concentration of 20 w/v, and stir 4 hour at room temperature.

### 3.3.3 Experimental setup

The polymer solution of nylon6 20%w/v was prepared in formic acid. It was contained in syringe which attached by a needle 24 Gauge. Electrical potential 25 kV was established between the spinneret and a stationary fiber collector plate using a high voltage power supplied (Spellman, model SL300P) with positive polarity. The spinneret-collector distance was kept constant 10 cm. The flow rate was controlled by syringe pumps (New Era Pump Systems, model NE-300) was kept constant at 0.2 ml/hr.

### 3.3.4 Preparation the filter media

The air filter media were composed of modified 4 layers which had diameter of 37 mm into a stack filter. The spunbond and melt blown membrane are commercial media which produce to filter media. The spunbond(S) is used for support media so it was used in layer 1and 4. The melt blown (M) media is used for removal the total particulate matter so it was used in layer 2. The layer 3 of air filter media was studied by the modification of the layer by varies the type of filters (no media, meltblown, nylon 6 electrospun nanofiber (NF) and C-shape PLA fiber) as shown in figure3.3. The C-shape PLA fiber and nylon6 nanofiber filter with various basis weight from 0.02, 0.07 and 0.10 $g/m^2$ were studied for layer3. In addition, 20 layers spunbond stack, with diameter of 37 mm was prepared for measuring total weight of total particulate matter as a control sample.

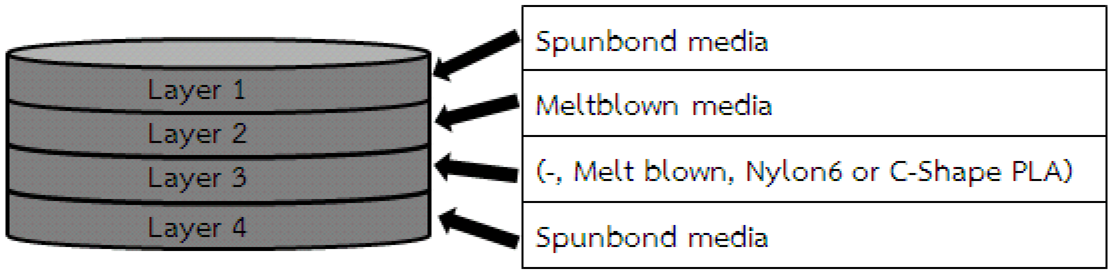



Figure3.10 Schematic diagram of the structure filter media used in this study.

We are prepare 6 sample conclude of

1. S/M/S = Spunbond / Meltblown / Spunbond
2. S/M/NF(T1)/S = Spunbond / Meltblown / Nylon6 (basis weight 0.02 g/m$^2$)/ Spunbond
3. S/M/NF(T2)/S = Spunbond / Meltblown / Nylon6 (basis weight 0.07 g/m$^2$)/ Spunbond
4. S/M/NF(T3)/S = Spunbond / Meltblown / Nylon6 (basis weight 0.10 g/m$^2$)/ Spunbond
5. S/M/C-shape PLA fiber/S = Spunbond / Meltblown / C-shape PLA fiber / Spunbond
6. S/M/M/S = Spunbond / Meltblown / Meltblown / Spunbond

### 3.3.5 Characterization

#### 3.3.5.1 Characterization of filter media

##### 3.3.5.1.1 Scanning Electron Microscope (SEM)

The morphology, fibers size and pore size of spunbond, melt blown, nylon6 electrospun nanofiber and PLA-PEO bicomponent electrospun fiber were observed by scanning electron microscope (SEM), Philips series XL 30 CP. Average fibers size for each sample was calculated from at least 100 individual fibers from SEM images. The pore size for each sample calculated from at least 100 pore, 3 value of each pore. The thickness of media measure by micrometer with attach to microscopy.

#### 3.3.5.2 Air filtration efficiency testing

The filtration efficiency was use a simple set up which have main idea from R.B. Griffith studied with some modify machine [45]. The side stream smoke was represented particulate matter for testing. It was passing through filter holder which contain filter test. The flow rate of air fixed at 0.5 l/min by air pump with control by rotameter and varies collection time from 1, 2, 4 to 6 liters which tested 3 time/sample. Figure3.11 showed experimental setup of a simplify filtration testing used in this study.

In this research, the filtration efficiency was determined by the total particulate matter collection method which compared the weight of filter media before and after exposure to testing particle. The testing method was adapted from ref. [46]. The weight of total particle matter was calculated by using the following equation

$$W_c = W_a - W_b \qquad 3.2$$

$W_c$ = The weight of total particulate matter.

$W_b$ = The weight of air filter media before testing.

$W_a$ = The weight of air filter media after testing.

The filtration efficiency percentage was calculated by using the following equation.

$$\%\ \text{Filtration efficiency} = \frac{W_C}{W_T} \times 100 \qquad 3.3$$

$W_T$ = The total weight particulate matter in each air volume testing.

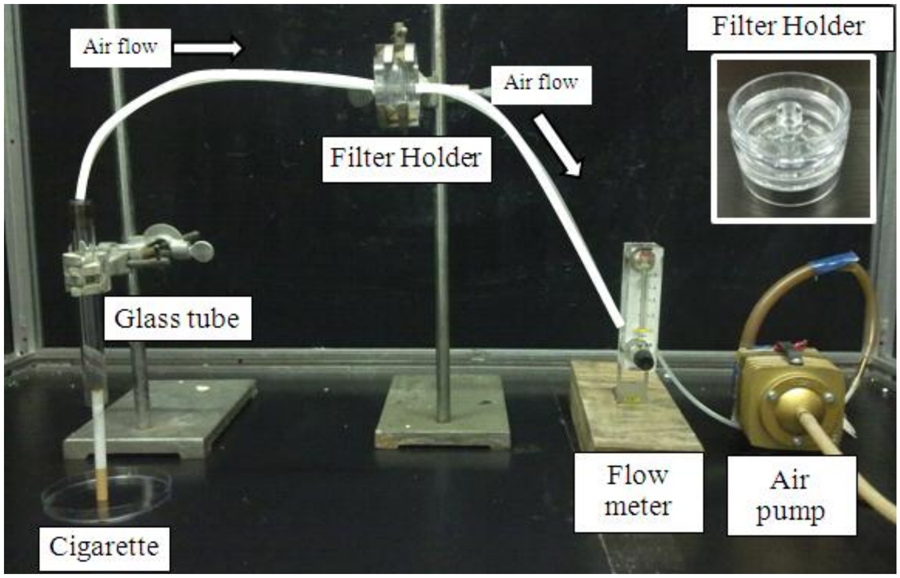



Figure3.11 Experimental set up for the air filtration efficiency testing.

# CHAPTER IV

# RESULTS AND DISCUSSION

## 4.1 Preparation of PLA electrospun fiber by electrospinning

### 4.1.1 Solution Properties

#### 4.1.1.1 Viscosity

PLA were dissolved in mixing solvent of chloroform ($CHCl_3$) and N,N-dimethylformamide (DMF) with chloroform:DMF volumetric mixing ratio at 100:0, 75:25, 50:50, 25:75 and 0:100. These solutions were prepared with various concentrations ranging from 8 to 20 %w/v and measured viscosity that showed in figure 4.1. The results showed polymer solution viscosity increased with increasing polymer solution concentration. Because the concentration increased also tend to increasing polymer chain entanglement or more intermolecular interactions then hardly move polymer chain so viscosity increased. Addition, higher DMF ratio also tends to lower viscosity.

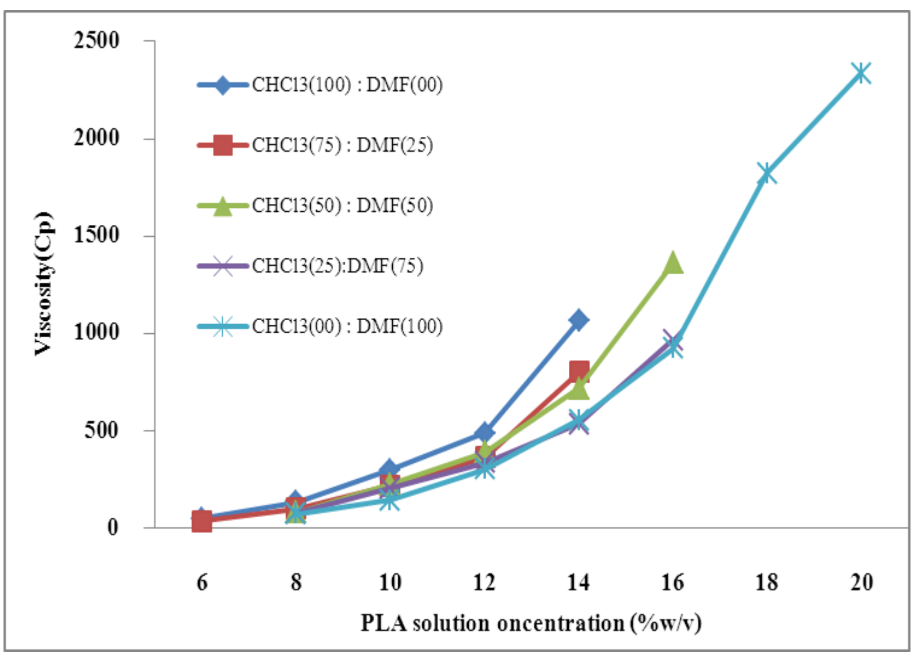



Figure 4.1 Effect of PLA solution concentration and solvent system on the viscosity.

#### 4.1.1.2 Conductivity

The conductivity is an indication of the ability to conduct a charge on the surface of polymer solution in the polymer jet. It is contribute factor to fiber formation in the electrospinning process. The higher conductivity of solution show result in higher a charge on the surface. Figure4.2 showed the conductivity increased with increasing DMF ratio in solution because DMF have a higher conductivity than chloroform. The low concentration, the conductivity was increased by concentration. When the concentration is over critical point, the conductivity decreased or has no effect on conductivity

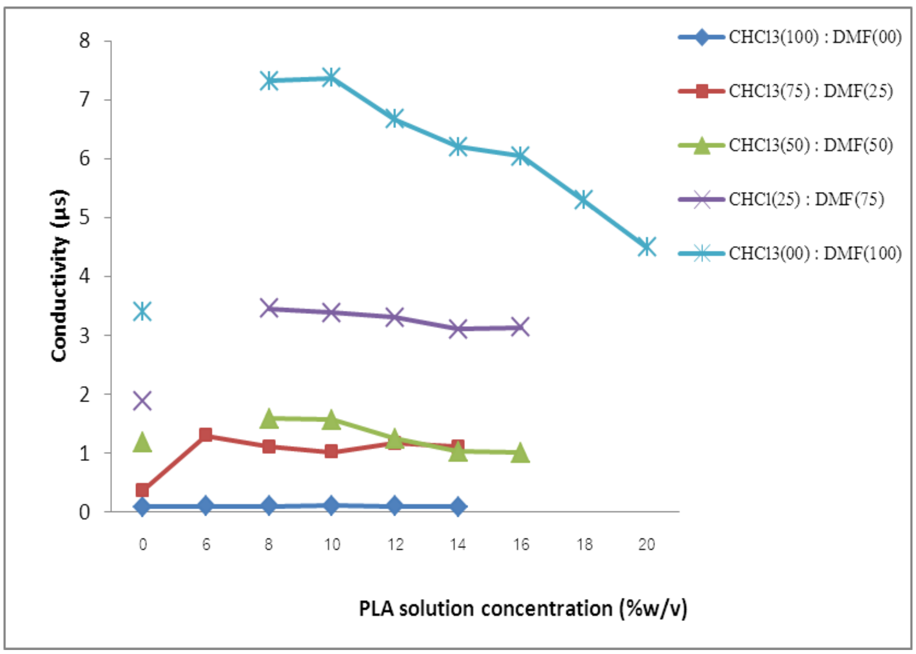



Figure 4.2 Effect of PLA solution concentration and solvent system on the conductivity.

### 4.1.2 Effect of electrospinning parameters on fiber formation

Table 4.1 Effect of solvent system and solution concentration on fiber size and morphology of PLA electrospun fiber.

| C | $CHCl_3$ : DMF 100:00 | | $CHCl_3$:DMF 75:25 | | $CHCl_3$:DMF 50:50 | | $CHCl_3$:DMF 25:75 | | $CHCl_3$:DMF 0:100 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M |
| 6 | 0.60±0.50 | Bead | 0.48±0.18 | Bead | | | | | | |
| 8 | 0.71±0.54 | Fiber | 0.87±0.21 | Fiber | 0.43±0.13 | Bead | 0.15±0.04 | Bead | 0.09±0.02 | Bead |
| 10 | 0.69±0.54 | Fiber | 1.30±0.42 | Fiber | 0.48±0.13 | Bead | 0.20±0.05 | Bead | 0.11±0.02 | Bead |
| 12 | 0.72±0.51 | Fiber | 1.64±0.71 | Fiber | 0.56±0.19 | Fiber | 0.21±0.04 | Bead | 0.15±0.02 | Bead |
| 14 | 0.75±0.74 | Fiber | 1.49±0.35 | Fiber | 0.79±0.13 | Fiber | 0.41±0.05 | Fiber | 0.24±0.04 | Bead |
| 16 | | | | | 0.94±0.19 | Fiber | 0.49±0.07 | Fiber | 0.30±0.05 | Bead |
| 18 | | | | | | | | | 0.40±0.06 | Fiber |
| 20 | | | | | | | | | 0.52±0.10 | Fiber |

C = concentration of PLA solution (%w/v), M = Morphology

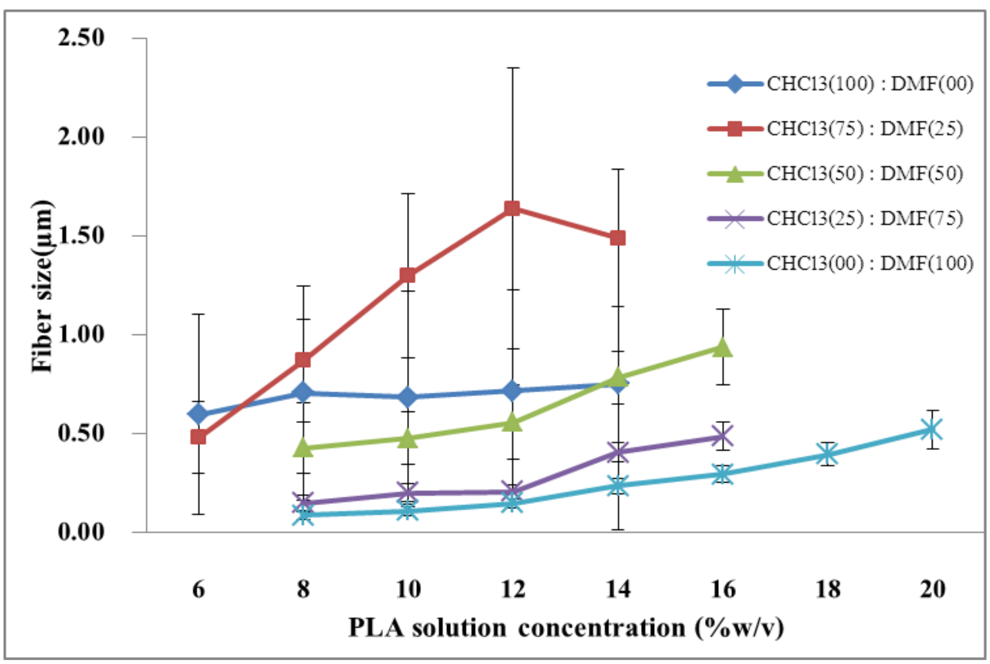



Figure 4.3 Effect of PLA solution concentration and solvent system on the fiber size.

[voltage =15kv, distance=15cm, flow rate=0.5ml/h.].

#### 4.1.2.1 Effect of solvent system

PLA solutions prepared in mixing solvent of chloroform ($CHCl_3$) and N,N-dimethylformamide (DMF) that show in table 4.1. PLA electrospun fibers obtained fiber without bead with the concentration of 8, 8, 12, 14 and 18%w/v in mixture solvent system of ($CHCl_3$:DMF/ 100:00, 75:25, 50:50, 25:75 and 00:100), respectively. These fibers were formed fiber size with 0.71±0.54, 0.87±0.21, 0.56±0.19, 0.40±0.05 and 0.40±0.06 μm that showed in figure4.3. The results showed higher DMF ratio required higher concentration to form fiber without bead. Figure 4.4 showed the morphology of PLA electrospun fiber obtained with various PLA solvent systems. In chloroform system got various fiber sizes because chloroform is bad spin ability and low conductivity. Higher DMF ratio also tend to decreased fiber size and smaller fiber size distribution [47]. These showed DMF improve spin ability of solution properties, similarly the results of [48, 49]. In addition, high DMF ratio in the solution also tended to yield fiber with smoother surface. Because chloroform has low boiling point and DMF has higher boiling point. The chloroform system got porous surface due to the moisture in the air form the droplet due to convection current on the surface of the polymer jet. As the fiber dries, the water droplets leave an effect on the fiber surface, pore structure was generate.
[50, 51]

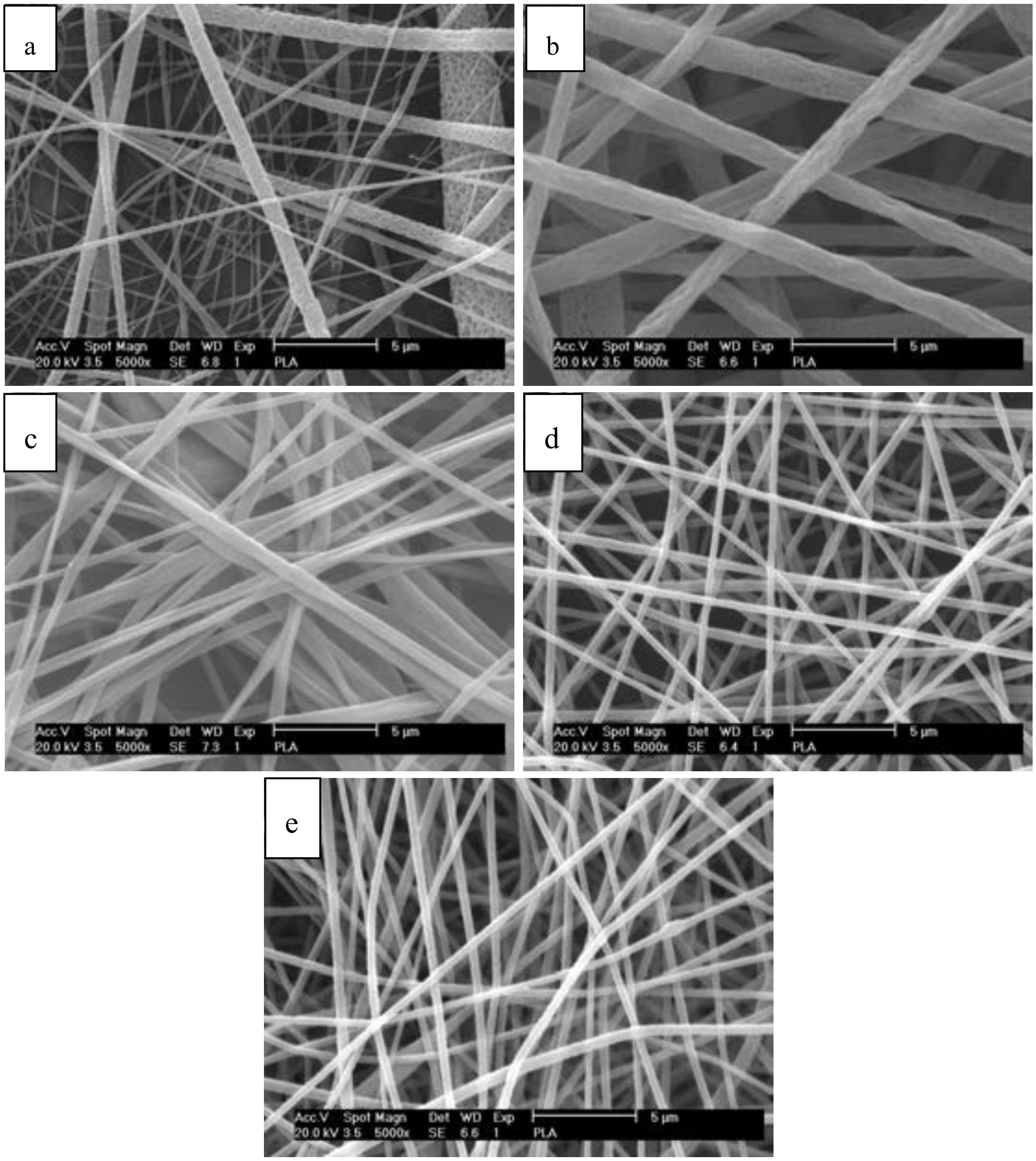



Figure 4.4 SEM images of PLA electrospun fiber obtained from (a) 8%w/v in $CHCl_3$:DMF 100:00, (b) 8%w/v in $CHCl_3$:DMF/75:25, (c) 12%w/v in $CHCl_3$:DMF/50:50, (d) 14%w/v in $CHCl_3$:DMF/25:75, (e) 18%w/v in $CHCl_3$:DMF/00:100 [v=15kv, d=15cm, F=0.5ml/h]

#### 4.1.2.2 Effect of solution concentration

The PLA solution concentration was vary from 6-20 w/v%, (depend on solvent systems). Table 4.1 showed results, the fiber size increased with increasing solution concentration due to increasing solution concentration also tend to increased viscosity, while the conductivity decreased or constant, that are impede the electrospinning force. Our finding was in agreement with previous reports of [52-55]. The morphology was also affected PLA solution concentration as it changed from bead-on-string fiber at low solution concentration to smooth fiber at high concentration. [56] The cause of beads can be removed using high concentration of solution because fibers without bead required enough chain entanglement to form stable polymer jet. Figures4.5 showed the morphology of PLA dissolved in ($CHCl_3$:DMF / 00:100) with various concentrations from 8-20%w/v.

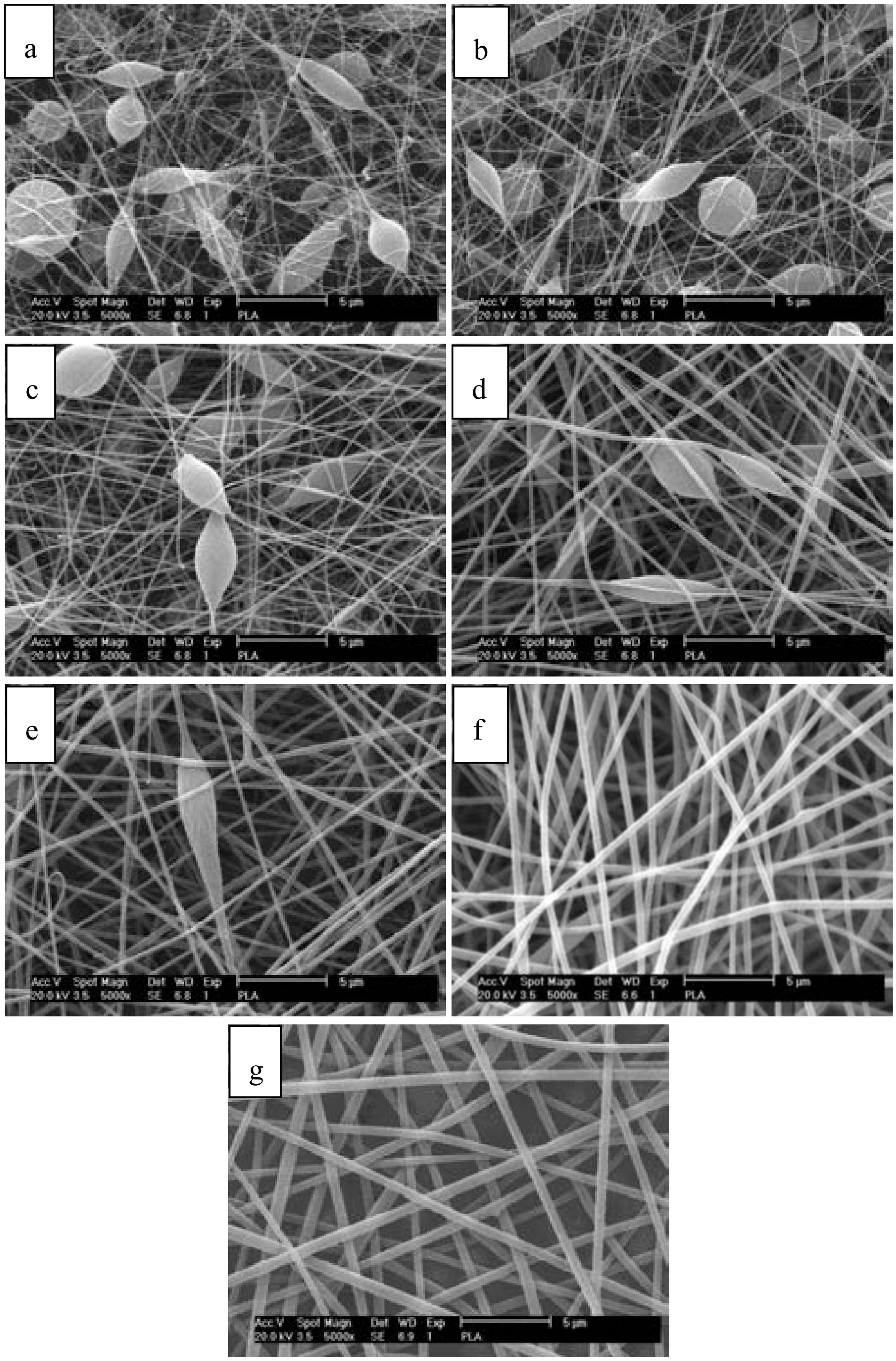



Figure 4.5 SEM images of PLA electrospun fiber obtained from various concentration (a) 8%w/v (b) 10%w/v (c) 12%w/v, (d) 14%w/v (e) 16%w/v, (f) 18 %w/v, (g) 20%w/v in ($CHCl_3$:DMF/00/100) [v=15kv, d=15cm, F=0.5ml/h.]

#### 4.1.2.3 Effect of solution flow rate

In this studied, PLA electrospun fiber was studied with various solution flow rate in range of 0.25-1.0ml/hr. Table4.2 and figure 4.6 showed increasing solution flow rate had a small effect on the fiber size but it effect to increased bead formation on the fiber . Because higher solution flow rate lead to yield higher mass flow or the droplet increased that effect to decreased charge density on surface polymer solution or charge repulsion decreased. Higher solution flow rate form bigger polymer droplet which charge density not enough for stable polymer jet then beads was generating on the fibers. [57-58] Figure 4.7 and 4.8 showed the morphology of fiber PLA electrospun fiber obtained from with various solution flow rate.

Table4.2 Effect of solution flow rate on fiber size and morphology of PLA electrospun fiber with various solvent systems.

| Flow rate (ml/hr) | $CHCl_3$(75) : DMF(25) | | $CHCl_3$(50) : DMF(50) | | $CHCl_3$(25) : DMF(75) | | $CHCl_3$(00) : DMF(100) | |
|---|---|---|---|---|---|---|---|---|
| | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M |
| 0.25 | 0.59±0.16 | Fiber | 0.41±0.14 | Fiber | 0.37±0.05 | Fiber | 0.37±0.06 | Fiber |
| 0.5 | 0.87±0.21 | Fiber | 0.56±0.19 | Fiber | 0.41±0.05 | Fiber | 0.40±0.06 | Fiber |
| 0.75 | 0.61±0.18 | Bead | 0.57±0.19 | Fiber | 0.42±0.085 | Fiber | 0.41±0.08 | Bead |
| 1 | 0.65±0.18 | Bead | 0.54±0.19 | bead | 0.39±0.07 | bead | 0.40±0.07 | Bead |

M= Morphology of electrospun fiber

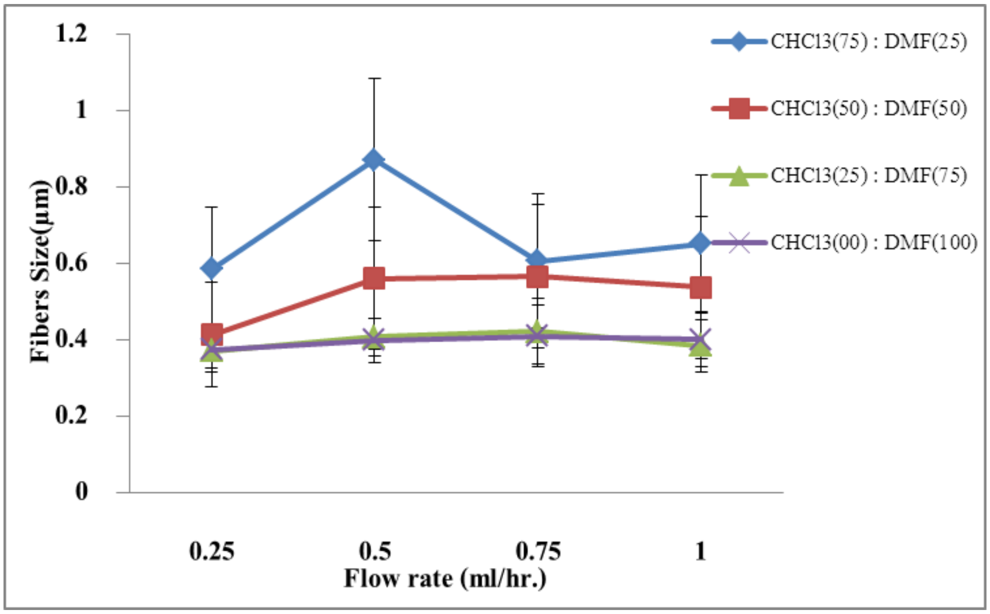



Figure4.6 Effect of solution flow rate on fibers size of PLA electrospun fiber.[v=15kv, d=15cm]

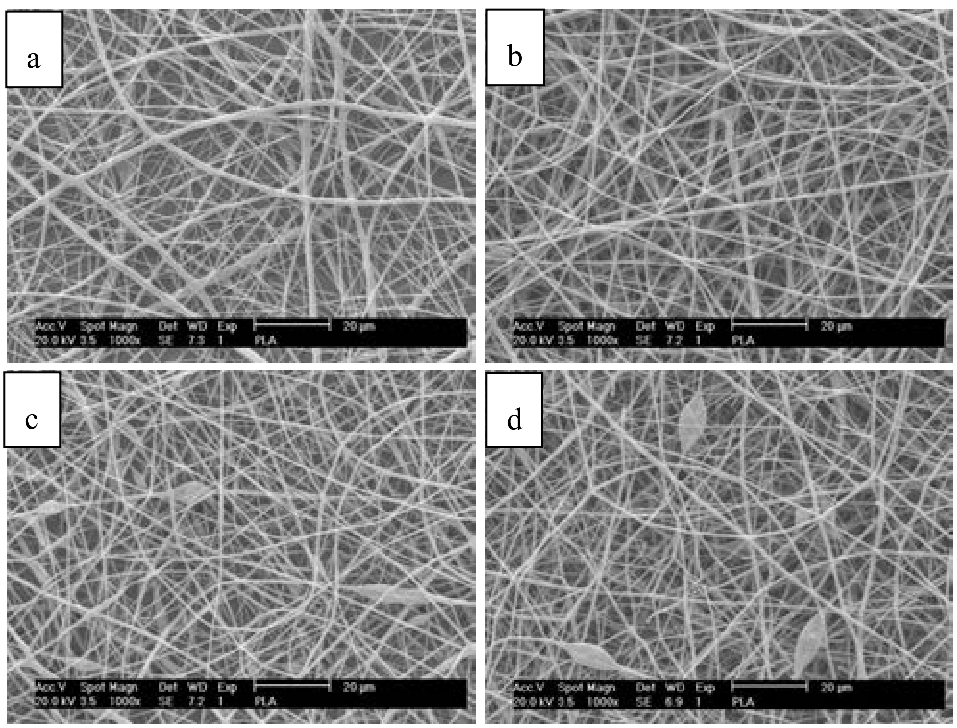



Figure 4.7 SEM images of PLA electrospun fiber obtained from PLA 8%w/v ($CHCl_3$:DMF/75:25) with various solution flow rate (a) 0.25ml/hr, (b) 0.5ml/hr, (c) 0.75ml/hr and (d)) 1.0ml/hr. [v=15kv, d=15cm]

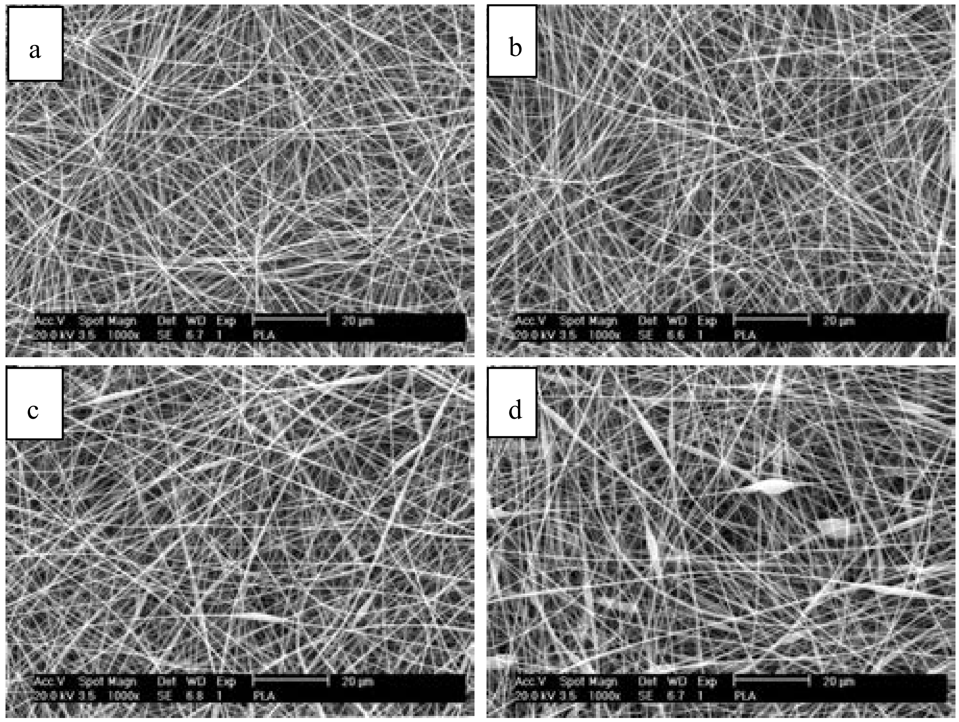



Figure 4.8 SEM images of PLA electrospun fiber obtained from PLA 18%w/v ($CHCl_3$:DMF/00:100) with various solution flow rate (a) 0.25ml/hr, (b) 0.5ml/hr,(c) 0.75ml/hr and (d) 1.0ml/hr. [v=15kv, d=15cm]

**4.1.2.4 Effect of applied voltage**

In this studied, I investigated applied voltage with various from 10 to 25 kV, which vary the solution flow rate at 0.5 and 1.0 ml/hr, that showed in table4.3 and figure4.9. At flow rate 0.5 ml/hr. the applied voltage had a small effect on fiber size and morphology, while PLA in DMF showed slight bead formation which it is may be in case of low charge repulsion force. Then we change the flow rate from 0.5 to 1.0 ml/hr. The results showed clearly on fiber size and morphology. Increasing applied voltage also tend to both effect with decreased and increased fiber size. Increasing applied voltage also tend to increased charge density that increased charge repulsion so the fiber size decreased. On the other hand, Increasing applied voltage influence on increased mass flow so the fiber size increased.[59-61] Addition, low applied voltage also tended to bead formation due to charge repulsion is not enough to stable polymer jet, that shows in figure4.10 and 4.11 [62].

Table 4.3 Effect of applied voltage on PLA electrospun fiber with various solvent system and solution flow rate at 0.5 ml/hr. and 1.0 ml/hr.

| Flow rate (ml/hr) | Applied voltage (kV) | $CHCl_3$(75) : DMF(25) | | $CHCl_3$(50) : DMF(50) | | $CHCl_3$(25) : DMF(75) | | $CHCl_3$(00) : DMF(100) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M |
| 0.5 | 10 | 0.95±0.55 | Fiber | 0.46±0.11 | Fiber | 0.40±0.07 | Fiber | 0.38±0.06 | Bead |
| 0.5 | 15 | 0.87±0.21 | Fiber | 0.56±0.19 | Fiber | 0.41±0.05 | Fiber | 0.40±0.06 | Fiber |
| 0.5 | 20 | 0.96±0.30 | Fiber | 0.60±0.13 | Fiber | 0.45±0.10 | Fiber | 0.40±0.09 | Fiber |
| 0.5 | 25 | 0.96±0.32 | Fiber | 0.55±0.14 | Fiber | 0.52±0.10 | Fiber | 0.41±0.07 | Fiber |
| 1 | 10 | 0.37±0.08 | Bead | 0.51±0.15 | Bead | 0.51±0.09 | Bead | 0.48±0.09 | Bead |
| 1 | 15 | 0.65±0.18 | Bead | 0.54±0.19 | Fiber | 0.39±0.07 | Bead | 0.40±0.07 | Bead |
| 1 | 20 | 0.77±0.27 | Fiber | 0.59±0.13 | Fiber | 0.45±0.08 | Fiber | 0.39±0.10 | Bead |
| 1 | 25 | 0.92±0.21 | Fiber | 0.72±0.14 | Fiber | 0.47±0.09 | Fiber | 0.37±0.08 | Bead |

M = Morphology of electrospun fibers

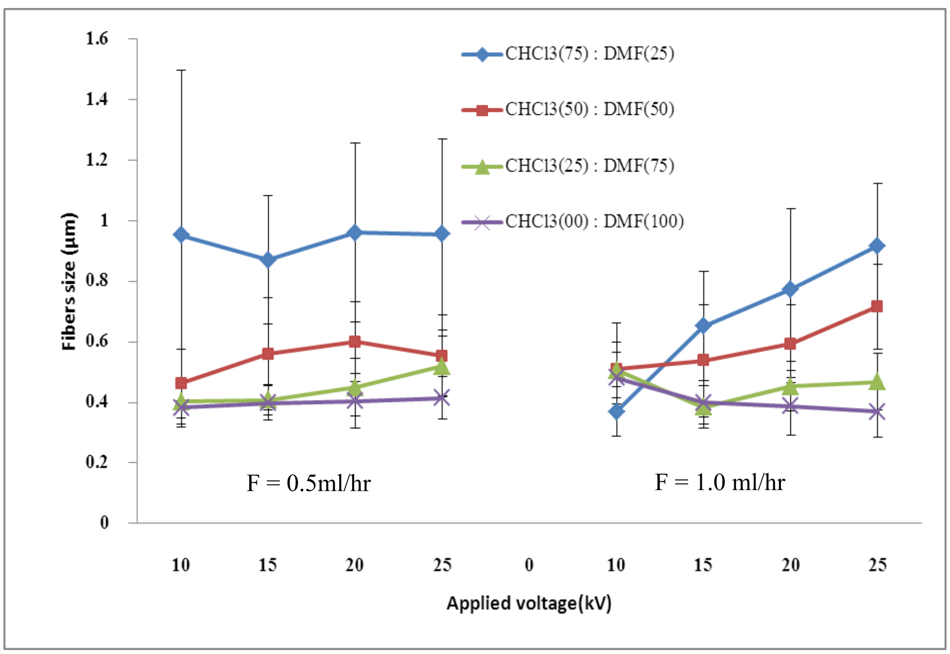



Figure 4.9 Effect of applied voltage on fiber size of PLA electrospun fiber with various solution flow rate at 0.5ml/hr and 1.0 ml.hr.[d=15cm]

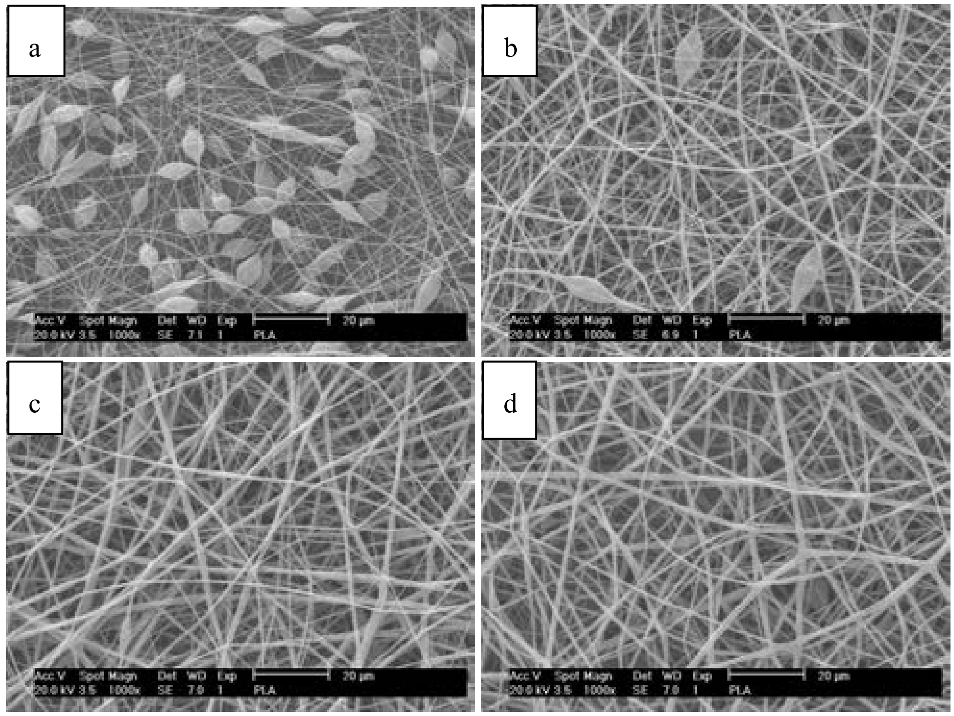



Figure 4.10 SEM images of PLA electrospun fiber obtained from PLA 8%w/v ($CHCl_3$:DMF/75:25) with various applied voltage (a)10kv (b)15kv (c)20kv (d)25kv.[d=15cm, F=1.0ml/hr.]

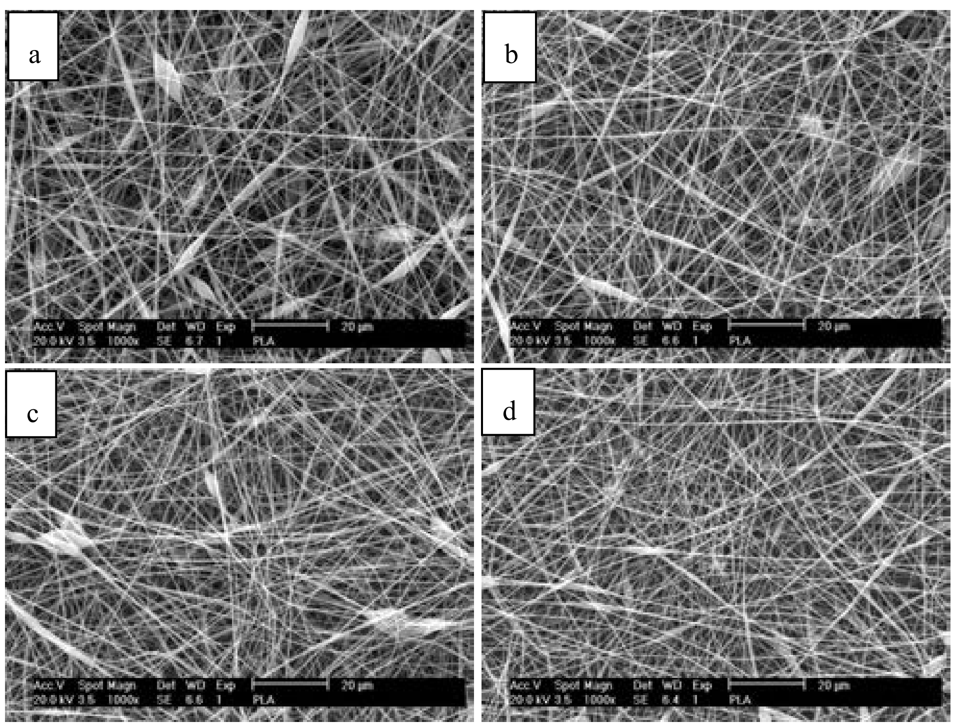



Figure 4.11 SEM images of PLA electrospun fiber obtained from PLA 18%w/v ($CHCl_3$:DMF/00:100) with various applied voltage (a)10kv (b)15kv (c)20kv (d)25kv.[d=15cm, F=1.0ml/hr.]

#### 4.1.2.5 Effect of gap distance

Table 4.4 and figure4.12 showed increasing the gap distance had a small effect on fibers size. But gap distance influence on morphology of fiber that increasing the gap distance form bead on the fiber. Figure 4.13 and 4.14 showed SEM image morphology of fiber. The gap distance is influence on elongation time and electric field strength. Increasing gap distance also tends to increased elongation time and decreased electric field strength. Then low electric field strength, bead was generated on fiber[63].

Table 4.4 Effect of gap distance on fiber size and morphology of PLA electrospun fiber with various solvent systems.

| Gap distance (cm) | $CHCl_3$(75) : DMF(25) | | $CHCl_3$(50) : DMF(50) | | $CHCl_3$(25) : DMF(75) | | $CHCl_3$(00) : DMF(100) | |
|---|---|---|---|---|---|---|---|---|
| | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M | Fiber size (μm) | M |
| 10 | 0.51±0.15 | Slightly Bead | 0.67±0.21 | Fiber | 0.45±0.12 | Slightly Bead | 0.44±0.09 | Slightly Bead |
| 15 | 0.65±0.18 | Slightly Bead | 0.54±0.19 | Fiber | 0.39±0.07 | Bead | 0.40±0.07 | Slightly Bead |
| 20 | 0.43±0.11 | Bead | 0.59±0.19 | Fiber | 0.45±0.10 | Bead | 0.39±0.09 | Bead |
| 25 | 0.46±0.12 | Bead | 0.64±0.18 | Fiber | 0.49±0.11 | Bead | 0.41±0.07 | Bead |

M=Morphology of fiber

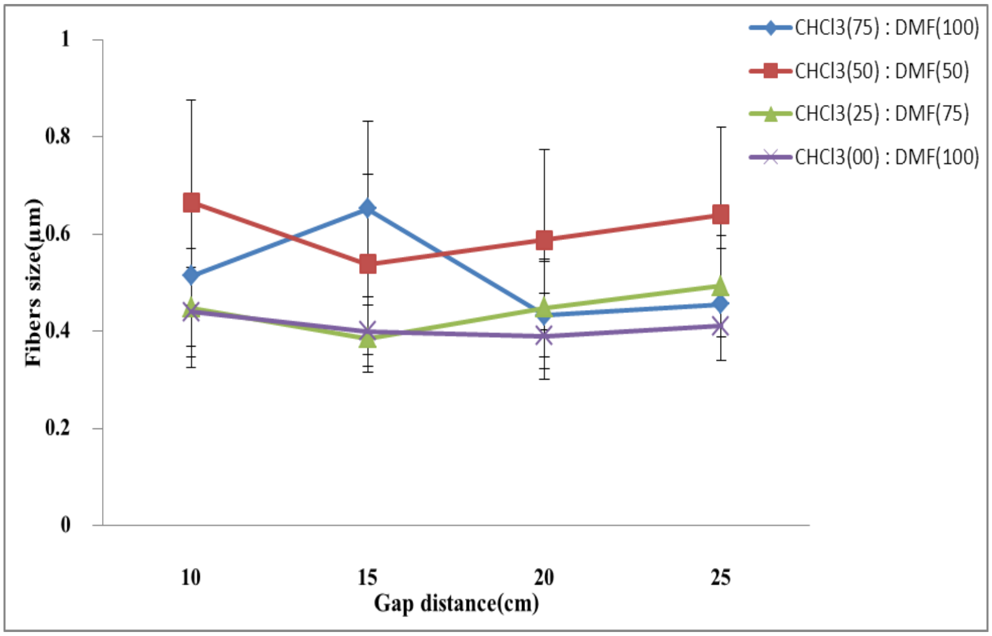



Figure 4.12 Effect of gap distance on fiber size of PLA electrospun fiber. [v=15kV, F=1.0ml/hr.]

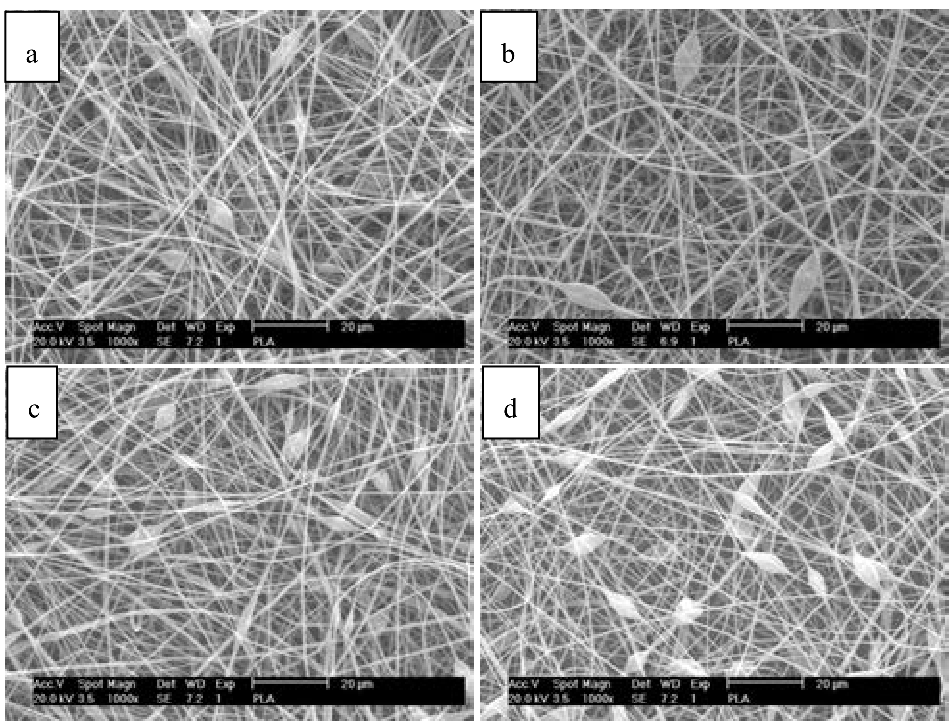



Figure4.13 SEM images of PLA electrospun fiber obtained from PLA 8%w/v ($CHCl_3$:DMF/75:25) with various gap distance (a)10cm (b)15cm (c)20cm (d)25cm. [v=15kV, F=1.0ml/hr.]

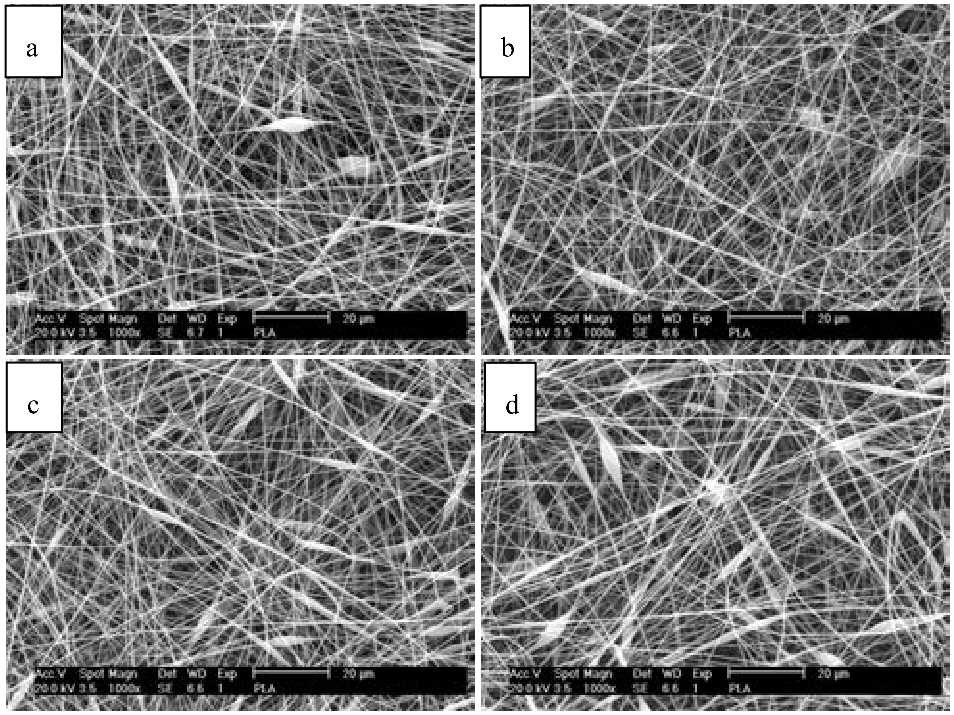



Figure4.14 SEM images of PLA electrospun fiber obtained from PLA 18%w/v ($CHCl_3$:DMF/00:100) with various gap distance (a)10cm (b)15cm (c)20cm (d)25cm. [v=15kV, F=1.0ml/hr.]

## 4.2 Preparation of PLA-PEO bicomponent fiber by co-electrospinning

### 4.2.1 Solution properties

#### 4.2.1.1 Viscosity

The viscosity of PLA and PEO were measured by viscometer, Figure 4.15 showed the viscosity of PEO with 1, 3 and 5 %w/v in $CHCl_3$ compared viscosity of PLA 8%w/v ($CHCl_3$:DMF/75:25), PLA 12%w/v($CHCl_3$:DMF/50:50), PLA 16%w/v($CHCl_3$:DMF/25:75) and PLA19%w/v( $CHCl_3$:DMF/00:100).

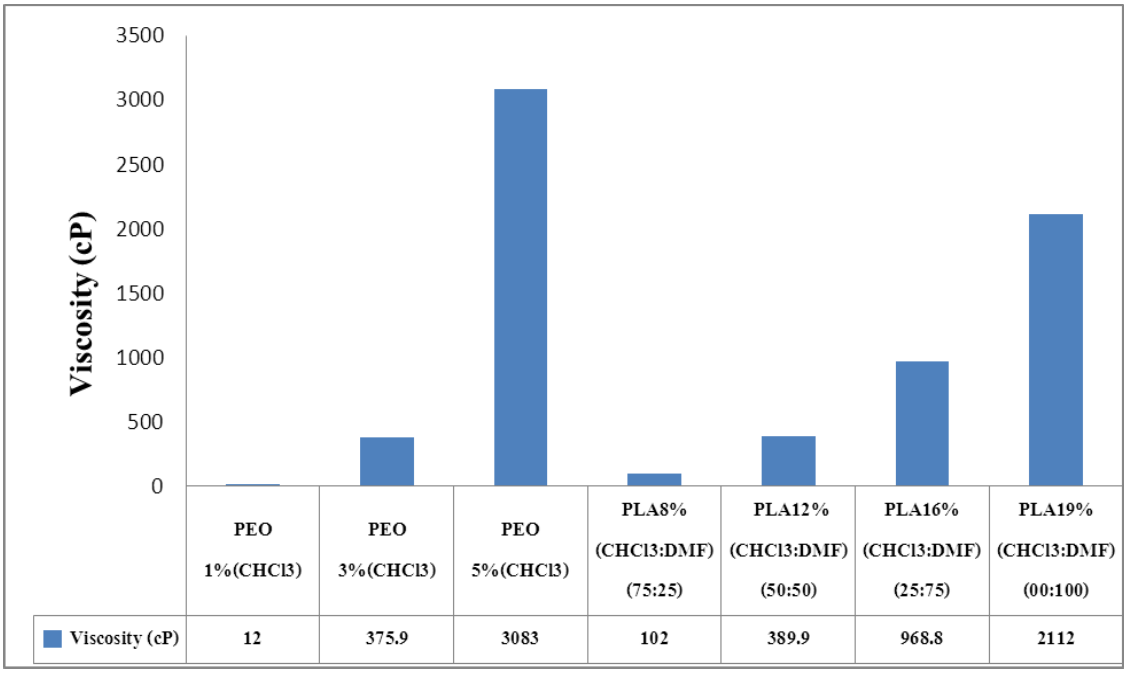
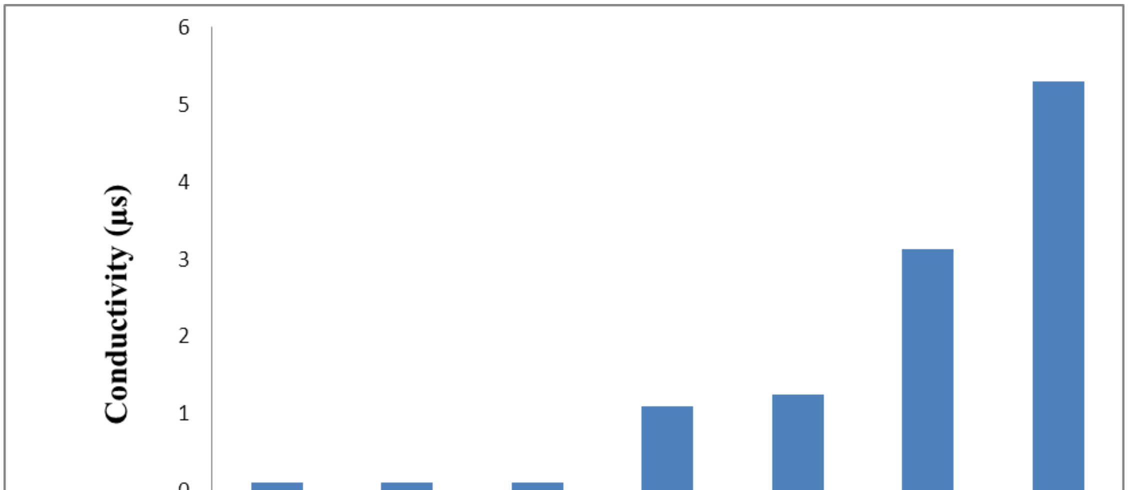



Figure 4.15 Effect of PEO solution concentration on viscosity,

and effect of solvent system on viscosity of PLA solution.

#### 4.2.1.2 Conductivity

The conductivity of PLA and PEO were measured by viscometer, Figure 4.15 showed the conductivity of PEO with 1, 3 and 5 %w/v in $CHCl_3$ compared conductivity of PLA 8%w/v ($CHCl_3$:DMF/75:25), PLA 12%w/v ($CHCl_3$:DMF/50:50), PLA 16%w/v ($CHCl_3$:DMF/25:75) and PLA19%w/v($CHCl_3$:DMF/00:100).




| | PEO 1%(CHCl3) | PEO 3%(CHCl3) | PEO 5%(CHCl3) | PLA8% (CHCl3:DMF) (75:25) | PLA12% (CHCl3:DMF) (50:50) | PLA16% (CHCl3:DMF) (25:75) | PLA19% (CHCl3:DMF) (00:100) |
|---|---|---|---|---|---|---|---|
| conductivity (μs) | 0.11 | 0.11 | 0.11 | 1.1 | 1.24 | 3.13 | 5.3 |

Figure 4.16 Effect of PEO concentration on conductivity,

and conductivity of PLA solution with various solvent system.

### 4.2.2 Effect of co-electrospinning parameters on fiber formation

#### 4.2.2.1 Effect of PLA solvent system

The solvent system is importance parameter, which clearly influence on morphology and fiber formation (refer from the effect of solvent system in part 1). For this part we choose the solvent system and concentration from part1, and using PEO 3%w/v dissolve in $CHCl_3$, that show in Table4.5 and figure 4.17. The results, we interested 2 solvent system that PLA 8%w/v ($CHCl_3$:DMF/75:25) obtained the larger fibers size (2.17±0.40 μm) and porous-smooth surface (called “porous surface system”). And 19%w/v ($CHCl_3$:DMF/00:100) obtain uniform fibers, smaller fibers size(1.07±0.13 μm) and smooth surface (called “smooth surface system”). Which we choose both systems for investigate the effect of processing parameters on PLA-PEO bicomponent fibers. Figure4.18 showed the morphology of fiber with various PLA solvent systems.

Table 4.5 Effect of PLA solvent system with various concentrations, on fiber size and morphology of PLA-PEO bicomponent electrospun fiber.

| No. | PLA solution | PEO in CHCl3) | Fiber size (μm) | Morphology |
|---|---|---|---|---|
| 1 | 8% w/v $CHCl_3$(75): DMF(25) | 3 %w/v | 2.17±0.40 | Fiber , Porous/smooth surface |
| 2 | 12% w/v $CHCl_3$(50): DMF(50) | 3 %w/v | 1.52±0.30 | Fiber , Smooth/smooth surface |
| 3 | 16% w/v $CHCl_3$(25): DMF(75) | 3 %w/v | 1.03±0.51 | Fiber , Smooth/smooth surface |
| 4 | 19% w/v $CHCl_3$(00): DMF(100) | 3 %w/v | 1.07±0.13 | Fiber , Smooth/smooth surface |

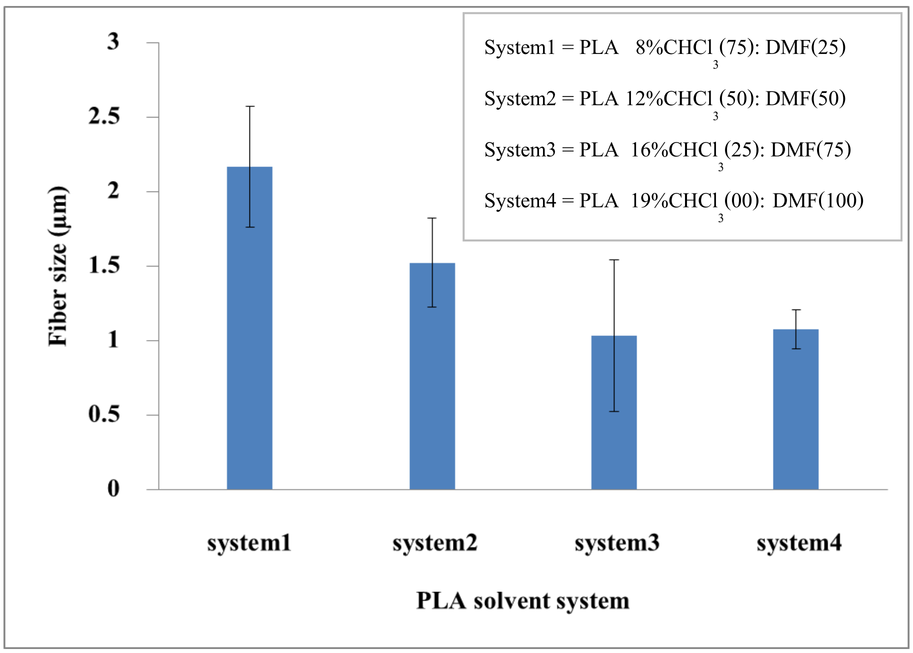



Figure4.17 Effect of PLA solvent system on fiber size of PLA-PEO bicomponent electrospun fiber.

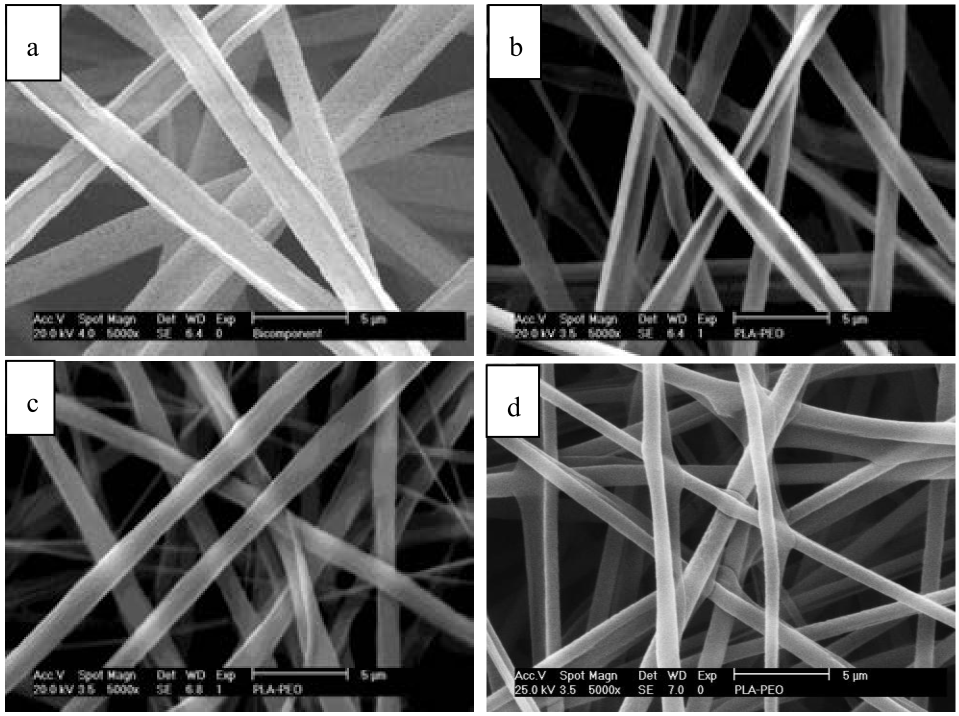



Figure4.18 SEM images of PLA-PEO bicomponent electrospun fiber obtained from various PLA solvent system (a) PLA 8%$CHCl_3$(75): DMF(25), (b)PLA 12%$CHCl_3$(50): DMF(50), (c) 16%$CHCl_3$(25): DMF(75) and (d) 19%$CHCl_3$(00): DMF(100).

Effect of PEO solution concentration, solution flow rate ratio and applied voltage on morphology and fiber formation of (Porous and smooth surface system) PLA-PEO bicomponent electrospun fiber were summarized in table 4.6 and 4.7

Table 4.6 Effect of PEO solution concentration, solution flow rate ratio and applied voltage on fibers size and morphology of PLA-PEO bicomponent electrospun fiber with porous surface system.

| Polymer concentration (%w/v) | | Solution flow rate (F) (ml/hr) | | Applied voltage (v) (kV) | Gap distance (d), (cm) | fibers size (μm) ±SD | Remarks |
|---|---|---|---|---|---|---|---|
| PLA | PEO | PLA | PEO | | | | |
| 8 | 1 | 0.5 | 0.5 | 15 | 20 | 1.08±0.26 | Bead |
| 8 | 3 | 0.5 | 0.5 | 15 | 20 | 2.17±0.40 | Fiber |
| 8 | 5 | 0.5 | 0.5 | 15 | 20 | 2.55±0.42 | Fiber |
| 8 | 3 | 1 | 0 | 15 | 20 | 0.83±0.41 | Bead |
| 8 | 3 | 0.9 | 0.1 | 15 | 20 | 0.39±0.08 | Bead |
| 8 | 3 | 0.75 | 0.25 | 15 | 20 | 2.06±0.29 | Bead |
| 8 | 3 | 0.5 | 0.5 | 15 | 20 | 2.17±0.40 | Fiber |
| 8 | 3 | 0.25 | 0.75 | 15 | 20 | 2.16±0.41 | Fiber |
| 8 | 3 | 0.1 | 0.9 | 15 | 20 | 2.56±0.20 | Fiber |
| 8 | 3 | 0 | 1 | 15 | 20 | 2.05±0.18 | Fiber |
| 8 | 3 | 0.5 | 0.5 | 10 | 20 | 2.78± 0.46 | Fiber |
| 8 | 3 | 0.5 | 0.5 | 20 | 20 | 2.19±0.38 | Fiber |
| 8 | 3 | 0.5 | 0.5 | 25 | 20 | 2.34±0.45 | Fiber |

Table 4.7 Effect of PEO solution concentration, solution flow rate ratio and applied voltage on fibers size and morphology of PLA-PEO bicomponent electrospun fiber with smooth surface system.

| Polymer concentration (%w/v) | | Solution flow rate (F) (ml/hr) | | Applied voltage (v) (kv) | Gap distance (d), (cm) | Average fiber size (μm) ±SD | Remarks |
|---|---|---|---|---|---|---|---|
| PLA | PEO | PLA | PEO | | | | |
| 19 | 1 | 0.5 | 0.5 | 15 | 20 | 0.71±0.15 | Bead |
| 19 | 3 | 0.5 | 0.5 | 15 | 20 | 1.07±0.13 | Fiber |
| 19 | 5 | 0.5 | 0.5 | 15 | 20 | 1.23±0.19 | Fiber |
| 19 | 3 | 1.0 | 0.0 | 15 | 20 | 0.23±0.06 | Bead |
| 19 | 3 | 0.9 | 0.1 | 15 | 20 | 0.12±0.03 | Bead |
| 19 | 3 | 0.75 | 0.25 | 15 | 20 | 0.41±0.32 | Bead |
| 19 | 3 | 0.5 | 0.5 | 15 | 20 | 1.07±0.13 | Fiber |
| 19 | 3 | 0.25 | 0.75 | 15 | 20 | 1.12±0.20 | Fiber |
| 19 | 3 | 0.1 | 0.9 | 15 | 20 | 1.51±0.24 | Fiber |
| 19 | 3 | 0.0 | 1.0 | 15 | 20 | 2.05±0.18 | Fiber |
| 19 | 3 | 0.5 | 0.5 | 10 | 20 | 0.94±0.19 | Bead |
| 19 | 3 | 0.5 | 0.5 | 20 | 20 | 1.03±0.15 | Slight Bead Formation |
| 19 | 3 | 0.5 | 0.5 | 25 | 20 | 1.13±0.20 | Slight Bead Formation |

#### 4.2.2.2 Effect of PEO concentration

Under processing condition stated in table 4.6 and 4.7, it was found that changing PEO concentration from 1 to 3 and 5 %w/v increased fiber size from porous surface 1.08±0.26 to 2.17±0.40 and 2.55±0.42, and the smooth surface system from 0.71±0.15 to 1.07±0.13 and 1.23±0.19 µm, respectively, that showed in figure4.19. Moreover, as shown in figure 4.20 and 4.21 fibers morphology was also affected PEO concentration as it changed from sporadically bead-on-string fiber at PEO concentration of 1%w/v to fairly smooth fiber at higher concentration. This could be the resulted of increase viscosity at higher PEO concentration that restricted PLA-PEO charged jet elongation. Our finding was in agreement with previous reports [64-68].

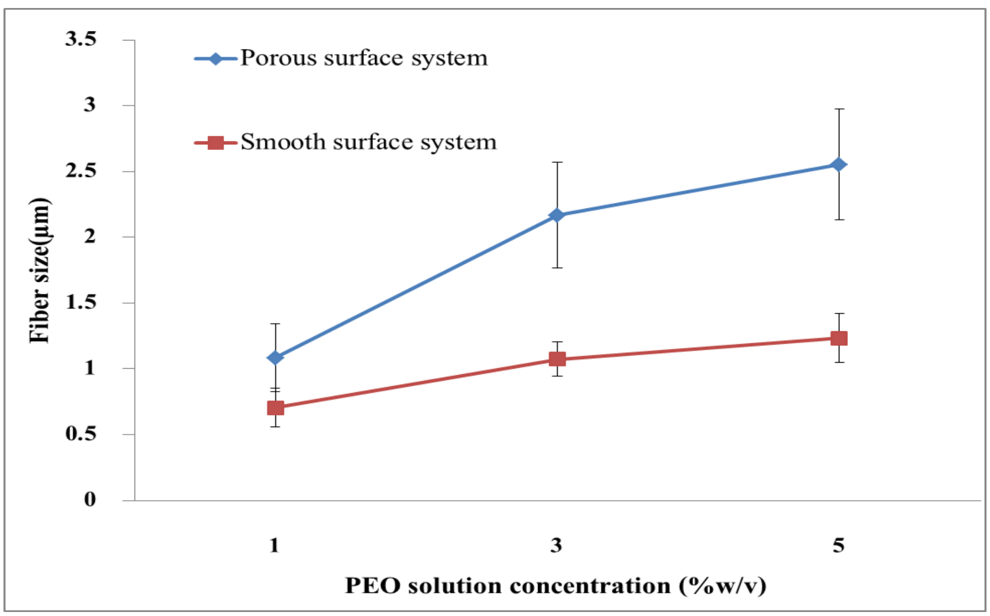



Figure4.19 Effect of PEO solution concentration on fiber size of PLA-PEO bicomponent fiber with porous surface system [PLA8%w/v ($CHCl_3$:DMF/75:25)] and smooth surface system [PLA19%w/v ($CHCl_3$:DMF/00:100)].

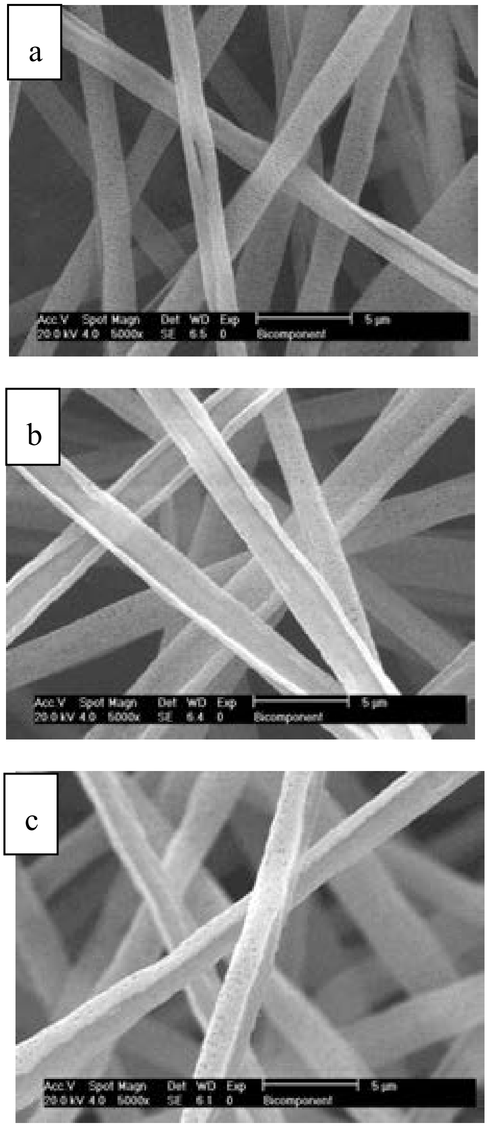



Figure 4.20 SEM images of PLA-PEO bicomponent fibers with porous surface system obtained from different PEO concentration in $CHCl_3$
(a) 1%w/v (b) 3%w/v (c) 5%w/v.

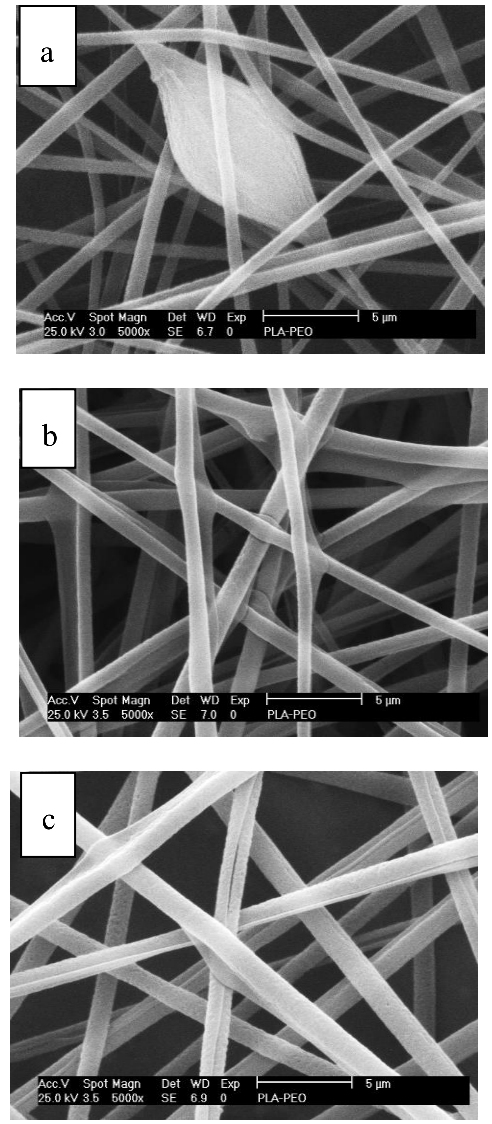



Figure 4.21 SEM images of PLA-PEO bicomponent fibers with smooth surface system obtained from different PEO concentration in $CHCl_3$
(a) 1%w/v (b) 3%w/v (c) 5%w/v.

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#### 4.2.2.3 Effect of solution flow rate ratio

Using the processing condition stated in table4.6 and 4.7, it was found that when the flow rate ratio of PLA:PEO was varied from 1.0:0.0 to 0.9:0.1, 0.75:0.25, 0.5:0.5, 0.25:0.75,0.1:0.9 and 0.0:1.0 ml/hr, the average fiber size was changed the porous surface system from 0.83±0.41, 0.39±0.08, 2.06±0.29, 2.17±0.40, 2.16±0.41, 2.56±0.20 and 2.05±0.18 μm, and the smooth surface system from 0.23±0.06 to 0.12±0.03, 0.41±0.32, 1.07±0.13, 1.12±0.20, 1.51±0.24 and 2.05±0.18 μm, as shown in figure 4.22. The fiber morphology was also changed from bead-on–string morphology found at high PLA portion to a fairly smooth fiber at PLA portion around or lower than 0.5 ml/hr, as shown in figure 4.23 and 4.24. These results showed PLA: PEO flow rate ratio influenced on the fiber size and morphology of fiber.

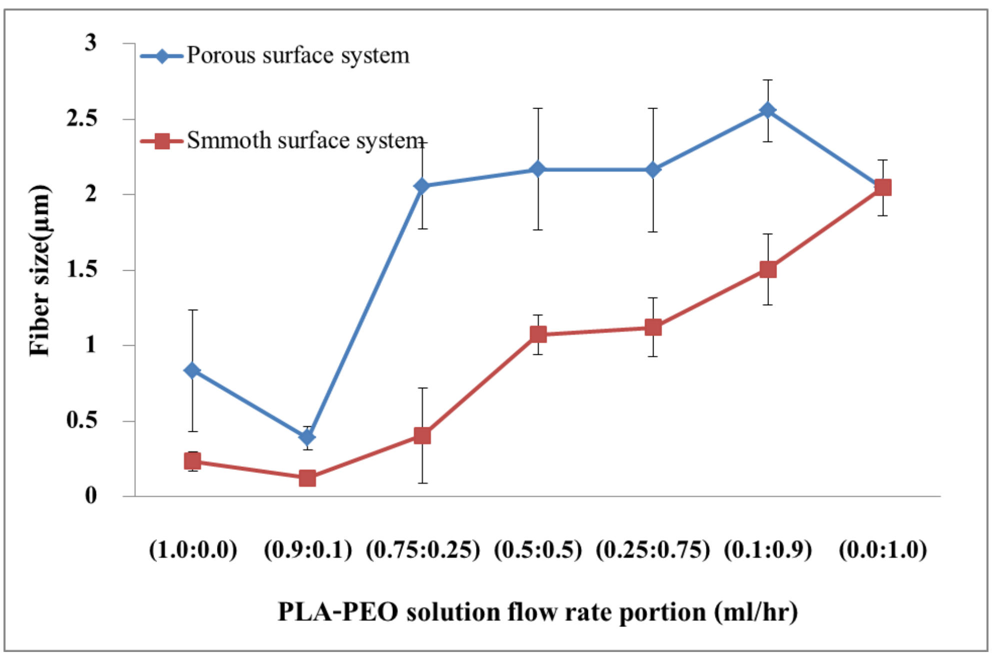



Figure 4.22 Effect of PLA-PEO solution flow rate ratio on fiber size of PLA-PEO bicomponent fiber with porous surface system [PLA8%w/v ($CHCl_3$:DMF/75:25)] and smooth surface system [PLA19%w/v ($CHCl_3$:DMF/00:100)].

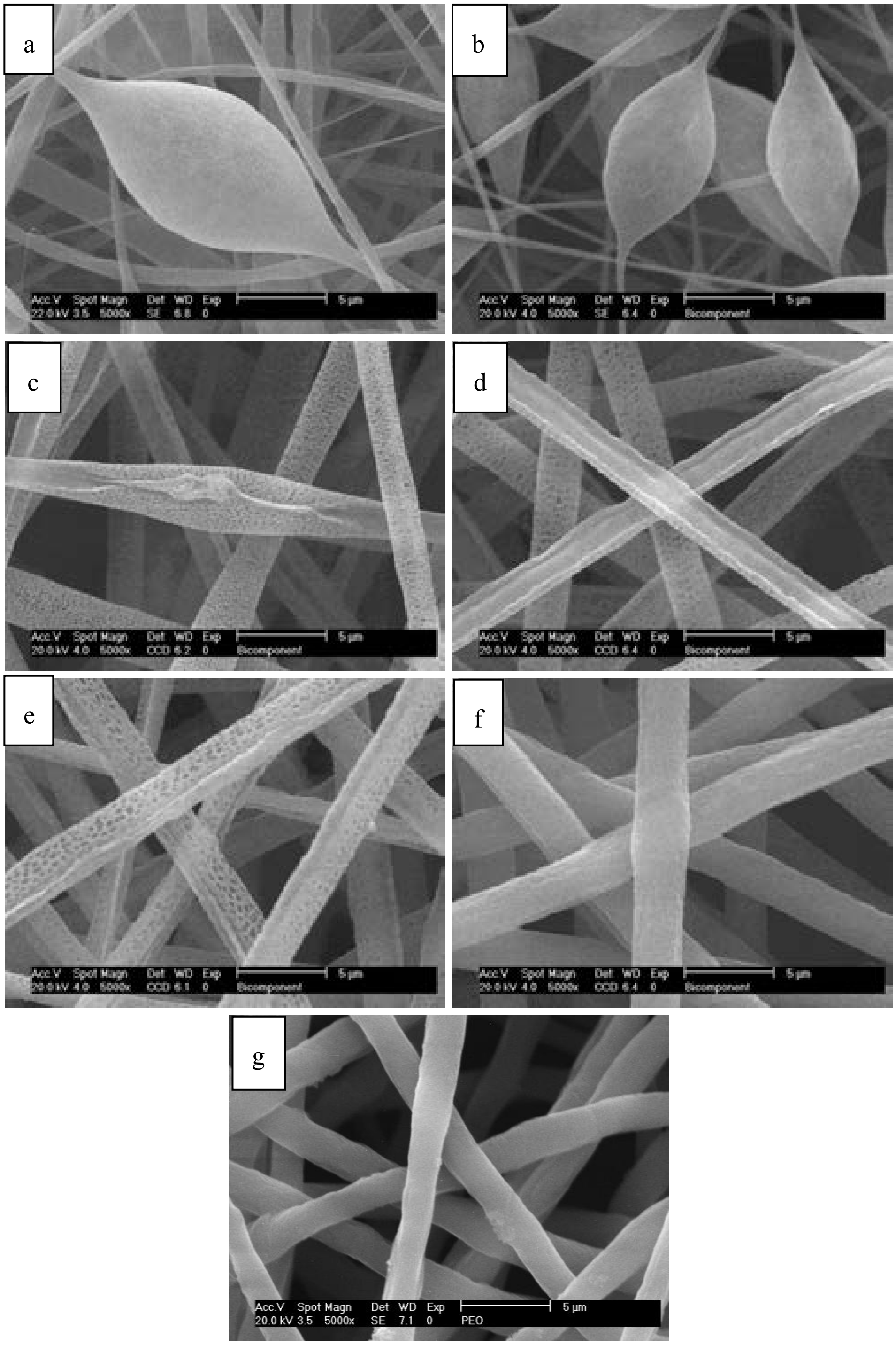



Figure 4.23 SEM images of PLA-PEO bicomponent fibers with porous surface system obtained from different PLA:PEO flow rate ratio (a)1.0:0.0 ml/h, (b) 0.9:0.1 ml/hr, (c) 0.75:0.25 ml/hr, (d) 0.5:0.5 ml/h(e) 0.25:0.75 ml/hr, (f) 0.9:0.1 ml/hr and (g)0:1.0 ml/hr. [v=15kV, d=20cm].

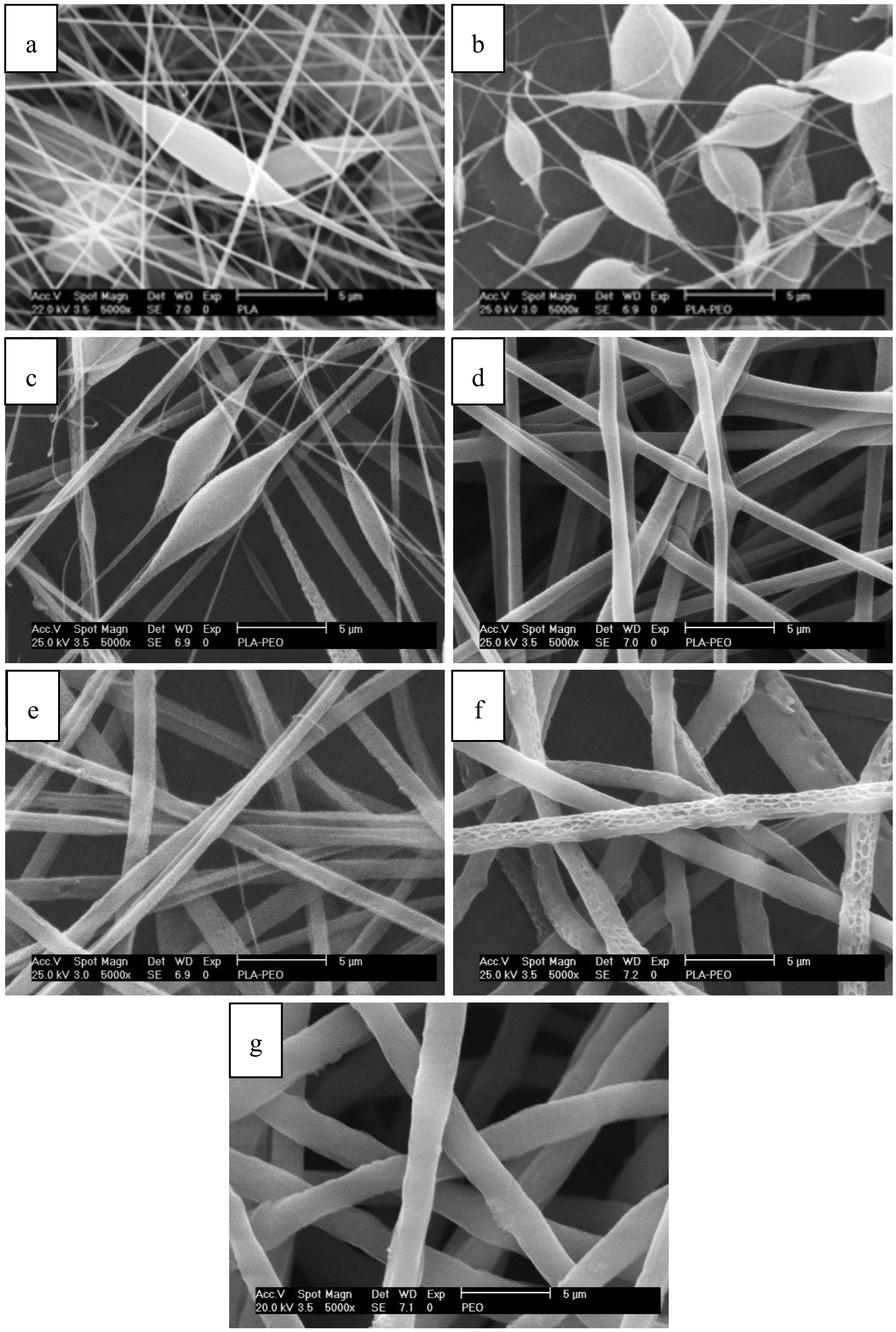



Figure 4.24 SEM images of PLA-PEO bicomponent fibers with smooth surface system obtained from different PLA-PEO flow rate ratio (a)1.0:0.0 ml/hr, (b) 0.9:0.1 ml/hr, (c) 0.75:0.25 ml/hr, (d) 0.5:0.5 ml/hr, (e) 0.25:0.75 ml/hr, (f) 0.9:0.1 ml/hr and (g) 0.0:1.0 ml/hr. [v=15kV, d=20cm].

#### 4.2.2.4 Effect of applied voltage

As shown in figures 4.25, increasing applied voltage from 10 to 15, 20 and 25 kV had small effect on fiber size of smooth surface system, as the size tended to increase slightly from 0.94±0.19to 1.07±0.13, 1.03±0.15 and 1.13±0.20 μm, respectively. Since the applied voltage affected on charge repulsion and solution mass flow rate [71-73], even though the experiment was conducted under constant flow rate, an actual flow rate at the jet forming site may fluctuated resulting in a morphology change and larger fiber size distribution. In addition, from visual observation during spinning process, a jet splitting at the spinneret tip were observed at high applied voltage (20 and 25 kV), which could also contribute to a formation of bead-on-string fibers.

While porous surface system, changing applied voltage from10 to 15 had effect on decreasing fibers size (from 2.78± 0.46 to 2.17±0.40 μm) because charge repulsion effect. Increasing applied voltage from 15 to 20 and 25 kV had small effect on fiber size tended to increase slightly from 2.17±0.40 to 2.19±0.38 and 2.34±0.45 μm, respectively. Figure 2.26 and 2.27 showed the morphology of PLA-PEO bicomponent electrospun fiber with various applied voltage.

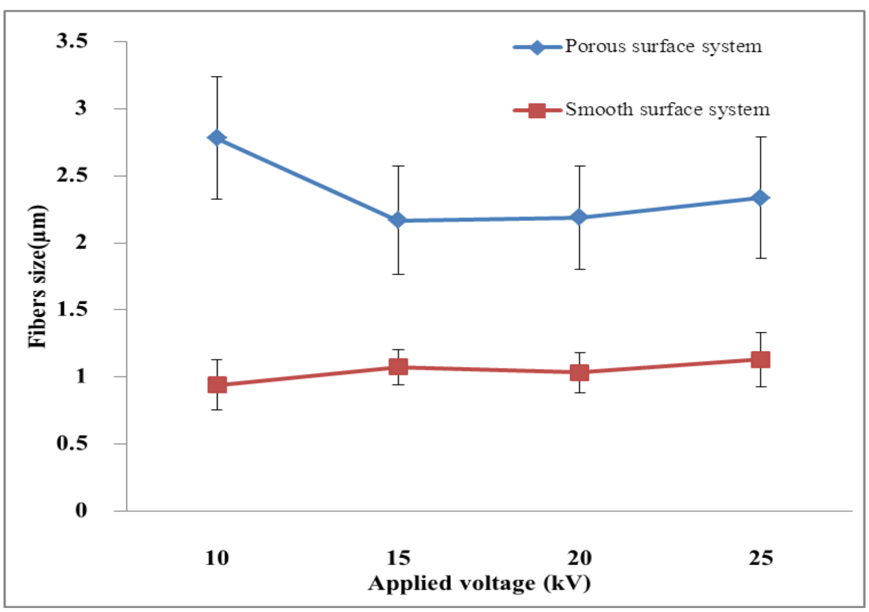



Figure 4.25 Effect of applied voltage on fiber size of PLA-PEO bicomponent fiber with various PLA solvent system of PLA 8%w/v ($CHCl_3$:DMF/75:25) and PLA 19%w/v ($CHCl_3$:DMF/00:100).

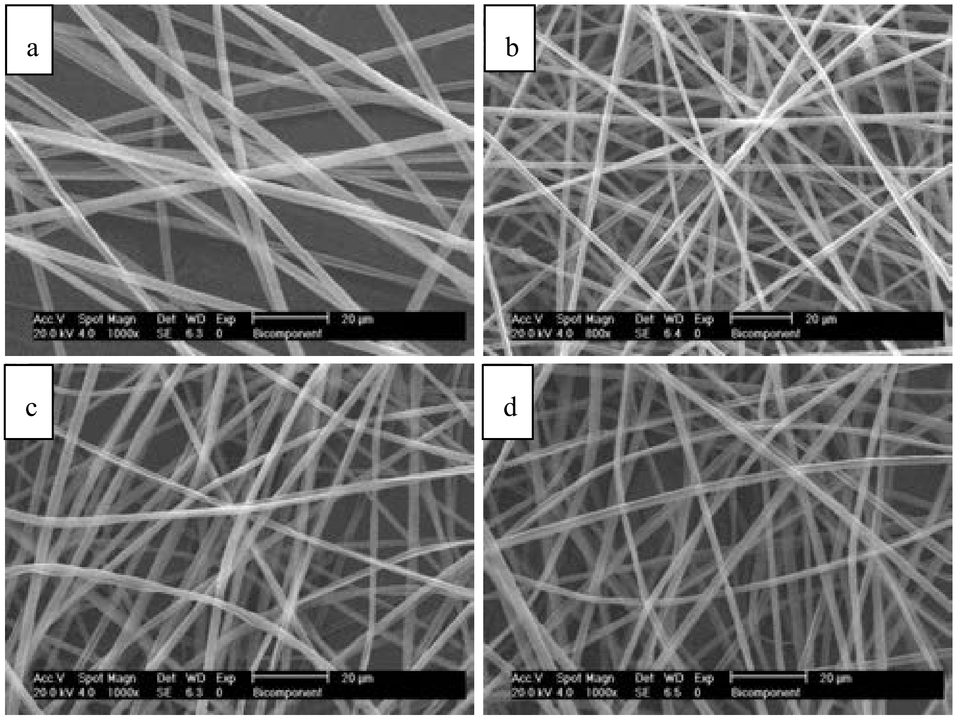



Figure 4.26 SEM images of PLA-PEO bicomponent fibers with porous surface system obtained from different applied voltage (a) 10kV, (b) 15kV, (c) 20kV and (d) 25 kV.

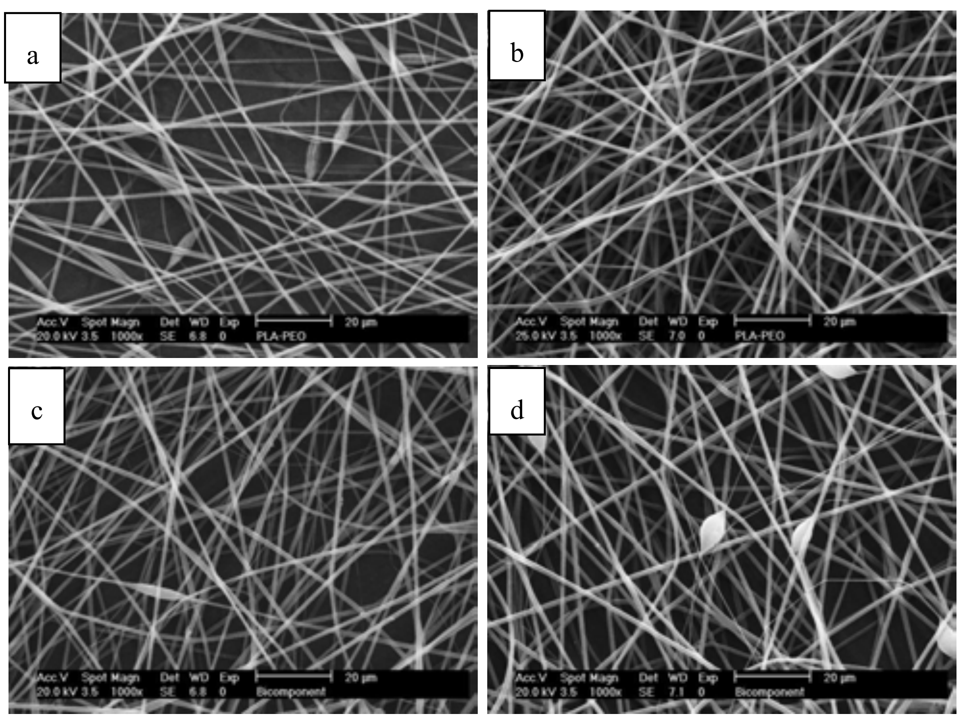



Figure 4.27 SEM images of PLA-PEO bicomponent fibers with smooth surface system obtained from different applied voltage (a) 10kV, (b) 15kV, (c) 20kV and (d) 25 kV.

### 4.2.3 PLA-PEO bicomponent fiber structure and composition

#### 4.2.3.1 PLA-PEO bicomponent fiber structure

Figure 4.28 and 4.29 showed SEM images of porous surface system and smooth surface system PLA-PEO fibers (electrospun from 0.5:0.5 ratio) before and after PEO removal. After water immersion for adequate period, the PEO phase of PLA-PEO fiber was completed removed and rendered the fiber to C-shape fiber composed of only PLA. Similar the result of [74] Since the composition of the bicomponent fibers could be controlled by solution flow rate ratio (as previously discussed) and solution concentration, this technique could be used to produce fibers with desired size and wall thickness in a simple and straight forward fashion. These fibers could be useful for various applications including filtration, biomedical and environmental applications.

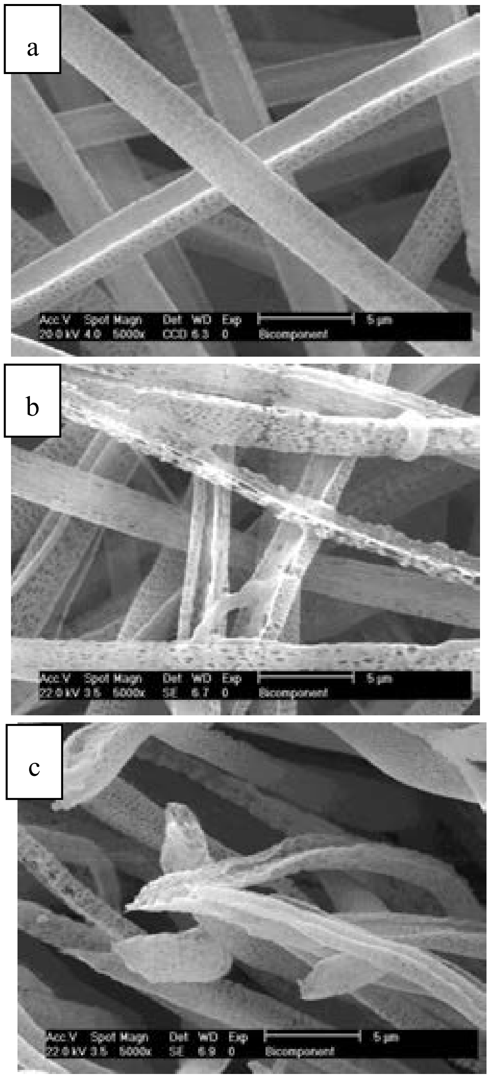



Figure 4.28 SEM images of PLA-PEO bicomponent fibers with porous surface prepared at PLA 8%w/v ($CHCl_3$:DMF/75:25) and PEO 3% w/v ($CHCl_3$) (a) before and (b,c) after PEO phase removal.

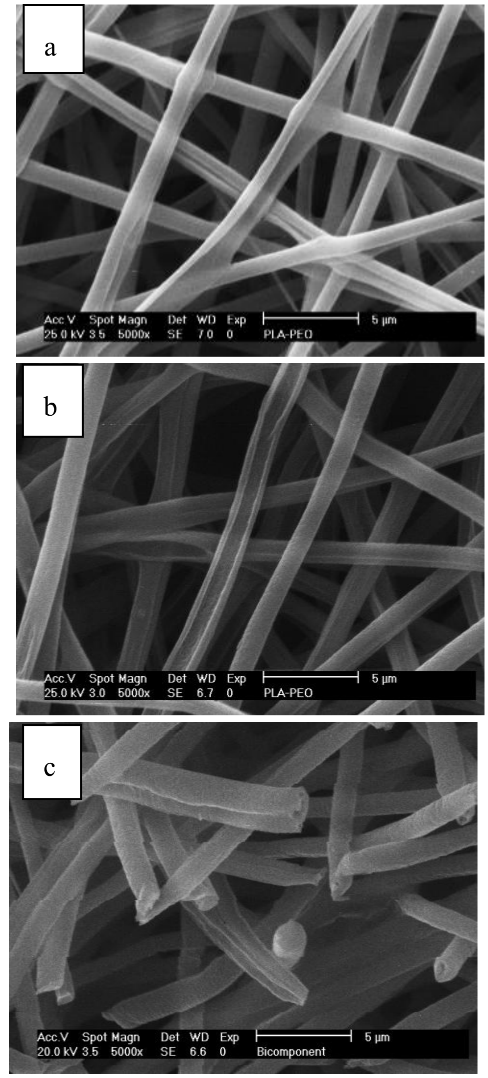



Figure 4.29 SEM images of PLA-PEO bicomponent fibers with smooth surface prepared at PLA19%w/v (DMF) and PEO 3% w/v ($CHCl_3$) (a) before and (b,c) after PEO phase removal.

**4.2.3.2 Fourier Transform Infrared Spectroscopy (FTIR)**

The compositions of PLA-PEO bicomponent electrospun fiber with various solution flow rate ratio were investigated by FTIR. By adjusting the flow ratio between 2 polymer phases, one can control the composition of the obtained bicomponent fiber as shown by FT-IR spectrum in figure 4.30 The IR spectrum of neat PLA fiber, graph (a), showed the carbonyl and C-H stretching around 1,750, 2,950 and 3,000cm$^{-1}$, while that of neat PEO fiber, graph (g), showed the C-H stretching around 2,900 cm$^{-1}$[69,70]. As the composition of these 2 phases changed, so did the intensity and proportion of these signature peaks.

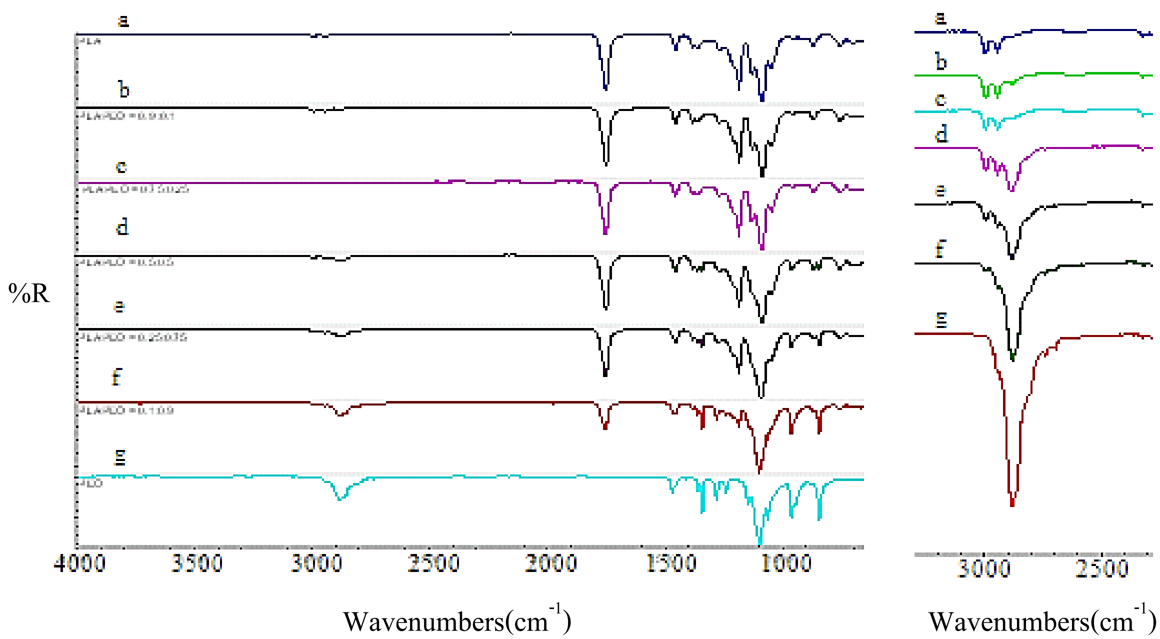



Figure 4.30 FTIR spectrum of PLA-PEO bicomponent fibers obtained from different PLA:PEO flow rate ratio (a) 1.0:0.0ml/hr, (b) 0.9:0.1ml/hr, (c) 0.75:0.25ml/hr, (d) 0.5:0.5ml/hr, (e) 0.25:0.75ml.hr, (f) 0.1:0.9ml/hr and (g) 0.0:1.0ml/hr, respectively.

In addition, Figure4.31 showed PLA, PEO, PLA-PEO bicomponent electrospun fiber with before and after PEO phase removal. The PLA-PEO bicomponent electrospun fiber with before PEO phase removal showed both of PLA and PEO peaks. While PLA-PEO bicomponent electrospun fiber with after PEO phase removal showed PLA peak only that indicate PEO phase can remove by water.

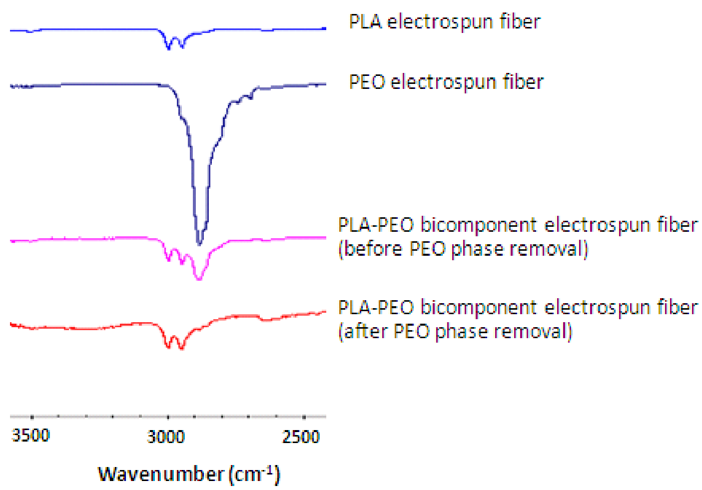



Figure4.31 FTIR spectrum of PLA, PEO and PLA-PEO bicomponent fibers before and after PEO phase removal.

**4.2.3.3 Thermal gravimetric analysis (TGA)**

The compositions and weight fraction of PLA-PEO bicomponent electrospun fibers were determined by TGA. Figure 4.32 and table 4.8 showed TGA thermogram of PLA, PEO and PLA-PEO bicomponent electrospun fibers with prepared from various PLA-PEO solution flow rate ratio portion. PLA and PEO electrospun fiber showed one weight loss regions at different temperature degradation (around 298$^{\circ}$C for PLA and around 400$^{\circ}$C for PEO). PLA-PEO bicomponent electrospun fiber with PLA-PEO flow rate ratio portions of 0.9:0.1 and 0.75:0.25 ml/hr. showed only one weight loss regions of PLA around 333-346 $^{\circ}$C without clear weight loss region of PEO. This could be because the PEO composition in the fiber was small compared to PLA phase as suggested by the calculation in table 4.8.

The PLA-PEO flow rate ratio of 0.5:0.5, 0.25:0.75 and 0.1:0.9 ml/hr showed clear decomposition of both PLA and PEO phases. These indicated that the composition of PLA-PEO bicomponent fibers were, indeed, proportional to PLA-PEO flow rate ratio. Table4.8 showed that the weight fraction of PLA and PEO phases determined from TGA thermogram and from the calculation were in good agreement.

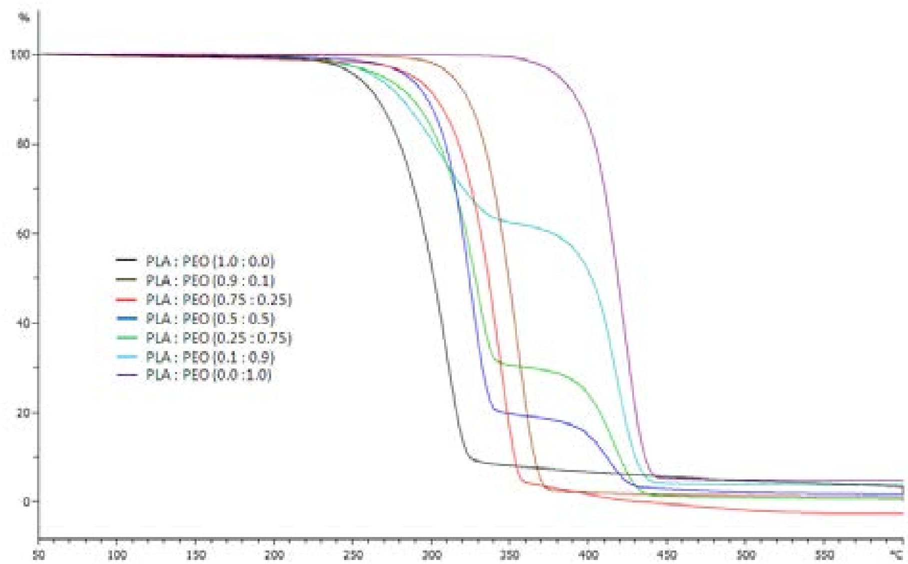



Figure4.32 TGA curve of PLA-PEO bicomponent with various PLA-PEO flow rate ratios.

Table 4.8 TGA characterization of PLA-PEO bicomponent with various flow rate ratios.

| Flow rate ratio (ml/hr:ml/hr) | | %weight fraction from calculation | | % weight fraction from TGA | | Td | |
|---|---|---|---|---|---|---|---|
| PLA | PEO | PLA | PEO | PEO | PEO | PLA | PEO |
| 1.00 | 0.00 | 100 | 0 | 100 | 0 | 298 | - |
| 0.90 | 0.10 | 98.28 | 1.72 | ~100 | * | 346 | * |
| 0.75 | 0.25 | 95 | 5 | ~100 | * | 333 | * |
| 0.50 | 0.50 | 86.36 | 13.64 | 82 | 18 | 315 | 410 |
| 0.25 | 0.75 | 67.86 | 32.14 | 70 | 30 | 319 | 412 |
| 0.10 | 0.90 | 41.30 | 58.70 | 40 | 60 | 299 | 417 |
| 0.00 | 1.00 | 0 | 100 | 0 | 100 | - | 418 |

Remark * = small peak (cannot evaluate)

Figure 4.33 and table 4.9 showed TGA characterization of PLA-PEO bicomponent electrospun fiber (PLA-PEO flow rate ration portion of 0.5:0.5 ml/hr) before and after PEO phase removal. From the thermogram, before PEO phase removal, there were two weight loss regions for PLA and PEO, but after PEO phase removal, the TGA thermogram showed a large weight loss regions of PLA, with a very small decomposition region of PEO, which could be because incomplete removal in the process. Nonetheless, the result showed that PEO could be removed by simply rinsing the fibers in water, as expected, leaving only PLA phases in a C-shape PLA fiber.

In addition figure 4.33 and table 4.9, porous surface system [8%PLA ($CHCl_3$: DMF/ 75:25) and 3% PEO ($CHCl_3$)] at flow rate ratio of 0.5:0.5 ml/hr:ml/hr showed PLA : PEO weight fraction around 75 : 25 % of fiber. While surface system [19%PLA (DMF) and 3% PEO ($CHCl_3$)] showed PLA:PEO weight fraction around 82 : 18% of fiber. Because higher PLA concentration tend to yield higher weight fraction or higher solid of PLA on the fiber.

However, the limitations of the instrumentation and access time, heat rate had to been used at 20$^{o}$C/min which is high to determine exact Td. However we can estimate the composition of PLA-PEO bicomponent fiber with various flow rate ratios and after PEO phase removal from TGA results.

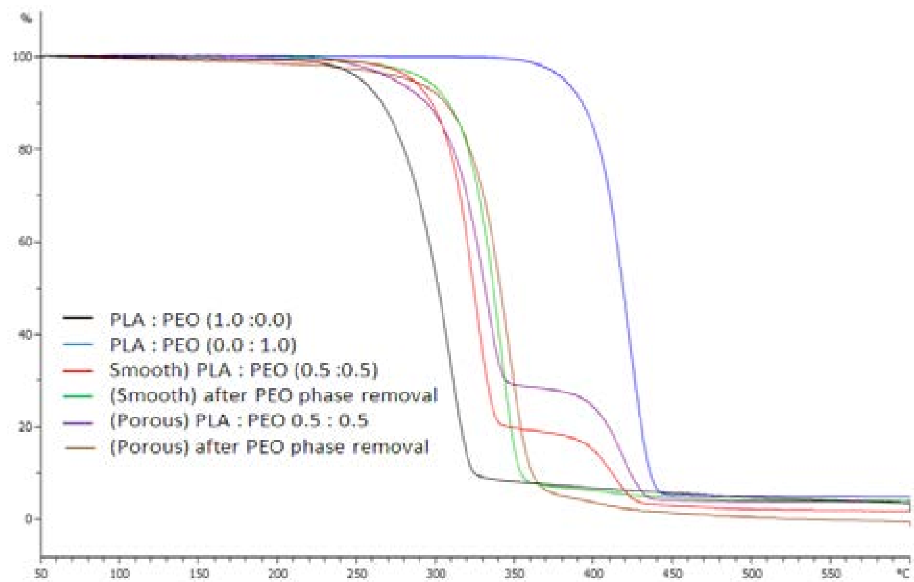



Figure4.33 TGA curve of PLA, PEO and PLA-PEO bicomponent with smooth surface system and porous surface system (before and after PEO phase removal).

Table 4.9 TGA characterization of PLA, PEO and PLA-PEO bicomponent with smooth surface system and porous surface system (before and after PEO phase removal).

| Flow rate ratio (ml/hr:ml/hr) | | %weight fraction from calculation | | % weight fraction from TGA | | Td | | Remark |
|---|---|---|---|---|---|---|---|---|
| PLA | PEO | PLA | PEO | PLA | PEO | PLA | PEO | |
| 1.0 | 0.0 | 100 | 0 | 100 | 0 | 298 | - | PLA electrospunfiber |
| 0.0 | 1.0 | 0 | 100 | 0 | 100 | - | 418 | PEO electrospunfiber |
| 0.5 | 0.5 | 86.36 | 13.64 | 82 | 18 | 315 | 410 | (smooth) before PEO phase removal |
| 0.5 | 0.5 | 100 | 0 | ~100 | * | 334 | * | (smooth) After PEO phase removal |
| 0.5 | 0.5 | 72.73 | 27.27 | 75 | 25 | 334 | 414 | (Porous) before PEO phase removal |
| 0.5 | 0.5 | 100 | 0 | ~100 | * | 338 | * | (Porous) After PEO phase removal |

Remark * = small peak (cannot evaluate)

### 4.2.4 Contact angle

The PLA-PEO bicomponent electrospun fiber with various PLA-PEO portions (from1.0:0.0 to 0.0:1.0 ml/hr) were studied surface properties by contact angle of water and glycerol. The results showed in figure 4.34 and 4.35. PEO electrospun fiber showed contact angle of water and glycerol around 0 ° and 30 ° indicating hydrophilic and oleophilic properties. PLA electrospun fiber showed contact angle of water and glycerol of around 125° and 140 °, respectively, which indicated hydrophobic and oleophobic properties. This finding was similar to other report [75]. The PLA-PEO bicomponent fibers prepared with 0.25-1.0 ml/hr of PLA portion showed hydrophobic properties, while those prepared with 0.1-1.0 ml/hr of PLA portion showed oleophobic properties. In addition, fibers with porous surface system showed slightly higher contact angle of water and glycerol than fiber with smooth surface system might due to higher surface roughness in the porous surface system compared to that of the smooth surface, which also similar to previous reports [76-77].

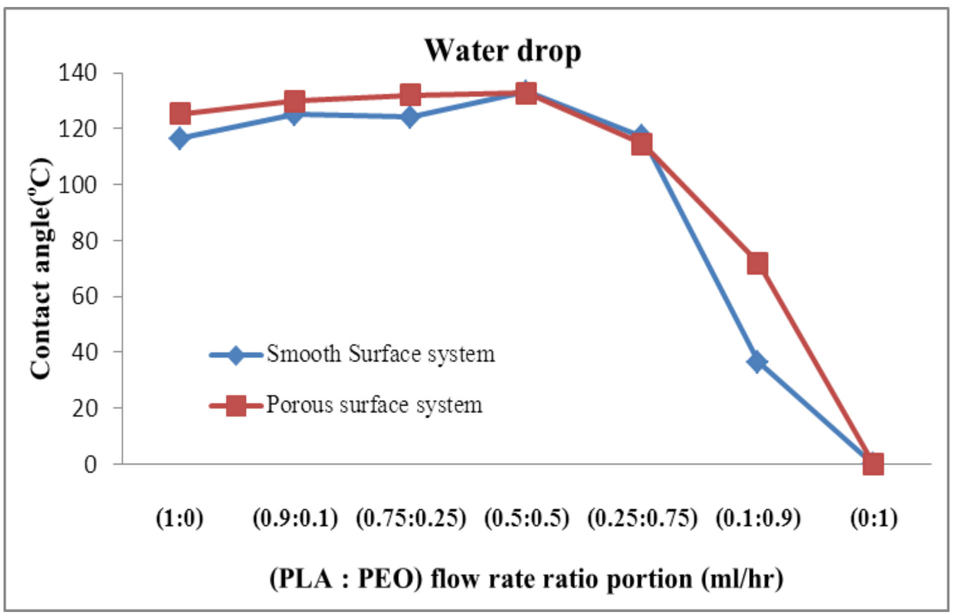



Figure4.34 The water drop contact angle measured on PLA-PEO bicomponent electrospun fibers with various PLA-PEO portions.

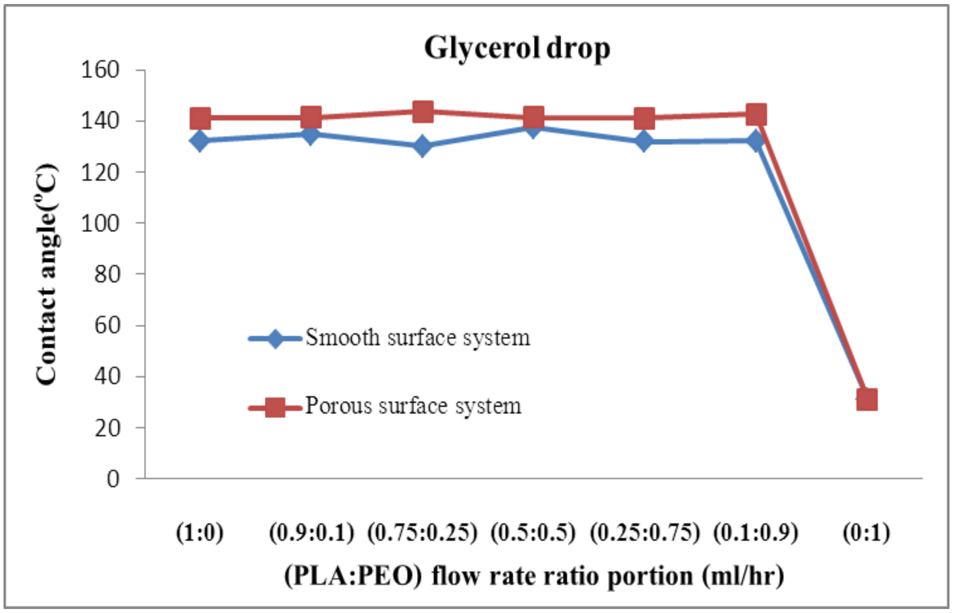



Figure4.35 The glycerol drop contact angle measured on PLA-PEO bicomponent electrospun fibers with various PLA-PEO portions.

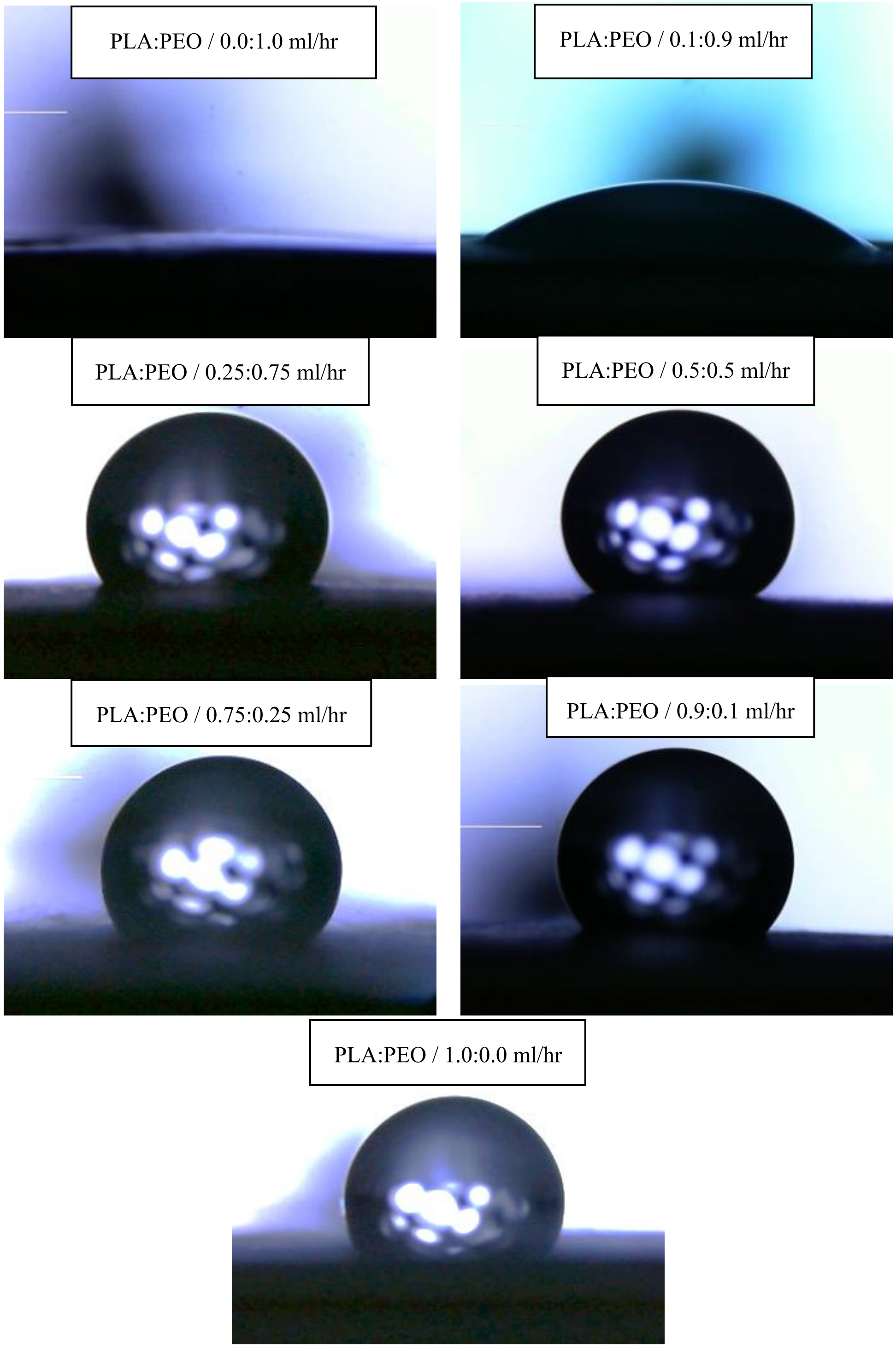



Figure4.36 Images of water dropped on PLA-PEO bicomponent electrospun fiber with various PLA and PEO portions.

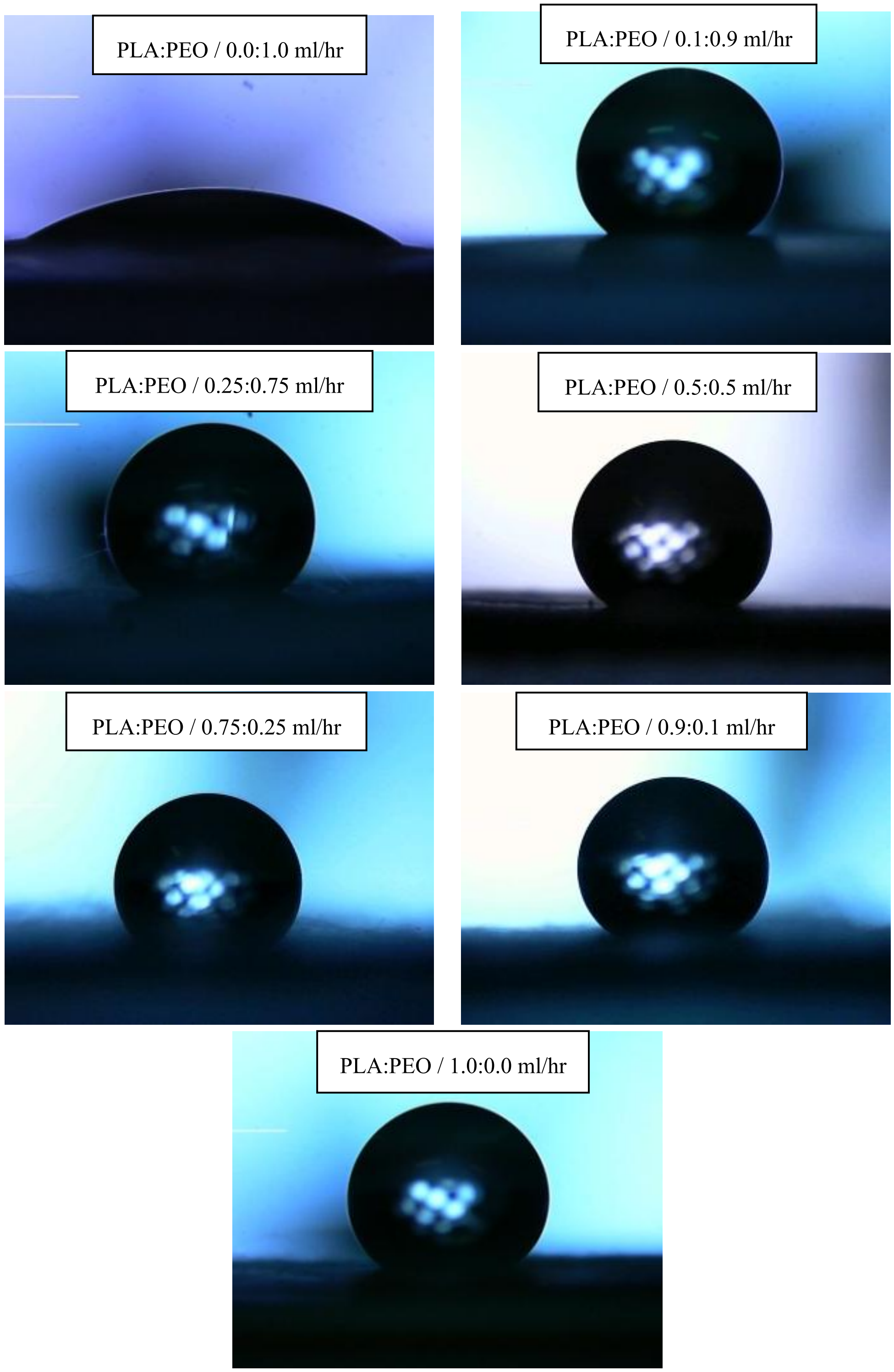



Figure4.37 Images of glycerol dropped on PLA-PEO bicomponent electrospun fiber with various PLA and PEO portions.

## 4.3 Air filtration testing

### 4.3.1 Characterization of filter media

The SEM images are demonstrated the morphology of filter as shown in figure4.38 (a-d). The spunbond, nylon6 nanofiber and C-shape PLA fiber were a uniform distribution of fiber. On the other hand, the melt blown was shown bad distribution of fiber. The average nylon6 electrospun nanofiber and C-shape PLA diameter were 0.13 and 1.52 micrometers, as compared to the spunbond fiber and melt blown fiber were 25 and 5 micrometers respectively,

The pore size was measured by image analysis technique. The spunbond, melt blown, nylon6 nanofibers and C-shape PLA fiber sizes were 48.09±27.67, 8.17±4.58, 0.24±0.10 and 2.23±1.19 μm respectively. Accordingly, fiber and pore size of nylon6 electrospun nanofiber and C-shape PLA fiber were smaller than commercials media as shown in table 4.10

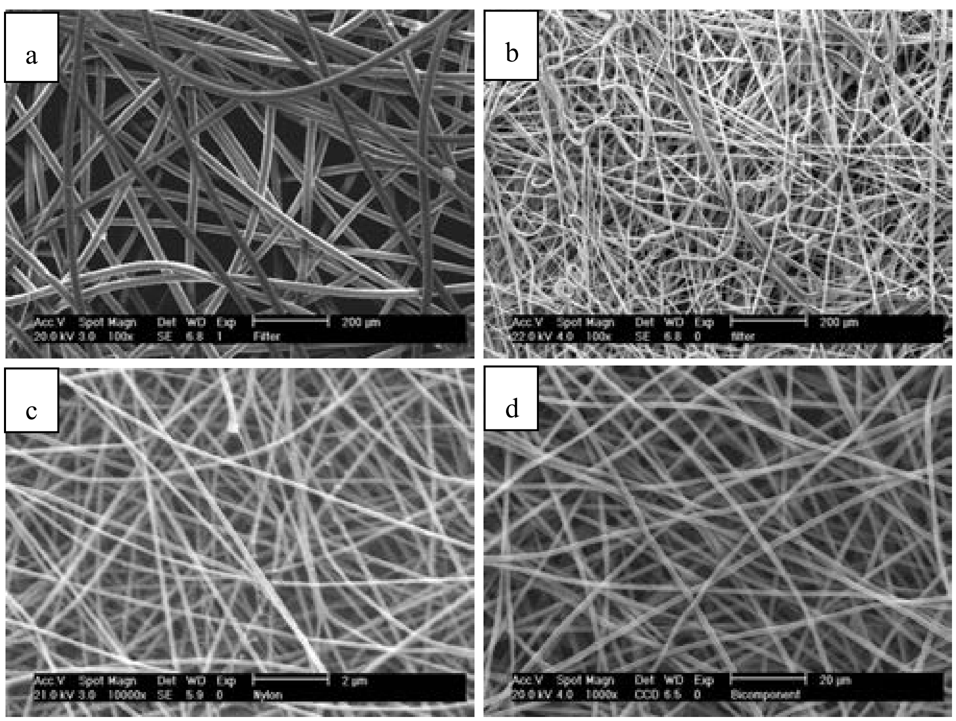



Figure4.38 SEM images showed morphology of (a) Spunbond (Magnification 100x), (b) Meltblown (Magnification 100x), (c) Nylon 6 nanofibers (Magnification 10,000x) and (d) PLA-PEO bicomponent fiber (Magnification 1,000x), respectively.

Table4.10 The characterization of filter media

| Filter type | Basis weight ($g/m^2$) | Thickness (mm) | diameter of fibers (μm) | Pore size (μm) |
|---|---|---|---|---|
| Spunbond | 0.34 | 0.211 | 24.72±2.04 | 48.10±27.67 |
| Melt blown | 0.21 | 0.136 | 5.51±3.77 | 8.18±4.58 |
| NF (T1) | 0.02 | 0.019 | 0.14±0.02 | 0.24±0.10 |
| NF (T2) | 0.07 | 0.030 | 0.14±0.02 | 0.24±0.10 |
| NF (T3) | 0.1 | 0.056 | 0.14±0.02 | 0.24±0.10 |
| C-shape PLA | 0.06 | 0.035 | 1.52±0.32 | 2.23±1.19 |

### 4.3.2 Filtration efficiency of modified filter media

The structure of filter media used in this study was listed below. Figure 4.39 showed the filtration efficiency of unmodified filter media samples and the modified air filter media with nylon6 electrospun fiber and C-shape PLA fiber.

1 S/M/S = Spunbond / Meltblown / Spunbond

2 S/M/NF(T1)/S = Spunbond / Meltblown / Nylon6 (basis weight 0.02 $g/m^2$)/ Spunbond

3 S/M/NF(T2)/S = Spunbond / Meltblown / Nylon6 (basis weight 0.07 $g/m^2$)/ Spunbond

4 S/M/NF(T3)/S = Spunbond / Meltblown / Nylon6 (basis weight 0.10 $g/m^2$)/ Spunbond

5 S/M/C-shape fiber/S = Spunbond / Meltblown / C-shape PLA / Spunbond

6 S/M/M/S = Spunbond / Meltblown / Meltblown / Spunbond

*** Experimental data was showed in appendix. The total particulate matter from air volume 1, 2, 4 and 6 liters were 3.44, 6.72, 11.04 and 15.27 mg, respectively

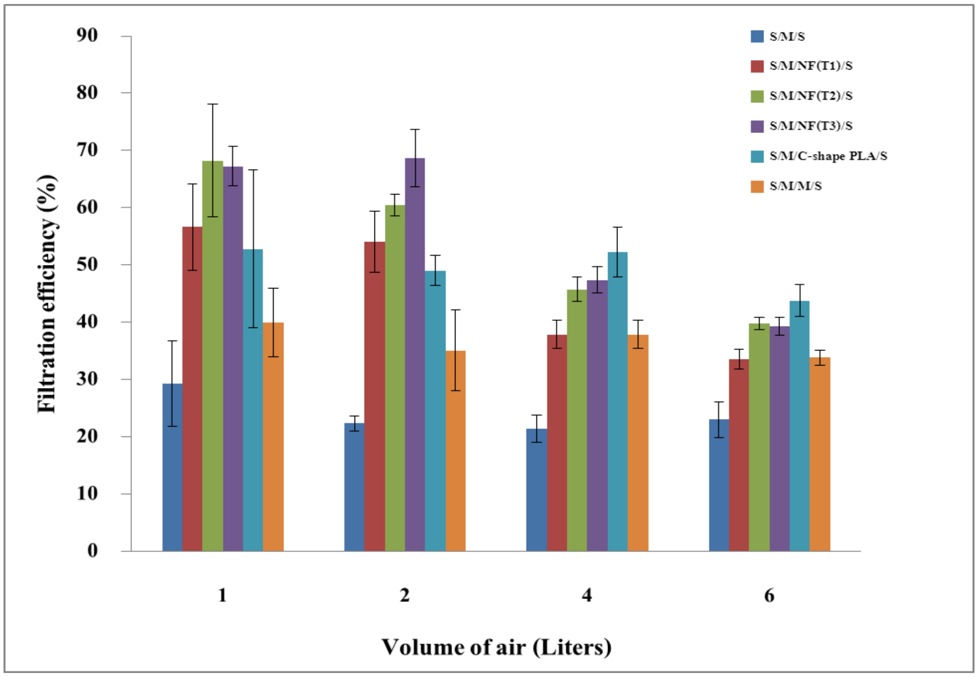



Figure4.39 Effect of air volume of side stream smoke on

filtration efficiency with various modified filter media.

To compare filter of S/M/S, S/M/T2/S, S/M/C-shape fiber/S and S/M/M/S, the filtration efficiency at v1 liter of air showed 29.36%, 68.25%, 52.76% and 39.99%. The filtration efficiency of modification of nylon6 and C-shape fiber were higher than original commercial air filter media. Our result was in good agreement with the previous reports [78-82]. Because the pore sizes of nylon 6 electrospun fiber mats were smaller than that of C-shape fiber and melt blown filter media, they demonstrated better filtration efficiency than C-shape fiber and melt blown filter media.

However, after 4 liters of air, the C-shape fiber modified media had higher filtration efficiency than nylon 6 electrospun fiber modified filter and melt blown media. The filtration efficiency of media modified with nylon 6 nanofibers at high volume of air was decreased because of the accumulation of the particulate matters inside the filter media. The pores of filter were saturated or clogged by the particulate matters. While C-shape fiber did not fouling so it could still collect particulate matters, making C-shape fiber to have higher filtration capacity than nylon6 electrospun fiber modified filter. As for melt blown fibers modified filter after subject to 4 liters of air, the particles were not collected well on melt blown modified filter since the pore sizes of the media was large enough for particles of various sizes to pass through, as showed in table 4.11

Increasing thickness or basis weight of nylon 6 electrospun nanofibers tended to increase filtration efficiency at the expense of higher pressure drop. This finding was similar to other report [83-85]. However, increasing thickness of nanofibers did not always improve filtration capacity of the modified filter since the front side of the nanofiber layers might be clogged with particles. The SEM images in figure 4.40 which showed the back side of nylon 6 T2 after subjecting to 4 liters of air flow, confirmed that the particle cannot passed through nylon6 T2 media.

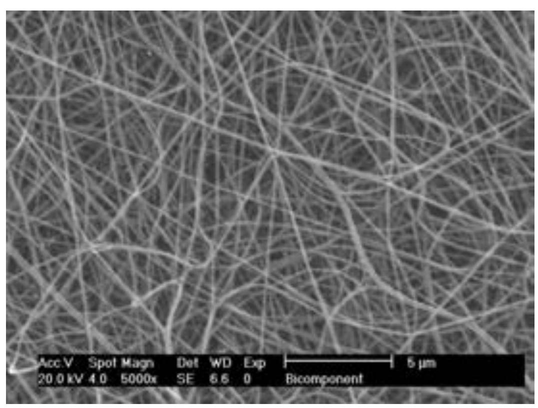
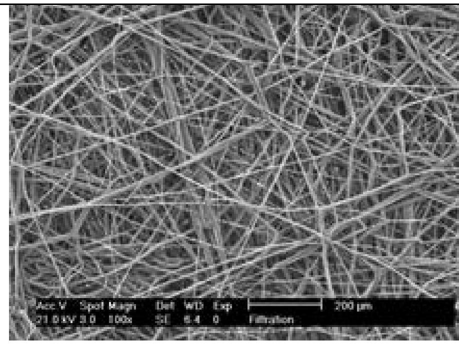
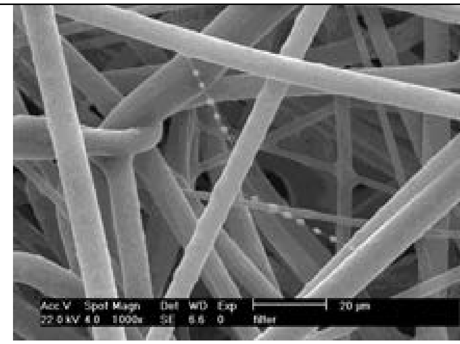
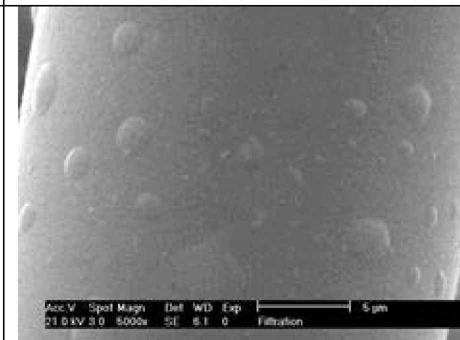
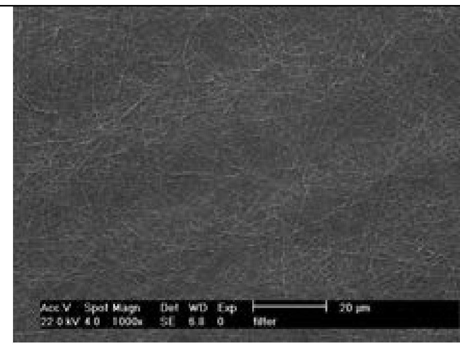
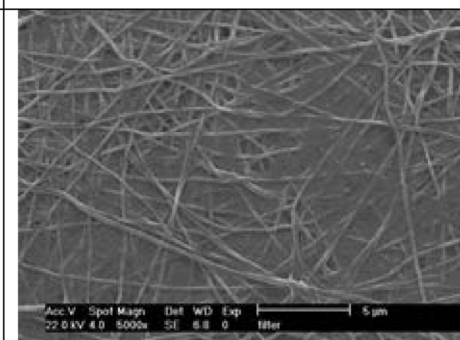
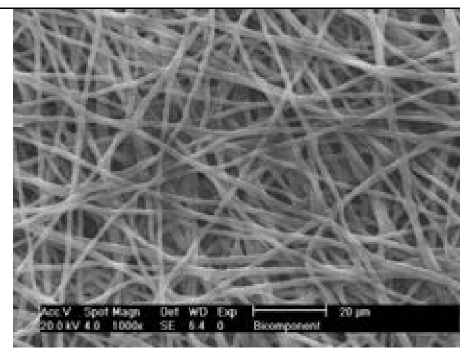
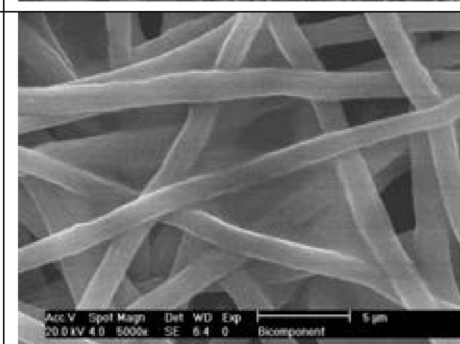



Figure4.40 SEM image of back side of nylon6 nanofibers media

after subjecting to filtration efficiency testing at 4 liters of air.

Table4.11 SEM image of spunbond, nylon6 electrospun fiber and C-shape PLA fiber after subjecting to filtration efficiency testing at 4 liters of air.

| | Magnification 100x | Magnification 1,000x | Magnification 5,000x |
|---|---|---|---|
| Spunbond |  |  |  |
| Nylon6 | |  |  |
| C-shape PLA fiber | |  |  |

# CHAPTER V

# CONCLUSION

The work in this research was separated into 3 main parts. The first part was an investigation of effect of key processing parameters in PLA electrospinning, which provided necessary knowledge required for the development of PLA-PEO bicomponents electrospinning in the second part of the thesis. The last part was the demonstration of the newly developed bicomponents fiber in filtration application.

## 5.1 PLA electrospun fiber by electrospinning

Effects of processing parameters of PLA were studied in this research. The PLA electrospun fiber formed fiber without bead at 8, 8, 12, 14 and 18%w/v, in solvent mixture system of ($CHCl_3$:DMF/ 100:00, 75:25, 50:50, 25:75 and 00:100), respectively. These formed fiber size with 0.707, 0.936, 0.560, 0.404 and 0.397 μm, respectively. The effect of solvent system, concentration, viscosity and conductivity showed clear influences on the resulting morphology and fiber size. The fiber size decreased with increasing DMF ratio and decreasing concentration. Increasing applied voltage showed both effect of increased and decreased fiber size. While increasing solution flow rate and increasing gap distance had a slight effect on fiber size, they affected on bead formation on fiber. In addition, high DMF ratio obtained smooth surface on the fiber.

## 5.2 PLA-PEO bicomponents fiber by co-electrospinning

PLA-PEO bicomponents fibers were successfully fabricated by co-electrospinning technique. The effect of PLA solution solvent system, PEO solution concentration and PLA:PEO solution flow rate ratio showed clear influence on fiber size and morphology. The surface of fiber was controlled by PLA solution solvent system. The fiber size increased with increasing PEO solution concentration. The compositions, morphology and fiber size can control by flow rate ratio, while an applied voltage showed minor impact on the fiber size. After PEO removal, the C-shape ultrafine fiber was generated.

## 5.3 Modification of filter with nylon6 and C-shape PLA fibers.

The last part of this research was to demonstrate potential use of electrospun nanofiber membrane in filtration application. Nylon 6 electrospun nanofiber membranes of various thickness and a C shape PLA electrospun fiber membrane derived from PLA-PEO bicomponent electrospinning were used to modified 3 plies filter media, consisted of spun bond-melt blown-spun bond PP nonwoven fiber mats, normally used in ordinary face mask. The three piles fiber media showed the lowest filtration efficiency as expected, while all modified filter media showed significantly higher efficiency. Nylon 6 nanofiber mat modified media showed highest filtration efficiency at low particle stress. However, they also had the least filtration capacity as pores in the media were fouled by the test particles. The C shape membrane modified filter media, while had lower filtration efficiency than the nylon 6 modified filter at low particle stress level, it had higher particles filtration capacity than the nylon 6 counter part.

**5.4 Future Aspects**

The bicomponent electrospun fiber can create advance fiber, smart fiber or novel fiber. These can be divided into several types. For example.

- Material or composition, we can choose the properties of materials used to produce fiber for suitable applications or development of the properties.
- Morphology, the morphology can control by processing parameter conclude of fiber, bead, porous surface, smooth surface and fiber size etc.
- Structure or geometry, to use creates other novel geometry structure. Different structures can be used in different applications. For example figure 5.1 show national fiber (structure)

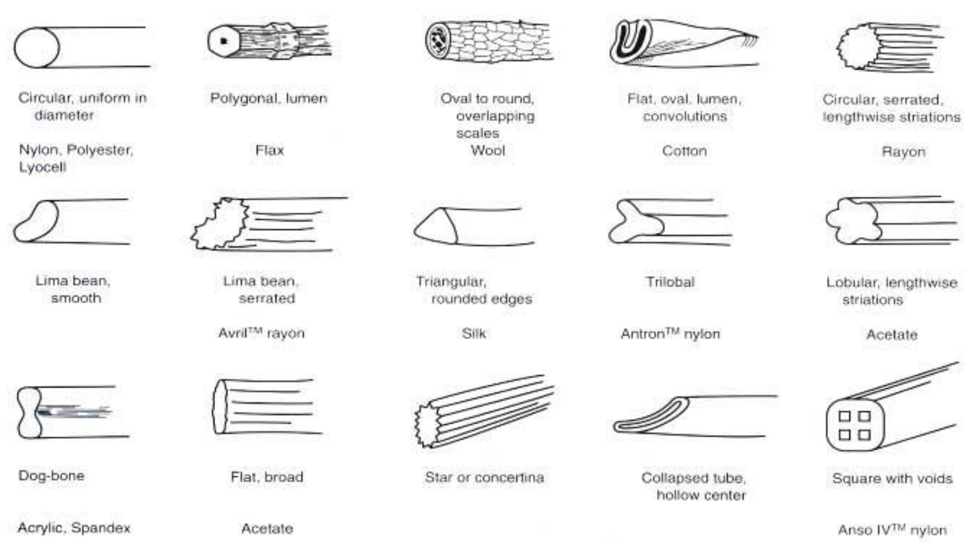



Figure 5.1 cross-section of national fiber [86].

The air filter testing still needs to be developed machine and analyzed such as particle pressure drop, particle counter etc. This knowledge, skills and logical way of scientific thinking can use to create air or liquid filtration which has high protective chemicals and high filtration efficiency.

# REFERENCES

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# Appendices

# Appendix A

Raw data: Average fiber size from SEM image

**Calculation of average fiber size**

Preparation of PLA electrospun fiber by electrospinning

$$\text{Average fiber size} = \frac{\sum_{1}^{n} di}{n}$$

di = Size of fiber segment

n = Total number of fiber

$$SD = \sqrt{\frac{\sum_{i=1}^{N}\left(X_i - \overline{X}\right)^2}{N}}$$

S = The standard deviation of the sample.

X = The midpoint of each class or individual.

$\overline{X}$ = The mean of the sample.

N = Number of samples.

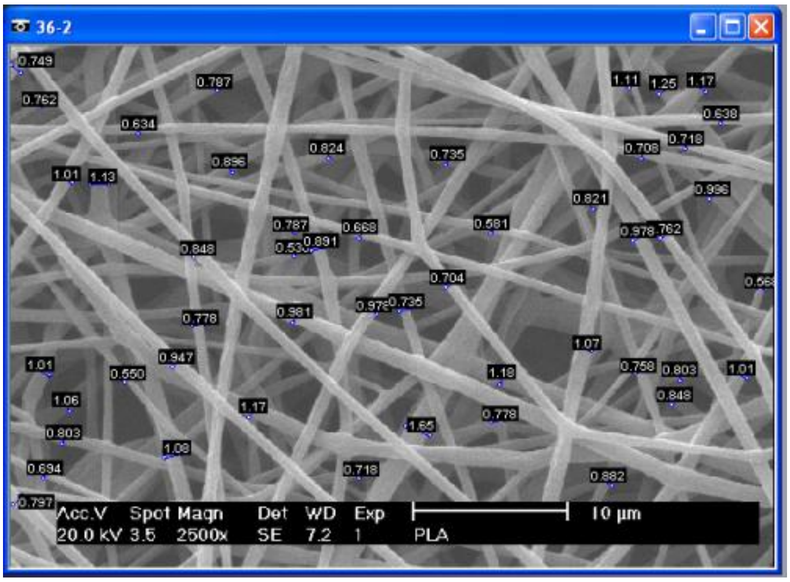

Table A1: Measured values of PLA fiber segments size electrospun at V=15kV, F=0.5ml/hr, d=15cm, PLA in $CHCl_3$:DMF (100:00 v/v) with various solution concentration.

| Solvent System | PLA ($CHCl_3$:DMF / 100:00) | | | | |
|---|---|---|---|---|---|
| Fiber Segment No. | Fiber Segment Size (µm) | | | | |
| | Concentration (%w/v) | | | | |
| | 6 | 8 | 10 | 12 | 14 |
| 1 | 0.14 | 0.14 | 0.27 | 0.64 | 0.35 |
| 2 | 0.22 | 0.19 | 0.57 | 0.74 | 0.16 |
| 3 | 0.35 | 0.38 | 0.25 | 0.4 | 0.21 |
| 4 | 0.18 | 0.18 | 0.49 | 0.4 | 0.19 |
| 5 | 0.18 | 0.15 | 0.68 | 0.89 | 0.3 |
| 6 | 0.22 | 0.18 | 0.33 | 0.4 | 0.15 |
| 7 | 0.18 | 0.14 | 0.24 | 0.74 | 0.25 |
| 8 | 0.18 | 0.39 | 0.3 | 0.96 | 0.33 |
| 9 | 0.18 | 0.19 | 0.25 | 0.91 | 0.43 |
| 10 | 0.21 | 0.25 | 0.35 | 0.54 | 0.3 |
| 11 | 0.18 | 0.25 | 0.35 | 0.64 | 0.22 |
| 12 | 0.19 | 0.18 | 0.38 | 0.96 | 0.3 |
| 13 | 0.3 | 0.22 | 0.82 | 1.09 | 0.33 |
| 14 | 0.18 | 0.18 | 0.36 | 1.01 | 0.13 |
| 15 | 0.21 | 0.21 | 0.4 | 2.00 | 0.36 |
| 16 | 0.15 | 0.16 | 0.26 | 1.13 | 0.21 |
| 17 | 0.16 | 0.18 | 0.6 | 2.00 | 0.3 |
| 18 | 0.42 | 0.62 | 0.51 | 1.44 | 0.62 |
| 19 | 0.27 | 0.35 | 0.54 | 1.69 | 0.893 |
| 20 | 0.18 | 0.27 | 0.4 | 1.93 | 0.2 |
| 21 | 0.51 | 0.28 | 0.57 | 0.21 | 0.29 |
| 22 | 0.46 | 0.21 | 0.54 | 0.27 | 0.37 |
| 23 | 0.19 | 0.6 | 1.02 | 0.33 | 0.32 |

| | | | | | |
|---|---|---|---|---|---|
| 24 | 0.23 | 1.03 | 1.92 | 0.35 | 0.41 |
| 25 | 0.32 | 0.37 | 1.02 | 0.21 | 0.22 |
| 26 | 0.42 | 0.45 | 0.4 | 0.28 | 0.714 |
| 27 | 0.28 | 0.5 | 0.81 | 0.22 | 0.27 |
| 28 | 0.6 | 0.82 | 0.65 | 0.21 | 0.33 |
| 29 | 0.42 | 0.62 | 0.9 | 0.57 | 0.39 |
| 30 | 0.76 | 0.87 | 0.72 | 0.7 | 0.88 |
| 31 | 0.64 | 0.79 | 1.55 | 0.18 | 0.49 |
| 32 | 1.07 | 0.79 | 3.4 | 0.35 | 0.37 |
| 33 | 0.74 | 0.7 | 0.4 | 0.43 | 0.7 |
| 34 | 1.79 | 0.79 | 0.65 | 0.23 | 1.03 |
| 35 | 2.53 | 0.79 | 0.57 | 0.25 | 1.29 |
| 36 | 0.74 | 0.7 | 0.81 | 1.46 | 0.4 |
| 37 | 0.8 | 1.41 | 0.4 | 0.36 | 0.96 |
| 38 | 0.71 | 2.05 | 0.36 | 0.26 | 0.74 |
| 39 | 0.91 | 0.79 | 0.54 | 0.44 | 1.3 |
| 40 | 0.91 | 1.27 | 0.4 | 0.47 | 1.3 |
| 41 | 1.07 | 1.45 | 0.51 | 0.75 | 0.74 |
| 42 | 0.74 | 1.49 | 0.54 | 0.65 | 0.96 |
| 43 | 1.01 | 1.49 | 0.65 | 0.38 | 1.36 |
| 44 | 1.04 | 1.27 | 0.57 | 0.36 | 2.26 |
| 45 | 1.29 | 1.49 | 0.54 | 0.51 | 2.04 |
| 46 | 1.62 | 1.45 | 1.02 | 1.87 | 1.54 |
| 47 | 0.74 | 1.06 | 1.92 | 1.1 | 1.97 |
| 48 | 0.57 | 1.45 | 1.02 | 0.81 | 3.95 |
| 49 | 1.14 | 1.76 | 0.72 | 0.72 | 1.79 |
| 50 | 1.44 | 1.8 | 0.81 | 0.48 | 2.09 |
| Average | 0.599 | 0.707 | 0.686 | 0.718 | 0.754 |
| SD | 0.504 | 0.541 | 0.539 | 0.509 | 0.741 |

Table A2: Measured values of PLA fiber segments electrospun at V=15kV, F=0.5ml/hr, d=15cm, PLA in ($CHCl_3$:DMF / 75:25) with various solution concentration.

| Solvent system | PLA ($CHCl_3$:DMF / 75:25) | | | | |
|---|---|---|---|---|---|
| Fiber Segment No. | Fiber size (μm) | | | | |
| | Concentration (%w/v) | | | | |
| | 6 | 8 | 10 | 12 | 14 |
| 1 | 0.725 | 0.72 | 1.91 | 1.45 | 1.61 |
| 2 | 0.254 | 0.75 | 1.64 | 3.11 | 2.52 |
| 3 | 0.423 | 0.54 | 1.2 | 0.988 | 1.23 |
| 4 | 0.513 | 0.79 | 1.13 | 2.18 | 1.45 |
| 5 | 0.758 | 0.78 | 2.24 | 1.33 | 1.47 |
| 6 | 0.508 | 0.57 | 1.98 | 1.25 | 1.27 |
| 7 | 0.254 | 1 | 1.05 | 2.81 | 1.66 |
| 8 | 0.568 | 0.82 | 1.51 | 2.88 | 1.72 |
| 9 | 0.428 | 1.11 | 2.16 | 0.996 | 1.39 |
| 10 | 0.223 | 1.25 | 1 | 1.23 | 1.34 |
| 11 | 0.55 | 0.88 | 1.01 | 1.06 | 1.35 |
| 12 | 0.254 | 1.01 | 1.15 | 1.35 | 1.63 |
| 13 | 0.428 | 1.65 | 1.27 | 1.7 | 1.02 |
| 14 | 0.498 | 0.74 | 1.05 | 1.34 | 1.35 |
| 15 | 0.787 | 0.79 | 1.54 | 1.21 | 1.29 |
| 16 | 0.472 | 0.76 | 1.83 | 0.19 | 1.42 |
| 17 | 0.498 | 1.08 | 1.65 | 1.37 | 1.48 |
| 18 | 0.29 | 0.69 | 1.1 | 1.42 | 1.39 |
| 19 | 0.29 | 0.8 | 1.11 | 1.45 | 1.49 |
| 20 | 0.803 | 1.01 | 0.7 | 1.97 | 1.4 |
| 21 | 0.563 | 0.9 | 1.03 | 3.55 | 1.74 |
| 22 | 0.315 | 0.82 | 0.64 | 1.89 | 1.37 |
| 23 | 0.189 | 1.13 | 2.25 | 1.16 | 1.26 |
| 24 | 0.451 | 0.85 | 1.42 | 1.35 | 1.45 |

| | | | | | |
|---|---|---|---|---|---|
| 25 | 0.708 | 0.8 | 0.96 | 1.23 | 1.57 |
| 26 | 0.428 | 0.76 | 1.11 | 3.9 | 1.67 |
| 27 | 0.821 | 0.71 | 0.8 | 1.3 | 1.17 |
| 28 | 0.199 | 0.72 | 1.06 | 2.79 | 1.2 |
| 29 | 0.29 | 0.64 | 1.42 | 1.07 | 1.05 |
| 30 | 0.63 | 1.17 | 1.15 | 1.94 | 1.41 |
| 31 | 0.254 | 1.18 | 0.92 | 1.09 | 1.57 |
| 32 | 0.352 | 0.58 | 0.71 | 1.7 | 1.27 |
| 33 | 0.315 | 0.76 | 1.55 | 1.87 | 1.42 |
| 34 | 0.802 | 0.98 | 1.02 | 1.06 | 1.88 |
| 35 | 0.493 | 0.63 | 2.19 | 0.851 | 1.48 |
| 36 | 0.536 | 1.01 | 1.08 | 1.27 | 2.59 |
| 37 | 0.513 | 1.06 | 1.29 | 1.33 | 1.27 |
| 38 | 0.223 | 0.8 | 1.14 | 1.01 | 1.14 |
| 39 | 0.708 | 0.55 | 0.85 | 2.08 | 1 |
| 40 | 0.411 | 0.95 | 1.11 | 1.54 | 1.35 |
| 41 | 0.488 | 1.17 | 1.9 | 2.43 | 1.43 |
| 42 | 0.602 | 0.98 | 1.23 | 1.36 | 1.76 |
| 43 | 0.199 | 1.07 | 1.56 | 1.65 | 1.29 |
| 44 | 0.508 | 0.67 | 1.56 | 1.36 | 2.74 |
| 45 | 0.602 | 0.78 | 1.36 | 1.26 | 1.77 |
| 46 | 0.598 | 0.85 | 0.85 | 1.8 | 1.41 |
| 47 | 0.649 | 0.89 | 1 | 1.77 | 1.25 |
| 48 | 0.451 | 0.98 | 1.42 | 1.07 | 1.54 |
| 49 | 0.493 | 0.74 | 0.86 | 1.86 | 1.48 |
| 50 | 0.718 | 0.7 | 1.39 | 2.24 | 1.47 |
| Average | 0.481 | 0.871 | 1.301 | 1.641 | 1.490 |
| SD | 0.182 | 0.212 | 0.418 | 0.710 | 0.347 |

Table A3: Measured values of PLA fiber segments electrospun at V=15kV, F=0.5ml/hr, d=15cm, PLA in ($CHCl_3$:DMF / 50:50) with various solution concentration.

| Solvent system | PLA ($CHCl_3$:DMF / 50:50) | | | | |
|---|---|---|---|---|---|
| Fiber Segment No. | Fiber size (µm) | | | | |
| | Concentration (%w/v) | | | | |
| | 8 | 10 | 12 | 14 | 16 |
| 1 | 0.363 | 0.63 | 0.623 | 0.493 | 0.958 |
| 2 | 0.448 | 0.493 | 0.249 | 0.896 | 1.05 |
| 3 | 0.489 | 0.472 | 0.498 | 0.758 | 1.01 |
| 4 | 0.436 | 0.359 | 0.872 | 0.749 | 0.718 |
| 5 | 0.52 | 0.445 | 0.334 | 0.958 | 0.996 |
| 6 | 0.528 | 0.445 | 0.441 | 0.649 | 1.1 |
| 7 | 0.463 | 0.568 | 0.523 | 0.664 | 0.918 |
| 8 | 0.49 | 0.513 | 0.334 | 0.848 | 0.981 |
| 9 | 0.459 | 0.352 | 0.872 | 0.668 | 0.978 |
| 10 | 0.249 | 0.513 | 0.493 | 0.697 | 0.848 |
| 11 | 0.325 | 0.29 | 0.857 | 0.55 | 0.758 |
| 12 | 0.334 | 0.254 | 0.246 | 0.758 | 0.803 |
| 13 | 0.284 | 0.513 | 0.6 | 0.86 | 0.718 |
| 14 | 0.441 | 0.508 | 0.557 | 0.762 | 1.25 |
| 15 | 0.52 | 0.563 | 0.458 | 0.902 | 0.986 |
| 16 | 0.389 | 0.359 | 0.459 | 0.735 | 0.803 |
| 17 | 0.459 | 0.352 | 0.624 | 0.775 | 0.821 |
| 18 | 0.5 | 0.29 | 0.658 | 0.697 | 0.634 |
| 19 | 0.389 | 0.797 | 0.504 | 0.848 | 0.871 |
| 20 | 0.411 | 0.581 | 0.425 | 0.86 | 0.981 |
| 21 | 0.332 | 0.664 | 0.523 | 0.902 | 0.821 |
| 22 | 0.423 | 0.563 | 0.52 | 0.803 | 1.38 |
| 23 | 0.493 | 0.223 | 0.411 | 0.848 | 0.708 |
| 24 | 0.223 | 0.282 | 0.428 | 0.749 | 0.926 |

| | | | | | |
|---|---|---|---|---|---|
| 25 | 0.236 | 0.379 | 0.712 | 0.704 | 0.803 |
| 26 | 0.533 | 0.411 | 0.775 | 0.762 | 1.27 |
| 27 | 0.352 | 0.498 | 0.599 | 0.638 | 1 |
| 28 | 0.498 | 0.536 | 0.458 | 0.472 | 0.845 |
| 29 | 0.523 | 0.606 | 1 | 0.63 | 1.04 |
| 30 | 0.635 | 0.352 | 0.5 | 0.926 | 0.704 |
| 31 | 0.363 | 0.568 | 0.634 | 0.902 | 1.01 |
| 32 | 0.493 | 0.598 | 0.332 | 0.762 | 1.69 |
| 33 | 0.47 | 0.735 | 0.394 | 0.915 | 0.824 |
| 34 | 0.412 | 0.63 | 1.1 | 0.86 | 0.871 |
| 35 | 0.284 | 0.428 | 0.778 | 1.09 | 0.787 |
| 36 | 0.29 | 0.498 | 0.349 | 0.86 | 1.07 |
| 37 | 0.479 | 0.513 | 0.459 | 0.697 | 0.882 |
| 38 | 0.43 | 0.602 | 0.493 | 0.848 | 1.13 |
| 39 | 0.363 | 0.428 | 0.563 | 0.986 | 1.14 |
| 40 | 0.803 | 0.315 | 0.363 | 0.851 | 0.88 |
| 41 | 0.655 | 0.352 | 0.508 | 0.787 | 0.92 |
| 42 | 0.381 | 0.223 | 0.347 | 0.988 | 0.71 |
| 43 | 0.352 | 0.498 | 0.472 | 0.649 | 0.8 |
| 44 | 0.347 | 0.536 | 0.733 | 0.649 | 0.71 |
| 45 | 0.284 | 0.664 | 0.528 | 0.735 | 0.95 |
| 46 | 0.225 | 0.649 | 0.583 | 0.602 | 0.86 |
| 47 | 0.459 | 0.568 | 0.754 | 0.787 | 1.06 |
| 48 | 0.831 | 0.398 | 0.643 | 0.996 | 1.04 |
| 49 | 0.6 | 0.359 | 0.803 | 1.03 | 1.06 |
| 50 | 0.303 | 0.581 | 0.599 | 0.762 | 0.85 |
| Average | 0.431 | 0.479 | 0.560 | 0.786 | 0.938 |
| SD | 0.130 | 0.134 | 0.186 | 0.134 | 0.191 |

Table A4: Measured values of PLA fiber segments electrospun at V=15kV, F=0.5ml/hr, d=15cm, PLA in ($CHCl_3$:DMF / 25:75) with various solution concentration.

| Solvent system | PLA ($CHCl_3$:DMF / 25:75) | | | | |
|---|---|---|---|---|---|
| Fiber Segment No. | Fiber size (µm) | | | | |
| | Concentration (%w/v) | | | | |
| | 8 | 10 | 12 | 14 | 16 |
| 1 | 0.167 | 0.205 | 0.263 | 0.424 | 0.498 |
| 2 | 0.106 | 0.22 | 0.226 | 0.354 | 0.424 |
| 3 | 0.167 | 0.192 | 0.168 | 0.374 | 0.528 |
| 4 | 0.152 | 0.243 | 0.181 | 0.359 | 0.49 |
| 5 | 0.152 | 0.238 | 0.262 | 0.352 | 0.463 |
| 6 | 0.19 | 0.192 | 0.22 | 0.387 | 0.5 |
| 7 | 0.151 | 0.167 | 0.291 | 0.352 | 0.374 |
| 8 | 0.196 | 0.151 | 0.205 | 0.424 | 0.445 |
| 9 | 0.168 | 0.186 | 0.151 | 0.459 | 0.47 |
| 10 | 0.119 | 0.181 | 0.167 | 0.352 | 0.401 |
| 11 | 0.119 | 0.192 | 0.173 | 0.494 | 0.47 |
| 12 | 0.106 | 0.173 | 0.239 | 0.472 | 0.451 |
| 13 | 0.139 | 0.203 | 0.287 | 0.349 | 0.436 |
| 14 | 0.145 | 0.173 | 0.173 | 0.401 | 0.394 |
| 15 | 0.152 | 0.173 | 0.172 | 0.332 | 0.479 |
| 16 | 0.151 | 0.213 | 0.214 | 0.493 | 0.643 |
| 17 | 0.119 | 0.243 | 0.202 | 0.448 | 0.523 |
| 18 | 0.152 | 0.239 | 0.202 | 0.424 | 0.394 |
| 19 | 0.119 | 0.186 | 0.245 | 0.474 | 0.498 |
| 20 | 0.119 | 0.192 | 0.192 | 0.368 | 0.646 |
| 21 | 0.128 | 0.151 | 0.192 | 0.428 | 0.5 |
| 22 | 0.143 | 0.181 | 0.245 | 0.428 | 0.401 |
| 23 | 0.168 | 0.19 | 0.243 | 0.428 | 0.411 |
| 24 | 0.121 | 0.269 | 0.203 | 0.368 | 0.387 |

| | | | | | |
|---|---|---|---|---|---|
| 25 | 0.106 | 0.196 | 0.192 | 0.425 | 0.458 |
| 26 | 0.086 | 0.192 | 0.192 | 0.381 | 0.428 |
| 27 | 0.098 | 0.202 | 0.205 | 0.394 | 0.537 |
| 28 | 0.152 | 0.186 | 0.31 | 0.332 | 0.441 |
| 29 | 0.16 | 0.234 | 0.205 | 0.352 | 0.498 |
| 30 | 0.168 | 0.22 | 0.192 | 0.401 | 0.627 |
| 31 | 0.095 | 0.152 | 0.234 | 0.352 | 0.401 |
| 32 | 0.16 | 0.186 | 0.168 | 0.389 | 0.564 |
| 33 | 0.151 | 0.225 | 0.22 | 0.424 | 0.578 |
| 34 | 0.271 | 0.16 | 0.19 | 0.49 | 0.598 |
| 35 | 0.245 | 0.152 | 0.168 | 0.423 | 0.638 |
| 36 | 0.119 | 0.143 | 0.152 | 0.49 | 0.5 |
| 37 | 0.151 | 0.236 | 0.238 | 0.5 | 0.495 |
| 38 | 0.186 | 0.186 | 0.173 | 0.424 | 0.49 |
| 39 | 0.287 | 0.192 | 0.243 | 0.347 | 0.537 |
| 40 | 0.119 | 0.239 | 0.239 | 0.368 | 0.412 |
| 41 | 0.181 | 0.213 | 0.238 | 0.424 | 0.49 |
| 42 | 0.152 | 0.452 | 0.239 | 0.463 | 0.498 |
| 43 | 0.135 | 0.181 | 0.216 | 0.5 | 0.537 |
| 44 | 0.152 | 0.214 | 0.192 | 0.43 | 0.568 |
| 45 | 0.253 | 0.205 | 0.196 | 0.374 | 0.451 |
| 46 | 0.121 | 0.214 | 0.168 | 0.349 | 0.568 |
| 47 | 0.16 | 0.258 | 0.203 | 0.379 | 0.394 |
| 48 | 0.16 | 0.22 | 0.203 | 0.424 | 0.445 |
| 49 | 0.152 | 0.186 | 0.173 | 0.401 | 0.508 |
| 50 | 0.135 | 0.186 | 0.151 | 0.424 | 0.529 |
| Average | 0.152 | 0.204 | 0.208 | 0.408 | 0.488 |
| SD | 0.042 | 0.046 | 0.037 | 0.049 | 0.071 |

Table A5: Measured values of PLA fiber segments electrospun at V=15kV, F=0.5ml/hr, d=15cm, PLA in ($CHCl_3$:DMF / 00:100) with various solution concentration.

| Solvent system | PLA ($CHCl_3$:DMF / 00:100) | | | | | | |
|---|---|---|---|---|---|---|---|
| Fiber Segment No. | Fiber size (µm) | | | | | | |
| | Concentration (%w/v) | | | | | | |
| | 8 | 10 | 12 | 14 | 16 | 18 | 20 |
| 1 | 0.067 | 0.095 | 0.121 | 0.192 | 0.31 | 0.374 | 0.385 |
| 2 | 0.071 | 0.119 | 0.152 | 0.238 | 0.343 | 0.463 | 0.458 |
| 3 | 0.086 | 0.095 | 0.098 | 0.22 | 0.238 | 0.352 | 0.519 |
| 4 | 0.128 | 0.098 | 0.16 | 0.341 | 0.271 | 0.381 | 0.578 |
| 5 | 0.086 | 0.101 | 0.128 | 0.319 | 0.313 | 0.299 | 0.455 |
| 6 | 0.095 | 0.139 | 0.192 | 0.266 | 0.249 | 0.423 | 0.343 |
| 7 | 0.053 | 0.095 | 0.145 | 0.263 | 0.258 | 0.459 | 0.408 |
| 8 | 0.101 | 0.098 | 0.143 | 0.22 | 0.287 | 0.332 | 0.725 |
| 9 | 0.066 | 0.119 | 0.16 | 0.216 | 0.337 | 0.401 | 0.556 |
| 10 | 0.056 | 0.119 | 0.172 | 0.22 | 0.286 | 0.411 | 0.543 |
| 11 | 0.095 | 0.119 | 0.192 | 0.238 | 0.405 | 0.325 | 0.382 |
| 12 | 0.098 | 0.106 | 0.172 | 0.226 | 0.263 | 0.504 | 0.665 |
| 13 | 0.126 | 0.151 | 0.128 | 0.19 | 0.253 | 0.394 | 0.465 |
| 14 | 0.067 | 0.106 | 0.168 | 0.298 | 0.266 | 0.325 | 0.556 |
| 15 | 0.067 | 0.086 | 0.196 | 0.298 | 0.279 | 0.401 | 0.679 |
| 16 | 0.075 | 0.119 | 0.168 | 0.214 | 0.372 | 0.398 | 0.54 |
| 17 | 0.086 | 0.121 | 0.127 | 0.192 | 0.394 | 0.352 | 0.48 |
| 18 | 0.106 | 0.098 | 0.145 | 0.192 | 0.31 | 0.459 | 0.535 |
| 19 | 0.101 | 0.172 | 0.145 | 0.238 | 0.303 | 0.412 | 0.523 |
| 20 | 0.095 | 0.095 | 0.145 | 0.303 | 0.284 | 0.29 | 0.508 |
| 21 | 0.106 | 0.106 | 0.145 | 0.249 | 0.303 | 0.284 | 0.401 |
| 22 | 0.067 | 0.086 | 0.111 | 0.176 | 0.214 | 0.347 | 0.424 |
| 23 | 0.095 | 0.173 | 0.145 | 0.284 | 0.223 | 0.334 | 0.606 |
| 24 | 0.075 | 0.086 | 0.141 | 0.254 | 0.254 | 0.423 | 0.769 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 25 | 0.106 | 0.151 | 0.157 | 0.211 | 0.275 | 0.47 | 0.352 |
| 26 | 0.098 | 0.128 | 0.18 | 0.205 | 0.29 | 0.401 | 0.523 |
| 27 | 0.075 | 0.121 | 0.157 | 0.211 | 0.303 | 0.43 | 0.615 |
| 28 | 0.095 | 0.067 | 0.145 | 0.275 | 0.275 | 0.379 | 0.662 |
| 29 | 0.098 | 0.098 | 0.127 | 0.275 | 0.354 | 0.43 | 0.523 |
| 30 | 0.071 | 0.106 | 0.141 | 0.176 | 0.29 | 0.459 | 0.662 |
| 31 | 0.119 | 0.119 | 0.176 | 0.249 | 0.325 | 0.352 | 0.6 |
| 32 | 0.067 | 0.139 | 0.127 | 0.275 | 0.223 | 0.428 | 0.52 |
| 33 | 0.075 | 0.119 | 0.106 | 0.249 | 0.254 | 0.547 | 0.573 |
| 34 | 0.121 | 0.143 | 0.145 | 0.284 | 0.381 | 0.424 | 0.423 |
| 35 | 0.098 | 0.095 | 0.111 | 0.214 | 0.256 | 0.359 | 0.489 |
| 36 | 0.095 | 0.106 | 0.127 | 0.214 | 0.249 | 0.394 | 0.401 |
| 37 | 0.071 | 0.128 | 0.157 | 0.236 | 0.254 | 0.394 | 0.547 |
| 38 | 0.086 | 0.095 | 0.141 | 0.303 | 0.332 | 0.436 | 0.504 |
| 39 | 0.071 | 0.071 | 0.176 | 0.225 | 0.301 | 0.389 | 0.536 |
| 40 | 0.106 | 0.095 | 0.149 | 0.225 | 0.379 | 0.458 | 0.615 |
| 41 | 0.098 | 0.101 | 0.145 | 0.19 | 0.268 | 0.398 | 0.583 |
| 42 | 0.101 | 0.119 | 0.145 | 0.236 | 0.295 | 0.424 | 0.647 |
| 43 | 0.098 | 0.106 | 0.18 | 0.176 | 0.315 | 0.303 | 0.389 |
| 44 | 0.086 | 0.075 | 0.127 | 0.225 | 0.301 | 0.43 | 0.436 |
| 45 | 0.095 | 0.086 | 0.149 | 0.254 | 0.332 | 0.428 | 0.599 |
| 46 | 0.071 | 0.086 | 0.225 | 0.223 | 0.325 | 0.382 | 0.374 |
| 47 | 0.095 | 0.106 | 0.141 | 0.284 | 0.315 | 0.394 | 0.463 |
| 48 | 0.098 | 0.121 | 0.149 | 0.225 | 0.332 | 0.347 | 0.551 |
| 49 | 0.086 | 0.091 | 0.157 | 0.223 | 0.301 | 0.528 | 0.537 |
| 50 | 0.085 | 0.106 | 0.141 | 0.249 | 0.347 | 0.354 | 0.504 |
| Average | 0.089 | 0.110 | 0.150 | 0.239 | 0.298 | 0.398 | 0.523 |
| SD | 0.018 | 0.023 | 0.024 | 0.039 | 0.045 | 0.058 | 0.099 |

Table A6 Measured values of PLA fiber segments electrospun at V=15kV, d=15cm, 8% PLA in ($CHCl_3$:DMF / 75:25) with various solution flow rate.

| Solvent system | 8% PLA ($CHCl_3$:DMF / 75:25) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Flow rate (ml/hr) | | | |
| | 0.25 | 0.5 | 0.75 | 1 |
| 1 | 0.59 | 0.72 | 0.967 | 0.78 |
| 2 | 0.489 | 0.75 | 0.451 | 0.482 |
| 3 | 0.735 | 0.54 | 0.68 | 0.887 |
| 4 | 0.6 | 0.79 | 0.733 | 1.06 |
| 5 | 0.647 | 0.78 | 0.47 | 0.602 |
| 6 | 0.459 | 0.57 | 0.677 | 0.754 |
| 7 | 0.581 | 1 | 0.458 | 0.382 |
| 8 | 0.6 | 0.82 | 0.428 | 0.819 |
| 9 | 0.725 | 1.11 | 0.852 | 0.759 |
| 10 | 0.649 | 1.25 | 0.647 | 0.819 |
| 11 | 0.47 | 0.88 | 0.332 | 0.504 |
| 12 | 0.889 | 1.01 | 0.523 | 0.764 |
| 13 | 0.702 | 1.65 | 0.658 | 0.356 |
| 14 | 0.548 | 0.74 | 0.523 | 0.551 |
| 15 | 0.647 | 0.79 | 0.445 | 0.587 |
| 16 | 0.352 | 0.76 | 0.747 | 0.677 |
| 17 | 0.779 | 1.08 | 0.332 | 0.554 |
| 18 | 0.725 | 0.69 | 0.662 | 0.745 |
| 19 | 0.498 | 0.8 | 0.835 | 0.895 |
| 20 | 0.315 | 1.01 | 0.256 | 0.568 |
| 21 | 0.472 | 0.9 | 0.668 | 0.728 |
| 22 | 0.424 | 0.82 | 0.303 | 0.677 |
| 23 | 0.635 | 1.13 | 0.586 | 0.723 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.676 | 0.85 | 0.857 | 0.349 |
| 25 | 0.772 | 0.8 | 0.6 | 0.532 |
| 26 | 0.647 | 0.76 | 0.945 | 0.477 |
| 27 | 0.573 | 0.71 | 0.881 | 0.994 |
| 28 | 0.635 | 0.72 | 0.303 | 0.462 |
| 29 | 0.932 | 0.64 | 0.673 | 0.462 |
| 30 | 0.627 | 1.17 | 0.677 | 0.603 |
| 31 | 0.6 | 1.18 | 0.699 | 0.511 |
| 32 | 0.65 | 0.58 | 0.684 | 0.652 |
| 33 | 0.54 | 0.76 | 0.557 | 0.477 |
| 34 | 0.33 | 0.98 | 0.379 | 0.876 |
| 35 | 0.55 | 0.63 | 0.489 | 0.537 |
| 36 | 0.66 | 1.01 | 0.568 | 0.925 |
| 37 | 0.35 | 1.06 | 0.684 | 0.704 |
| 38 | 0.58 | 0.8 | 0.463 | 0.527 |
| 39 | 0.28 | 0.55 | 0.638 | 0.654 |
| 40 | 0.52 | 0.95 | 0.479 | 0.627 |
| 41 | 0.47 | 1.17 | 0.548 | 0.682 |
| 42 | 0.52 | 0.98 | 0.463 | 0.587 |
| 43 | 0.63 | 1.07 | 0.459 | 0.482 |
| 44 | 0.93 | 0.67 | 0.603 | 0.717 |
| 45 | 0.42 | 0.78 | 0.699 | 1.14 |
| 46 | 0.75 | 0.85 | 0.655 | 0.573 |
| 47 | 0.32 | 0.89 | 0.74 | 0.59 |
| 48 | 0.79 | 0.98 | 0.646 | 0.508 |
| 49 | 0.26 | 0.74 | 0.984 | 0.527 |
| 50 | 0.71 | 0.7 | 0.677 | 0.738 |
| Average | 0.585 | 0.871 | 0.606 | 0.652 |
| SD | 0.161 | 0.212 | 0.175 | 0.180 |

Table A7 Measured values of PLA fiber segments electrospun at V=15kV, d=15cm, 12% PLA in ($CHCl_3$:DMF / 50:50) with various solution flow rate.

| Solvent system | 12% PLA ($CHCl_3$:DMF / 50:50) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Flow rate (ml/hr) | | | |
| | 0.25 | 0.5 | 0.75 | 1 |
| 1 | 0.615 | 0.623 | 0.568 | 0.852 |
| 2 | 0.504 | 0.249 | 0.479 | 0.704 |
| 3 | 0.411 | 0.498 | 1.06 | 0.489 |
| 4 | 0.423 | 0.872 | 0.282 | 0.354 |
| 5 | 0.246 | 0.334 | 0.504 | 0.898 |
| 6 | 0.317 | 0.441 | 0.479 | 0.256 |
| 7 | 0.223 | 0.523 | 1.03 | 0.743 |
| 8 | 0.586 | 0.334 | 0.349 | 0.6 |
| 9 | 0.29 | 0.872 | 1.03 | 0.606 |
| 10 | 0.398 | 0.493 | 0.349 | 0.498 |
| 11 | 0.268 | 0.857 | 0.436 | 0.424 |
| 12 | 0.474 | 0.246 | 0.569 | 0.563 |
| 13 | 0.819 | 0.6 | 0.627 | 0.586 |
| 14 | 0.459 | 0.557 | 0.608 | 0.211 |
| 15 | 0.303 | 0.458 | 0.398 | 0.246 |
| 16 | 0.394 | 0.459 | 0.472 | 0.536 |
| 17 | 0.249 | 0.624 | 0.568 | 0.214 |
| 18 | 0.374 | 0.658 | 0.606 | 0.451 |
| 19 | 0.352 | 0.504 | 0.568 | 0.441 |
| 20 | 0.246 | 0.425 | 0.352 | 0.804 |
| 21 | 0.6 | 0.523 | 0.59 | 0.655 |
| 22 | 0.411 | 0.52 | 0.673 | 0.548 |
| 23 | 0.458 | 0.411 | 0.573 | 0.708 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.699 | 0.428 | 0.616 | 0.425 |
| 25 | 0.401 | 0.712 | 0.394 | 0.411 |
| 26 | 0.474 | 0.775 | 0.459 | 0.756 |
| 27 | 0.332 | 0.599 | 0.791 | 0.223 |
| 28 | 0.256 | 0.458 | 0.504 | 0.284 |
| 29 | 0.205 | 1 | 1.11 | 0.634 |
| 30 | 0.557 | 0.5 | 0.586 | 0.713 |
| 31 | 0.537 | 0.634 | 0.705 | 0.627 |
| 32 | 0.647 | 0.332 | 0.504 | 0.93 |
| 33 | 0.268 | 0.394 | 0.598 | 0.676 |
| 34 | 0.451 | 1.1 | 0.489 | 0.211 |
| 35 | 0.354 | 0.778 | 0.504 | 0.615 |
| 36 | 0.332 | 0.349 | 0.498 | 0.852 |
| 37 | 0.424 | 0.459 | 0.769 | 0.55 |
| 38 | 0.301 | 0.493 | 0.387 | 0.249 |
| 39 | 0.49 | 0.563 | 0.352 | 0.533 |
| 40 | 0.573 | 0.363 | 0.59 | 0.528 |
| 41 | 0.398 | 0.508 | 0.445 | 0.458 |
| 42 | 0.223 | 0.347 | 0.635 | 0.655 |
| 43 | 0.479 | 0.472 | 0.74 | 0.421 |
| 44 | 0.586 | 0.733 | 0.504 | 0.411 |
| 45 | 0.44 | 0.528 | 0.756 | 0.627 |
| 46 | 0.374 | 0.583 | 0.533 | 0.533 |
| 47 | 0.225 | 0.754 | 0.472 | 0.655 |
| 48 | 0.47 | 0.643 | 0.458 | 0.53 |
| 49 | 0.374 | 0.803 | 0.43 | 0.499 |
| 50 | 0.317 | 0.512 | 0.29 | 0.512 |
| Average | 0.412 | 0.558 | 0.566 | 0.538 |
| SD | 0.137 | 0.186 | 0.189 | 0.186 |

Table A8 Measured values of PLA fiber segments electrospun at V=15kV, d=15cm, 14% PLA in ($CHCl_3$:DMF / 25:75) with various solution flow rate.

| Solvent system | 14% PLA ($CHCl_3$:DMF / 25:75) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (µm) | | | |
| | Flow rate (ml/hr) | | | |
| | 0.25 | 0.5 | 0.75 | 1 |
| 1 | 0.459 | 0.424 | 0.401 | 0.381 |
| 2 | 0.401 | 0.354 | 0.398 | 0.325 |
| 3 | 0.379 | 0.374 | 0.445 | 0.374 |
| 4 | 0.425 | 0.359 | 0.325 | 0.246 |
| 5 | 0.332 | 0.352 | 0.424 | 0.387 |
| 6 | 0.354 | 0.387 | 0.423 | 0.359 |
| 7 | 0.352 | 0.352 | 0.315 | 0.282 |
| 8 | 0.441 | 0.424 | 0.389 | 0.284 |
| 9 | 0.459 | 0.459 | 0.347 | 0.368 |
| 10 | 0.352 | 0.352 | 0.401 | 0.381 |
| 11 | 0.381 | 0.494 | 0.647 | 0.494 |
| 12 | 0.29 | 0.472 | 0.374 | 0.332 |
| 13 | 0.347 | 0.349 | 0.319 | 0.332 |
| 14 | 0.275 | 0.401 | 0.401 | 0.332 |
| 15 | 0.389 | 0.332 | 0.325 | 0.412 |
| 16 | 0.325 | 0.493 | 0.315 | 0.568 |
| 17 | 0.379 | 0.448 | 0.428 | 0.458 |
| 18 | 0.368 | 0.424 | 0.441 | 0.428 |
| 19 | 0.352 | 0.474 | 0.284 | 0.424 |
| 20 | 0.319 | 0.368 | 0.424 | 0.368 |
| 21 | 0.315 | 0.428 | 0.394 | 0.394 |
| 22 | 0.401 | 0.428 | 0.334 | 0.537 |
| 23 | 0.398 | 0.428 | 0.458 | 0.379 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.301 | 0.368 | 0.428 | 0.363 |
| 25 | 0.284 | 0.425 | 0.523 | 0.474 |
| 26 | 0.448 | 0.381 | 0.493 | 0.254 |
| 27 | 0.354 | 0.394 | 0.363 | 0.493 |
| 28 | 0.389 | 0.332 | 0.528 | 0.472 |
| 29 | 0.401 | 0.352 | 0.394 | 0.394 |
| 30 | 0.401 | 0.401 | 0.436 | 0.401 |
| 31 | 0.381 | 0.352 | 0.441 | 0.436 |
| 32 | 0.352 | 0.389 | 0.458 | 0.401 |
| 33 | 0.325 | 0.424 | 0.528 | 0.317 |
| 34 | 0.352 | 0.49 | 0.398 | 0.352 |
| 35 | 0.325 | 0.423 | 0.463 | 0.325 |
| 36 | 0.325 | 0.49 | 0.349 | 0.451 |
| 37 | 0.394 | 0.5 | 0.325 | 0.441 |
| 38 | 0.394 | 0.424 | 0.474 | 0.379 |
| 39 | 0.368 | 0.347 | 0.374 | 0.284 |
| 40 | 0.458 | 0.368 | 0.401 | 0.412 |
| 41 | 0.387 | 0.424 | 0.528 | 0.374 |
| 42 | 0.389 | 0.463 | 0.424 | 0.374 |
| 43 | 0.354 | 0.5 | 0.586 | 0.249 |
| 44 | 0.332 | 0.43 | 0.705 | 0.349 |
| 45 | 0.394 | 0.374 | 0.451 | 0.354 |
| 46 | 0.374 | 0.349 | 0.334 | 0.381 |
| 47 | 0.401 | 0.379 | 0.325 | 0.411 |
| 48 | 0.349 | 0.424 | 0.508 | 0.459 |
| 49 | 0.363 | 0.401 | 0.411 | 0.424 |
| 50 | 0.425 | 0.424 | 0.459 | 0.401 |
| Average | 0.370 | 0.408 | 0.422 | 0.385 |
| SD | 0.045 | 0.049 | 0.085 | 0.069 |

Table A9 Measured values of PLA fiber segments electrospun at V=15kV, d=15cm, 18% PLA in ($CHCl_3$:DMF / 00:100) with various solution flow rate.

| Solvent system | 18% PLA ($CHCl_3$:DMF / 00:100) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (µm) | | | |
| | Flow rate (ml/hr) | | | |
| | 0.25 | 0.5 | 0.75 | 1 |
| 1 | 0.363 | 0.374 | 0.557 | 0.347 |
| 2 | 0.412 | 0.463 | 0.583 | 0.359 |
| 3 | 0.325 | 0.352 | 0.5 | 0.389 |
| 4 | 0.401 | 0.381 | 0.363 | 0.479 |
| 5 | 0.363 | 0.299 | 0.368 | 0.441 |
| 6 | 0.275 | 0.423 | 0.363 | 0.363 |
| 7 | 0.354 | 0.459 | 0.319 | 0.379 |
| 8 | 0.319 | 0.332 | 0.354 | 0.55 |
| 9 | 0.332 | 0.401 | 0.303 | 0.459 |
| 10 | 0.268 | 0.411 | 0.301 | 0.368 |
| 11 | 0.394 | 0.325 | 0.282 | 0.334 |
| 12 | 0.424 | 0.504 | 0.441 | 0.332 |
| 13 | 0.319 | 0.394 | 0.459 | 0.381 |
| 14 | 0.374 | 0.325 | 0.424 | 0.315 |
| 15 | 0.359 | 0.401 | 0.315 | 0.398 |
| 16 | 0.352 | 0.398 | 0.411 | 0.557 |
| 17 | 0.352 | 0.352 | 0.458 | 0.528 |
| 18 | 0.394 | 0.459 | 0.5 | 0.359 |
| 19 | 0.299 | 0.412 | 0.504 | 0.47 |
| 20 | 0.347 | 0.29 | 0.374 | 0.398 |
| 21 | 0.275 | 0.284 | 0.459 | 0.458 |
| 22 | 0.52 | 0.347 | 0.325 | 0.474 |
| 23 | 0.498 | 0.334 | 0.401 | 0.352 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.394 | 0.423 | 0.268 | 0.394 |
| 25 | 0.319 | 0.47 | 0.398 | 0.334 |
| 26 | 0.411 | 0.401 | 0.319 | 0.319 |
| 27 | 0.332 | 0.43 | 0.303 | 0.352 |
| 28 | 0.359 | 0.379 | 0.451 | 0.412 |
| 29 | 0.436 | 0.43 | 0.441 | 0.354 |
| 30 | 0.428 | 0.459 | 0.332 | 0.389 |
| 31 | 0.424 | 0.352 | 0.319 | 0.5 |
| 32 | 0.334 | 0.428 | 0.394 | 0.299 |
| 33 | 0.394 | 0.547 | 0.504 | 0.379 |
| 34 | 0.368 | 0.424 | 0.489 | 0.394 |
| 35 | 0.325 | 0.359 | 0.459 | 0.6 |
| 36 | 0.381 | 0.394 | 0.424 | 0.401 |
| 37 | 0.325 | 0.394 | 0.424 | 0.315 |
| 38 | 0.389 | 0.436 | 0.635 | 0.347 |
| 39 | 0.325 | 0.389 | 0.401 | 0.411 |
| 40 | 0.352 | 0.458 | 0.445 | 0.412 |
| 41 | 0.254 | 0.398 | 0.428 | 0.5 |
| 42 | 0.424 | 0.424 | 0.445 | 0.363 |
| 43 | 0.445 | 0.303 | 0.394 | 0.301 |
| 44 | 0.498 | 0.43 | 0.389 | 0.368 |
| 45 | 0.398 | 0.428 | 0.489 | 0.394 |
| 46 | 0.374 | 0.382 | 0.354 | 0.315 |
| 47 | 0.398 | 0.394 | 0.49 | 0.459 |
| 48 | 0.459 | 0.347 | 0.436 | 0.441 |
| 49 | 0.354 | 0.528 | 0.436 | 0.325 |
| 50 | 0.459 | 0.354 | 0.275 | 0.445 |
| Average | 0.374 | 0.398 | 0.410 | 0.400 |
| SD | 0.059 | 0.058 | 0.081 | 0.071 |

Table A10 Measured values of PLA fiber segments electrospun at F=0.5ml/hr, d=15cm, 8% PLA in ($CHCl_3$:DMF / 75:25) with various applied voltage.

| Solvent system | 8% PLA ($CHCl_3$:DMF / 75:25) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Applied voltage (kV) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 1.16 | 0.72 | 0.803 | 1 |
| 2 | 0.857 | 0.75 | 0.902 | 0.708 |
| 3 | 1.42 | 0.54 | 0.945 | 0.787 |
| 4 | 1.74 | 0.79 | 0.758 | 1.78 |
| 5 | 1.56 | 0.78 | 0.568 | 0.694 |
| 6 | 1.76 | 0.57 | 0.824 | 0.845 |
| 7 | 1.51 | 1 | 0.668 | 1.49 |
| 8 | 1.13 | 0.82 | 0.891 | 1.1 |
| 9 | 0.896 | 1.11 | 0.848 | 0.945 |
| 10 | 1.58 | 1.25 | 1.83 | 0.803 |
| 11 | 1.35 | 0.88 | 0.851 | 1.48 |
| 12 | 0.602 | 1.01 | 1.07 | 0.918 |
| 13 | 1.37 | 1.65 | 0.762 | 0.697 |
| 14 | 0.821 | 0.74 | 1.56 | 0.848 |
| 15 | 1.48 | 0.79 | 1.35 | 0.694 |
| 16 | 0.981 | 0.76 | 0.704 | 0.857 |
| 17 | 1.44 | 1.08 | 1.05 | 1.29 |
| 18 | 1.15 | 0.69 | 1 | 0.568 |
| 19 | 0.749 | 0.8 | 0.749 | 1.23 |
| 20 | 0.824 | 1.01 | 0.981 | 0.902 |
| 21 | 1.83 | 0.9 | 1.05 | 1.07 |
| 22 | 0.697 | 0.82 | 0.704 | 0.958 |
| 23 | 0.606 | 1.13 | 1.01 | 1.2 |

| | | | | |
|---|---|---|---|---|
| 24 | 1.89 | 0.85 | 0.704 | 1.01 |
| 25 | 1.95 | 0.8 | 0.915 | 1.1 |
| 26 | 0.735 | 0.76 | 0.697 | 0.891 |
| 27 | 0.848 | 0.71 | 0.749 | 0.958 |
| 28 | 1.25 | 0.72 | 1.18 | 1.13 |
| 29 | 0.536 | 0.64 | 1.2 | 1.73 |
| 30 | 1.64 | 1.17 | 0.787 | 0.902 |
| 31 | 1.11 | 1.18 | 0.55 | 0.848 |
| 32 | 0.145 | 0.58 | 0.871 | 0.918 |
| 33 | 0.166 | 0.76 | 1.41 | 1.05 |
| 34 | 1.57 | 0.98 | 0.857 | 0.871 |
| 35 | 1.68 | 0.63 | 0.926 | 1.07 |
| 36 | 0.445 | 1.01 | 0.926 | 0.725 |
| 37 | 0.63 | 1.06 | 0.947 | 0.602 |
| 38 | 0.536 | 0.8 | 1.49 | 1 |
| 39 | 0.145 | 0.55 | 1.54 | 1.09 |
| 40 | 0.152 | 0.95 | 0.705 | 1.06 |
| 41 | 0.498 | 1.17 | 0.947 | 0.758 |
| 42 | 0.198 | 0.98 | 0.88 | 1.44 |
| 43 | 0.602 | 1.07 | 1.51 | 0.694 |
| 44 | 0.664 | 0.67 | 0.743 | 0.945 |
| 45 | 0.758 | 0.78 | 0.787 | 0.857 |
| 46 | 0.145 | 0.85 | 0.87 | 0.848 |
| 47 | 0.106 | 0.89 | 0.551 | 0.915 |
| 48 | 0.105 | 0.98 | 0.882 | 0.107 |
| 49 | 0.508 | 0.74 | 0.94 | 0.107 |
| 50 | 1.05 | 0.7 | 1.63 | 1.28 |
| Average | 0.952 | 0.871 | 0.961 | 0.955 |
| SD | 0.548 | 0.212 | 0.296 | 0.315 |

Table A11 Measured values of PLA fiber segments electrospun at F=0.5ml/hr, d=15cm, 12% PLA in ($CHCl_3$:DMF / 50:50) with various applied voltage.

| Solvent system | 12% PLA ($CHCl_3$:DMF / 50:50) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Applied voltage (kV) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.401 | 0.623 | 0.725 | 0.394 |
| 2 | 0.508 | 0.249 | 0.627 | 0.753 |
| 3 | 0.394 | 0.498 | 0.401 | 0.787 |
| 4 | 0.615 | 0.872 | 0.547 | 0.425 |
| 5 | 0.578 | 0.334 | 0.387 | 0.787 |
| 6 | 0.43 | 0.441 | 0.599 | 0.428 |
| 7 | 0.5 | 0.523 | 0.529 | 0.791 |
| 8 | 0.319 | 0.334 | 0.831 | 0.424 |
| 9 | 0.451 | 0.872 | 0.49 | 0.606 |
| 10 | 0.43 | 0.493 | 0.363 | 0.317 |
| 11 | 0.43 | 0.857 | 0.33 | 0.55 |
| 12 | 0.713 | 0.246 | 0.758 | 0.451 |
| 13 | 0.782 | 0.6 | 0.379 | 0.325 |
| 14 | 0.394 | 0.557 | 0.43 | 0.387 |
| 15 | 0.536 | 0.458 | 0.504 | 0.513 |
| 16 | 0.354 | 0.459 | 0.649 | 0.445 |
| 17 | 0.43 | 0.624 | 0.493 | 0.581 |
| 18 | 0.459 | 0.658 | 0.504 | 0.332 |
| 19 | 0.551 | 0.504 | 0.523 | 0.548 |
| 20 | 0.569 | 0.425 | 0.673 | 0.664 |
| 21 | 0.368 | 0.523 | 0.411 | 0.598 |
| 22 | 0.381 | 0.52 | 0.658 | 0.504 |
| 23 | 0.49 | 0.411 | 0.49 | 0.445 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.528 | 0.428 | 0.568 | 0.379 |
| 25 | 0.87 | 0.712 | 0.551 | 0.504 |
| 26 | 0.474 | 0.775 | 0.775 | 0.74 |
| 27 | 0.43 | 0.599 | 0.63 | 0.547 |
| 28 | 0.52 | 0.458 | 0.563 | 0.668 |
| 29 | 0.635 | 1 | 0.905 | 0.563 |
| 30 | 0.445 | 0.5 | 0.606 | 0.332 |
| 31 | 0.368 | 0.634 | 0.649 | 0.616 |
| 32 | 0.436 | 0.332 | 0.718 | 0.758 |
| 33 | 0.301 | 0.394 | 0.749 | 0.508 |
| 34 | 0.319 | 1.1 | 0.513 | 0.458 |
| 35 | 0.436 | 0.778 | 0.638 | 0.676 |
| 36 | 0.379 | 0.349 | 0.709 | 0.624 |
| 37 | 0.445 | 0.459 | 0.602 | 0.474 |
| 38 | 0.301 | 0.493 | 0.581 | 0.55 |
| 39 | 0.401 | 0.563 | 0.697 | 0.43 |
| 40 | 0.379 | 0.363 | 0.803 | 0.508 |
| 41 | 0.359 | 0.508 | 0.568 | 0.712 |
| 42 | 0.47 | 0.347 | 0.508 | 0.5 |
| 43 | 0.423 | 0.472 | 0.536 | 0.557 |
| 44 | 0.47 | 0.733 | 0.602 | 0.649 |
| 45 | 0.389 | 0.528 | 0.803 | 0.479 |
| 46 | 0.379 | 0.583 | 0.649 | 0.829 |
| 47 | 0.498 | 0.754 | 0.704 | 0.59 |
| 48 | 0.49 | 0.643 | 0.749 | 0.733 |
| 49 | 0.498 | 0.803 | 0.606 | 0.573 |
| 50 | 0.352 | 0.599 | 0.697 | 0.635 |
| Average | 0.462 | 0.560 | 0.600 | 0.553 |
| SD | 0.114 | 0.186 | 0.131 | 0.136 |

Table A12 Measured values of PLA fiber segments electrospun at F=0.5ml/hr, d=15cm, 14% PLA in ($CHCl_3$:DMF / 25:75) with various applied voltage.

| Solvent system | 14% PLA ($CHCl_3$:DMF / 25:75) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (µm) | | | |
| | Applied voltage (kV) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.448 | 0.424 | 0.539 | 0.775 |
| 2 | 0.315 | 0.354 | 0.315 | 0.463 |
| 3 | 0.254 | 0.374 | 0.387 | 0.547 |
| 4 | 0.325 | 0.359 | 0.352 | 0.638 |
| 5 | 0.5 | 0.352 | 0.474 | 0.539 |
| 6 | 0.389 | 0.387 | 0.583 | 0.451 |
| 7 | 0.43 | 0.352 | 0.424 | 0.694 |
| 8 | 0.368 | 0.424 | 0.325 | 0.458 |
| 9 | 0.573 | 0.459 | 0.389 | 0.533 |
| 10 | 0.5 | 0.352 | 0.458 | 0.401 |
| 11 | 0.459 | 0.494 | 0.563 | 0.423 |
| 12 | 0.424 | 0.472 | 0.498 | 0.423 |
| 13 | 0.246 | 0.349 | 0.428 | 0.569 |
| 14 | 0.352 | 0.401 | 0.424 | 0.425 |
| 15 | 0.459 | 0.332 | 0.463 | 0.508 |
| 16 | 0.368 | 0.493 | 0.458 | 0.557 |
| 17 | 0.374 | 0.448 | 0.381 | 0.479 |
| 18 | 0.379 | 0.424 | 0.352 | 0.459 |
| 19 | 0.401 | 0.474 | 0.374 | 0.775 |
| 20 | 0.352 | 0.368 | 0.352 | 0.424 |
| 21 | 0.513 | 0.428 | 0.349 | 0.412 |
| 22 | 0.423 | 0.428 | 0.537 | 0.523 |
| 23 | 0.459 | 0.428 | 0.537 | 0.479 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.387 | 0.368 | 0.303 | 0.523 |
| 25 | 0.352 | 0.425 | 0.43 | 0.568 |
| 26 | 0.352 | 0.381 | 0.387 | 0.479 |
| 27 | 0.424 | 0.394 | 0.533 | 0.459 |
| 28 | 0.359 | 0.332 | 0.43 | 0.616 |
| 29 | 0.424 | 0.352 | 0.389 | 0.573 |
| 30 | 0.463 | 0.401 | 0.708 | 0.529 |
| 31 | 0.459 | 0.352 | 0.445 | 0.436 |
| 32 | 0.441 | 0.389 | 0.564 | 0.394 |
| 33 | 0.557 | 0.424 | 0.564 | 0.55 |
| 34 | 0.401 | 0.49 | 0.646 | 0.603 |
| 35 | 0.523 | 0.423 | 0.411 | 0.528 |
| 36 | 0.389 | 0.49 | 0.583 | 0.451 |
| 37 | 0.319 | 0.5 | 0.451 | 0.6 |
| 38 | 0.334 | 0.424 | 0.363 | 0.623 |
| 39 | 0.394 | 0.347 | 0.494 | 0.425 |
| 40 | 0.352 | 0.368 | 0.599 | 0.536 |
| 41 | 0.474 | 0.424 | 0.379 | 0.5 |
| 42 | 0.225 | 0.463 | 0.398 | 0.423 |
| 43 | 0.458 | 0.374 | 0.412 | 0.655 |
| 44 | 0.387 | 0.43 | 0.282 | 0.354 |
| 45 | 0.458 | 0.374 | 0.459 | 0.523 |
| 46 | 0.347 | 0.349 | 0.474 | 0.43 |
| 47 | 0.411 | 0.379 | 0.394 | 0.445 |
| 48 | 0.441 | 0.424 | 0.352 | 0.782 |
| 49 | 0.315 | 0.401 | 0.458 | 0.563 |
| 50 | 0.354 | 0.424 | 0.615 | 0.479 |
| Average | 0.402 | 0.406 | 0.450 | 0.520 |
| SD | 0.074 | 0.047 | 0.095 | 0.099 |

Table A13 Measured values of PLA fiber segments electrospun at F=0.5ml/hr, d=15cm, 18% PLA in ($CHCl_3$:DMF / 00:100) with various applied voltage.

| Solvent system | 18% PLA ($CHCl_3$:DMF / 00:100) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Applied voltage (kV) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.401 | 0.374 | 0.374 | 0.363 |
| 2 | 0.349 | 0.463 | 0.332 | 0.334 |
| 3 | 0.363 | 0.352 | 0.463 | 0.352 |
| 4 | 0.394 | 0.381 | 0.282 | 0.394 |
| 5 | 0.332 | 0.299 | 0.374 | 0.368 |
| 6 | 0.49 | 0.423 | 0.334 | 0.352 |
| 7 | 0.352 | 0.459 | 0.347 | 0.528 |
| 8 | 0.301 | 0.332 | 0.564 | 0.424 |
| 9 | 0.489 | 0.401 | 0.303 | 0.347 |
| 10 | 0.47 | 0.411 | 0.459 | 0.513 |
| 11 | 0.424 | 0.325 | 0.424 | 0.436 |
| 12 | 0.325 | 0.504 | 0.528 | 0.47 |
| 13 | 0.29 | 0.394 | 0.547 | 0.445 |
| 14 | 0.246 | 0.325 | 0.635 | 0.474 |
| 15 | 0.423 | 0.401 | 0.301 | 0.479 |
| 16 | 0.494 | 0.398 | 0.394 | 0.479 |
| 17 | 0.352 | 0.352 | 0.352 | 0.299 |
| 18 | 0.394 | 0.459 | 0.325 | 0.489 |
| 19 | 0.352 | 0.412 | 0.317 | 0.381 |
| 20 | 0.489 | 0.29 | 0.474 | 0.325 |
| 21 | 0.379 | 0.284 | 0.315 | 0.387 |
| 22 | 0.394 | 0.347 | 0.425 | 0.504 |
| 23 | 0.425 | 0.334 | 0.548 | 0.445 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.412 | 0.423 | 0.424 | 0.424 |
| 25 | 0.368 | 0.47 | 0.325 | 0.387 |
| 26 | 0.347 | 0.401 | 0.394 | 0.354 |
| 27 | 0.352 | 0.43 | 0.317 | 0.325 |
| 28 | 0.401 | 0.379 | 0.412 | 0.349 |
| 29 | 0.354 | 0.43 | 0.43 | 0.513 |
| 30 | 0.349 | 0.459 | 0.381 | 0.47 |
| 31 | 0.374 | 0.352 | 0.459 | 0.352 |
| 32 | 0.363 | 0.428 | 0.301 | 0.334 |
| 33 | 0.254 | 0.547 | 0.363 | 0.458 |
| 34 | 0.325 | 0.424 | 0.325 | 0.489 |
| 35 | 0.317 | 0.359 | 0.463 | 0.352 |
| 36 | 0.381 | 0.394 | 0.249 | 0.401 |
| 37 | 0.325 | 0.354 | 0.325 | 0.647 |
| 38 | 0.411 | 0.436 | 0.508 | 0.401 |
| 39 | 0.441 | 0.389 | 0.29 | 0.334 |
| 40 | 0.368 | 0.458 | 0.394 | 0.368 |
| 41 | 0.389 | 0.398 | 0.479 | 0.529 |
| 42 | 0.394 | 0.424 | 0.504 | 0.389 |
| 43 | 0.49 | 0.303 | 0.381 | 0.354 |
| 44 | 0.374 | 0.43 | 0.568 | 0.401 |
| 45 | 0.394 | 0.428 | 0.319 | 0.47 |
| 46 | 0.474 | 0.332 | 0.533 | 0.354 |
| 47 | 0.394 | 0.394 | 0.498 | 0.389 |
| 48 | 0.268 | 0.347 | 0.335 | 0.458 |
| 49 | 0.537 | 0.489 | 0.412 | 0.424 |
| 50 | 0.389 | 0.354 | 0.401 | 0.387 |
| Average | 0.383 | 0.395 | 0.404 | 0.414 |
| SD | 0.064 | 0.057 | 0.090 | 0.070 |

Table A14 Measured values of PLA fiber segments electrospun at F=1.0 ml/hr, d=15cm, 8% PLA in ($CHCl_3$:DMF / 75:25) with various applied voltage.

| Solvent system | 8% PLA ($CHCl_3$:DMF / 75:25) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Applied voltage (kV) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.223 | 0.78 | 0.803 | 1.02 |
| 2 | 0.536 | 0.482 | 0.847 | 0.49 |
| 3 | 0.303 | 0.887 | 0.655 | 0.749 |
| 4 | 0.474 | 1.06 | 0.347 | 0.758 |
| 5 | 0.319 | 0.602 | 0.347 | 0.74 |
| 6 | 0.256 | 0.754 | 0.59 | 0.598 |
| 7 | 0.394 | 0.382 | 0.564 | 1.5 |
| 8 | 0.359 | 0.819 | 0.445 | 0.726 |
| 9 | 0.354 | 0.759 | 0.86 | 0.804 |
| 10 | 0.303 | 0.819 | 1.02 | 0.811 |
| 11 | 0.254 | 0.504 | 1.02 | 0.694 |
| 12 | 0.425 | 0.764 | 1.26 | 1.07 |
| 13 | 0.332 | 0.356 | 0.608 | 0.708 |
| 14 | 0.425 | 0.551 | 0.813 | 0.953 |
| 15 | 0.436 | 0.587 | 0.387 | 1.07 |
| 16 | 0.379 | 0.677 | 0.557 | 1.03 |
| 17 | 0.317 | 0.554 | 1.29 | 0.958 |
| 18 | 0.474 | 0.745 | 0.948 | 0.74 |
| 19 | 0.349 | 0.895 | 0.837 | 1.02 |
| 20 | 0.412 | 0.568 | 0.753 | 0.851 |
| 21 | 0.29 | 0.728 | 0.6 | 0.804 |
| 22 | 0.303 | 0.677 | 1.03 | 1.03 |
| 23 | 0.303 | 0.723 | 0.564 | 0.896 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.458 | 0.349 | 1.07 | 0.915 |
| 25 | 0.401 | 0.532 | 1.09 | 0.976 |
| 26 | 0.317 | 0.477 | 0.74 | 1.3 |
| 27 | 0.325 | 0.994 | 0.722 | 0.798 |
| 28 | 0.479 | 0.462 | 1.22 | 0.852 |
| 29 | 0.379 | 0.462 | 1.18 | 0.924 |
| 30 | 0.401 | 0.603 | 1.03 | 0.59 |
| 31 | 0.256 | 0.511 | 0.606 | 0.882 |
| 32 | 0.299 | 0.652 | 0.713 | 1.071 |
| 33 | 0.301 | 0.477 | 0.903 | 1.01 |
| 34 | 0.352 | 0.876 | 0.523 | 1.28 |
| 35 | 0.43 | 0.537 | 1.09 | 0.813 |
| 36 | 0.599 | 0.925 | 0.394 | 0.817 |
| 37 | 0.401 | 0.704 | 0.702 | 1.17 |
| 38 | 0.428 | 0.527 | 0.898 | 1.24 |
| 39 | 0.401 | 0.654 | 0.523 | 0.83 |
| 40 | 0.394 | 0.627 | 0.903 | 0.852 |
| 41 | 0.319 | 0.682 | 0.598 | 0.798 |
| 42 | 0.347 | 0.587 | 0.568 | 1.19 |
| 43 | 0.424 | 0.482 | 0.696 | 0.912 |
| 44 | 0.374 | 0.717 | 0.824 | 1.03 |
| 45 | 0.49 | 1.14 | 0.702 | 1.087 |
| 46 | 0.394 | 0.573 | 0.801 | 1.042 |
| 47 | 0.303 | 0.59 | 0.801 | 0.742 |
| 48 | 0.303 | 0.508 | 0.632 | 0.989 |
| 49 | 0.445 | 0.527 | 0.798 | 0.698 |
| 50 | 0.284 | 0.738 | 0.798 | 1.092 |
| Average | 0.370 | 0.652 | 0.773 | 0.918 |
| SD | 0.083 | 0.180 | 0.268 | 0.206 |

Table A15 Measured values of PLA fiber segments electrospun at F=1.0 ml/hr, d=15cm, 12% PLA in ($CHCl_3$:DMF / 50:50) with various applied voltage.

| Solvent system | 12% PLA ($CHCl_3$:DMF / 50:50) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Applied voltage (kV) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.47 | 0.852 | 0.49 | 0.883 |
| 2 | 0.599 | 0.704 | 0.569 | 0.624 |
| 3 | 0.458 | 0.489 | 0.635 | 0.946 |
| 4 | 0.29 | 0.354 | 0.557 | 0.749 |
| 5 | 0.909 | 0.898 | 0.822 | 0.872 |
| 6 | 0.394 | 0.256 | 0.583 | 0.677 |
| 7 | 0.586 | 0.743 | 0.539 | 0.458 |
| 8 | 0.664 | 0.6 | 1.07 | 0.798 |
| 9 | 0.647 | 0.606 | 0.349 | 0.846 |
| 10 | 0.472 | 0.498 | 0.508 | 0.638 |
| 11 | 0.49 | 0.424 | 0.472 | 0.459 |
| 12 | 0.615 | 0.563 | 0.623 | 0.479 |
| 13 | 0.43 | 0.586 | 0.787 | 0.817 |
| 14 | 0.424 | 0.211 | 0.84 | 0.425 |
| 15 | 0.655 | 0.246 | 0.568 | 0.694 |
| 16 | 0.459 | 0.536 | 0.756 | 0.568 |
| 17 | 0.536 | 0.214 | 0.573 | 0.753 |
| 18 | 0.479 | 0.451 | 0.704 | 0.772 |
| 19 | 0.568 | 0.441 | 0.662 | 0.837 |
| 20 | 0.368 | 0.804 | 0.557 | 0.787 |
| 21 | 0.363 | 0.655 | 0.55 | 0.726 |
| 22 | 0.458 | 0.548 | 0.504 | 0.638 |
| 23 | 0.301 | 0.708 | 0.649 | 0.563 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.726 | 0.425 | 0.458 | 0.746 |
| 25 | 0.249 | 0.411 | 0.599 | 0.743 |
| 26 | 0.29 | 0.756 | 0.694 | 0.623 |
| 27 | 0.451 | 0.223 | 0.533 | 0.775 |
| 28 | 0.223 | 0.284 | 0.528 | 0.704 |
| 29 | 0.568 | 0.634 | 0.699 | 0.804 |
| 30 | 0.68 | 0.713 | 0.537 | 0.753 |
| 31 | 0.436 | 0.627 | 0.529 | 0.573 |
| 32 | 0.782 | 0.93 | 0.59 | 0.649 |
| 33 | 0.412 | 0.676 | 0.599 | 1.04 |
| 34 | 0.578 | 0.211 | 0.459 | 0.705 |
| 35 | 0.317 | 0.615 | 0.753 | 0.746 |
| 36 | 0.55 | 0.852 | 0.718 | 0.819 |
| 37 | 0.445 | 0.55 | 0.602 | 0.804 |
| 38 | 0.513 | 0.249 | 0.445 | 0.709 |
| 39 | 0.448 | 0.533 | 0.49 | 0.779 |
| 40 | 0.43 | 0.528 | 0.423 | 0.803 |
| 41 | 0.547 | 0.458 | 0.472 | 0.909 |
| 42 | 0.602 | 0.655 | 0.436 | 0.726 |
| 43 | 0.824 | 0.421 | 0.586 | 0.424 |
| 44 | 0.837 | 0.411 | 0.528 | 0.504 |
| 45 | 0.438 | 0.627 | 0.494 | 0.648 |
| 46 | 0.621 | 0.533 | 0.718 | 0.883 |
| 47 | 0.517 | 0.655 | 0.635 | 0.775 |
| 48 | 0.349 | 0.53 | 0.458 | 0.753 |
| 49 | 0.513 | 0.499 | 0.59 | 0.819 |
| 50 | 0.528 | 0.512 | 0.704 | 0.623 |
| Average | 0.510 | 0.538 | 0.593 | 0.717 |
| SD | 0.151 | 0.186 | 0.129 | 0.140 |

Table A16 Measured values of PLA fiber segments electrospun at F=1.0 ml/hr, d=15cm, 14% PLA in ($CHCl_3$:DMF / 25:75) with various applied voltage.

| Solvent system | 14% PLA ($CHCl_3$:DMF / 25:75) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (µm) | | | |
| | Applied voltage (kV) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.573 | 0.381 | 0.482 | 0.301 |
| 2 | 0.349 | 0.325 | 0.396 | 0.459 |
| 3 | 0.445 | 0.374 | 0.476 | 0.387 |
| 4 | 0.5 | 0.246 | 0.321 | 0.428 |
| 5 | 0.649 | 0.387 | 0.631 | 0.472 |
| 6 | 0.649 | 0.359 | 0.501 | 0.583 |
| 7 | 0.411 | 0.282 | 0.689 | 0.581 |
| 8 | 0.528 | 0.284 | 0.428 | 0.332 |
| 9 | 0.458 | 0.368 | 0.561 | 0.504 |
| 10 | 0.441 | 0.381 | 0.415 | 0.441 |
| 11 | 0.498 | 0.494 | 0.362 | 0.411 |
| 12 | 0.602 | 0.332 | 0.482 | 0.379 |
| 13 | 0.702 | 0.332 | 0.466 | 0.523 |
| 14 | 0.352 | 0.332 | 0.511 | 0.43 |
| 15 | 0.568 | 0.412 | 0.444 | 0.451 |
| 16 | 0.398 | 0.568 | 0.532 | 0.379 |
| 17 | 0.578 | 0.458 | 0.427 | 0.508 |
| 18 | 0.55 | 0.428 | 0.292 | 0.436 |
| 19 | 0.655 | 0.424 | 0.482 | 0.718 |
| 20 | 0.489 | 0.368 | 0.454 | 0.436 |
| 21 | 0.411 | 0.394 | 0.382 | 0.445 |
| 22 | 0.489 | 0.537 | 0.476 | 0.423 |
| 23 | 0.458 | 0.379 | 0.462 | 0.528 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.658 | 0.363 | 0.527 | 0.523 |
| 25 | 0.726 | 0.474 | 0.482 | 0.349 |
| 26 | 0.529 | 0.254 | 0.327 | 0.347 |
| 27 | 0.424 | 0.493 | 0.431 | 0.635 |
| 28 | 0.564 | 0.472 | 0.39 | 0.493 |
| 29 | 0.539 | 0.394 | 0.454 | 0.411 |
| 30 | 0.498 | 0.401 | 0.384 | 0.347 |
| 31 | 0.428 | 0.436 | 0.493 | 0.359 |
| 32 | 0.381 | 0.401 | 0.501 | 0.523 |
| 33 | 0.635 | 0.317 | 0.496 | 0.389 |
| 34 | 0.479 | 0.352 | 0.462 | 0.638 |
| 35 | 0.441 | 0.325 | 0.335 | 0.445 |
| 36 | 0.441 | 0.451 | 0.426 | 0.401 |
| 37 | 0.539 | 0.441 | 0.382 | 0.401 |
| 38 | 0.398 | 0.379 | 0.533 | 0.513 |
| 39 | 0.47 | 0.284 | 0.461 | 0.317 |
| 40 | 0.479 | 0.412 | 0.439 | 0.508 |
| 41 | 0.424 | 0.374 | 0.37 | 0.508 |
| 42 | 0.451 | 0.374 | 0.319 | 0.394 |
| 43 | 0.381 | 0.249 | 0.639 | 0.598 |
| 44 | 0.451 | 0.349 | 0.392 | 0.548 |
| 45 | 0.5 | 0.354 | 0.462 | 0.423 |
| 46 | 0.479 | 0.381 | 0.482 | 0.581 |
| 47 | 0.668 | 0.411 | 0.482 | 0.643 |
| 48 | 0.504 | 0.459 | 0.433 | 0.489 |
| 49 | 0.528 | 0.424 | 0.356 | 0.49 |
| 50 | 0.569 | 0.401 | 0.524 | 0.55 |
| Average | 0.507 | 0.385 | 0.453 | 0.468 |
| SD | 0.093 | 0.069 | 0.081 | 0.093 |

Table A17 Measured values of PLA fiber segments electrospun at F=1.0 ml/hr, d=15cm, 18% PLA in ($CHCl_3$:DMF / 00:100) with various applied voltage.

| Solvent system | 18% PLA ($CHCl_3$:DMF / 00:100) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (µm) | | | |
| | Applied voltage (kV) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.489 | 0.347 | 0.284 | 0.352 |
| 2 | 0.425 | 0.359 | 0.489 | 0.436 |
| 3 | 0.412 | 0.389 | 0.317 | 0.332 |
| 4 | 0.424 | 0.479 | 0.379 | 0.513 |
| 5 | 0.451 | 0.441 | 0.43 | 0.424 |
| 6 | 0.436 | 0.363 | 0.498 | 0.459 |
| 7 | 0.387 | 0.379 | 0.246 | 0.352 |
| 8 | 0.474 | 0.55 | 0.387 | 0.379 |
| 9 | 0.551 | 0.459 | 0.368 | 0.268 |
| 10 | 0.445 | 0.368 | 0.428 | 0.445 |
| 11 | 0.463 | 0.334 | 0.303 | 0.282 |
| 12 | 0.47 | 0.332 | 0.381 | 0.474 |
| 13 | 0.275 | 0.381 | 0.275 | 0.275 |
| 14 | 0.712 | 0.315 | 0.319 | 0.423 |
| 15 | 0.504 | 0.398 | 0.254 | 0.401 |
| 16 | 0.379 | 0.557 | 0.436 | 0.479 |
| 17 | 0.564 | 0.528 | 0.315 | 0.573 |
| 18 | 0.569 | 0.359 | 0.319 | 0.411 |
| 19 | 0.425 | 0.47 | 0.363 | 0.504 |
| 20 | 0.634 | 0.398 | 0.458 | 0.352 |
| 21 | 0.6 | 0.458 | 0.43 | 0.479 |
| 22 | 0.498 | 0.474 | 0.299 | 0.315 |
| 23 | 0.489 | 0.352 | 0.441 | 0.275 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.474 | 0.394 | 0.43 | 0.268 |
| 25 | 0.463 | 0.334 | 0.317 | 0.301 |
| 26 | 0.303 | 0.319 | 0.458 | 0.436 |
| 27 | 0.563 | 0.352 | 0.381 | 0.451 |
| 28 | 0.536 | 0.412 | 0.428 | 0.379 |
| 29 | 0.332 | 0.354 | 0.743 | 0.398 |
| 30 | 0.394 | 0.389 | 0.498 | 0.441 |
| 31 | 0.479 | 0.5 | 0.332 | 0.284 |
| 32 | 0.445 | 0.299 | 0.284 | 0.412 |
| 33 | 0.411 | 0.379 | 0.254 | 0.284 |
| 34 | 0.394 | 0.394 | 0.282 | 0.325 |
| 35 | 0.649 | 0.6 | 0.529 | 0.451 |
| 36 | 0.491 | 0.401 | 0.352 | 0.303 |
| 37 | 0.523 | 0.315 | 0.387 | 0.249 |
| 38 | 0.557 | 0.347 | 0.249 | 0.268 |
| 39 | 0.504 | 0.411 | 0.441 | 0.301 |
| 40 | 0.513 | 0.412 | 0.513 | 0.347 |
| 41 | 0.47 | 0.5 | 0.401 | 0.315 |
| 42 | 0.498 | 0.363 | 0.334 | 0.317 |
| 43 | 0.568 | 0.301 | 0.43 | 0.325 |
| 44 | 0.557 | 0.368 | 0.423 | 0.504 |
| 45 | 0.493 | 0.394 | 0.401 | 0.303 |
| 46 | 0.379 | 0.315 | 0.459 | 0.246 |
| 47 | 0.441 | 0.459 | 0.268 | 0.249 |
| 48 | 0.55 | 0.441 | 0.528 | 0.325 |
| 49 | 0.459 | 0.325 | 0.479 | 0.35 |
| 50 | 0.539 | 0.445 | 0.398 | 0.411 |
| Average | 0.481 | 0.400 | 0.388 | 0.369 |
| SD | 0.084 | 0.071 | 0.095 | 0.083 |

Table A18 Measured values of PLA fiber segments electrospun at V=15kV, F=1.0 ml/hr, 8% PLA in ($CHCl_3$:DMF / 75:25) with various collecting distance.

| Solvent system | 8% PLA ($CHCl_3$:DMF / 75:25) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Collecting distance (cm) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.284 | 0.78 | 0.396 | 0.389 |
| 2 | 0.6 | 0.482 | 0.401 | 0.325 |
| 3 | 0.635 | 0.887 | 0.321 | 0.459 |
| 4 | 0.459 | 1.06 | 0.567 | 0.423 |
| 5 | 0.423 | 0.602 | 0.39 | 0.508 |
| 6 | 0.662 | 0.754 | 0.415 | 0.529 |
| 7 | 0.739 | 0.382 | 0.427 | 0.315 |
| 8 | 0.504 | 0.819 | 0.433 | 0.317 |
| 9 | 0.635 | 0.759 | 0.619 | 0.374 |
| 10 | 0.634 | 0.819 | 0.317 | 0.303 |
| 11 | 0.303 | 0.504 | 0.451 | 0.424 |
| 12 | 0.709 | 0.764 | 0.286 | 0.523 |
| 13 | 0.463 | 0.356 | 0.504 | 0.635 |
| 14 | 0.441 | 0.551 | 0.362 | 0.615 |
| 15 | 0.655 | 0.587 | 0.461 | 0.394 |
| 16 | 0.779 | 0.677 | 0.561 | 0.359 |
| 17 | 0.301 | 0.554 | 0.654 | 0.445 |
| 18 | 0.319 | 0.745 | 0.39 | 0.498 |
| 19 | 0.401 | 0.895 | 0.718 | 0.713 |
| 20 | 0.508 | 0.568 | 0.428 | 0.387 |
| 21 | 0.359 | 0.728 | 0.561 | 0.568 |
| 22 | 0.394 | 0.677 | 0.305 | 0.673 |
| 23 | 0.352 | 0.723 | 0.27 | 0.624 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.603 | 0.349 | 0.327 | 0.537 |
| 25 | 0.557 | 0.532 | 0.461 | 0.352 |
| 26 | 0.615 | 0.477 | 0.717 | 0.47 |
| 27 | 0.794 | 0.994 | 0.454 | 0.523 |
| 28 | 0.523 | 0.462 | 0.427 | 0.583 |
| 29 | 0.394 | 0.462 | 0.303 | 0.608 |
| 30 | 0.479 | 0.603 | 0.476 | 0.472 |
| 31 | 0.583 | 0.511 | 0.508 | 0.662 |
| 32 | 0.568 | 0.652 | 0.327 | 0.368 |
| 33 | 0.539 | 0.477 | 0.415 | 0.349 |
| 34 | 0.354 | 0.876 | 0.356 | 0.423 |
| 35 | 0.528 | 0.537 | 0.356 | 0.379 |
| 36 | 0.6 | 0.925 | 0.476 | 0.325 |
| 37 | 0.394 | 0.704 | 0.551 | 0.387 |
| 38 | 0.903 | 0.527 | 0.449 | 0.646 |
| 39 | 0.389 | 0.654 | 0.317 | 0.249 |
| 40 | 0.668 | 0.627 | 0.327 | 0.504 |
| 41 | 0.379 | 0.682 | 0.303 | 0.354 |
| 42 | 0.303 | 0.587 | 0.356 | 0.537 |
| 43 | 0.284 | 0.482 | 0.619 | 0.352 |
| 44 | 0.528 | 0.717 | 0.317 | 0.47 |
| 45 | 0.676 | 1.14 | 0.451 | 0.529 |
| 46 | 0.448 | 0.573 | 0.303 | 0.315 |
| 47 | 0.528 | 0.59 | 0.476 | 0.459 |
| 48 | 0.494 | 0.508 | 0.508 | 0.423 |
| 49 | 0.514 | 0.527 | 0.401 | 0.379 |
| 50 | 0.479 | 0.738 | 0.451 | 0.325 |
| Average | 0.514 | 0.652 | 0.433 | 0.456 |
| SD | 0.146 | 0.176 | 0.111 | 0.115 |

Table A19 Measured values of PLA fiber segments electrospun at V=15kV, F=1.0 ml/hr, 12% PLA in ($CHCl_3$:DMF / 50:50) with various collecting distance.

| Solvent system | 12% PLA ($CHCl_3$:DMF / 50:50) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Collecting distance (cm) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.441 | 0.852 | 0.643 | 0.568 |
| 2 | 0.557 | 0.704 | 0.424 | 0.401 |
| 3 | 0.655 | 0.489 | 0.851 | 0.458 |
| 4 | 0.317 | 0.354 | 0.423 | 0.694 |
| 5 | 0.669 | 0.898 | 0.643 | 0.573 |
| 6 | 0.608 | 0.256 | 0.317 | 0.638 |
| 7 | 0.811 | 0.743 | 0.6 | 0.743 |
| 8 | 0.655 | 0.6 | 0.669 | 0.726 |
| 9 | 0.599 | 0.606 | 0.523 | 0.635 |
| 10 | 0.63 | 0.498 | 0.352 | 0.352 |
| 11 | 0.578 | 0.424 | 0.615 | 0.676 |
| 12 | 0.673 | 0.563 | 0.374 | 0.603 |
| 13 | 0.529 | 0.586 | 0.664 | 0.692 |
| 14 | 1.07 | 0.211 | 0.684 | 0.875 |
| 15 | 0.55 | 0.246 | 0.749 | 0.699 |
| 16 | 0.474 | 0.536 | 1.02 | 0.451 |
| 17 | 0.436 | 0.214 | 0.817 | 0.459 |
| 18 | 0.598 | 0.451 | 0.557 | 0.479 |
| 19 | 0.401 | 0.441 | 0.857 | 0.379 |
| 20 | 0.474 | 0.804 | 0.772 | 0.673 |
| 21 | 0.325 | 0.655 | 0.463 | 0.655 |
| 22 | 0.557 | 0.548 | 0.394 | 0.709 |
| 23 | 1.06 | 0.708 | 0.782 | 0.539 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.647 | 0.425 | 0.354 | 0.608 |
| 25 | 0.961 | 0.411 | 0.762 | 0.794 |
| 26 | 0.932 | 0.756 | 0.359 | 0.725 |
| 27 | 0.606 | 0.223 | 0.479 | 0.837 |
| 28 | 0.846 | 0.284 | 0.726 | 0.882 |
| 29 | 0.813 | 0.634 | 0.374 | 0.694 |
| 30 | 0.463 | 0.713 | 0.557 | 0.762 |
| 31 | 0.573 | 0.627 | 0.813 | 0.436 |
| 32 | 1.14 | 0.93 | 0.586 | 0.441 |
| 33 | 0.772 | 0.676 | 0.694 | 0.753 |
| 34 | 0.528 | 0.211 | 0.523 | 0.606 |
| 35 | 0.704 | 0.615 | 0.299 | 1.09 |
| 36 | 0.772 | 0.852 | 0.451 | 0.528 |
| 37 | 1 | 0.55 | 0.347 | 0.401 |
| 38 | 0.664 | 0.249 | 0.635 | 0.598 |
| 39 | 0.332 | 0.533 | 0.608 | 0.63 |
| 40 | 0.635 | 0.528 | 0.735 | 1.24 |
| 41 | 1.16 | 0.458 | 0.634 | 0.87 |
| 42 | 0.747 | 0.655 | 0.334 | 0.822 |
| 43 | 0.624 | 0.421 | 0.84 | 0.84 |
| 44 | 0.52 | 0.411 | 0.669 | 0.441 |
| 45 | 0.315 | 0.627 | 0.669 | 0.458 |
| 46 | 0.769 | 0.533 | 0.902 | 0.533 |
| 47 | 0.704 | 0.655 | 0.424 | 0.504 |
| 48 | 0.669 | 0.53 | 0.211 | 0.638 |
| 49 | 0.988 | 0.499 | 0.523 | 0.504 |
| 50 | 0.702 | 0.512 | 0.705 | 0.692 |
| Average | 0.665 | 0.538 | 0.588 | 0.640 |
| SD | 0.211 | 0.186 | 0.186 | 0.179 |

Table A20 Measured values of PLA fiber segments electrospun at V=15kV, F=1.0 ml/hr, 14% PLA in ($CHCl_3$:DMF / 25:75) with various collecting distance.

| Solvent system | 14% PLA ($CHCl_3$:DMF / 25:75) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | |
| | Collecting distance (cm) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.387 | 0.381 | 0.379 | 0.381 |
| 2 | 0.489 | 0.325 | 0.424 | 0.598 |
| 3 | 0.445 | 0.374 | 0.676 | 0.424 |
| 4 | 0.49 | 0.246 | 0.398 | 0.646 |
| 5 | 0.578 | 0.387 | 0.547 | 0.539 |
| 6 | 0.847 | 0.359 | 0.425 | 0.634 |
| 7 | 0.563 | 0.282 | 0.47 | 0.523 |
| 8 | 0.379 | 0.284 | 0.379 | 0.508 |
| 9 | 0.284 | 0.368 | 0.436 | 0.347 |
| 10 | 0.428 | 0.381 | 0.401 | 0.394 |
| 11 | 0.568 | 0.494 | 0.504 | 0.441 |
| 12 | 0.29 | 0.332 | 0.5 | 0.387 |
| 13 | 0.347 | 0.332 | 0.586 | 0.459 |
| 14 | 0.354 | 0.332 | 0.458 | 0.479 |
| 15 | 0.463 | 0.412 | 0.381 | 0.504 |
| 16 | 0.334 | 0.568 | 0.445 | 0.425 |
| 17 | 0.319 | 0.458 | 0.43 | 0.5 |
| 18 | 0.49 | 0.428 | 0.325 | 0.394 |
| 19 | 0.451 | 0.424 | 0.401 | 0.448 |
| 20 | 0.47 | 0.368 | 0.428 | 0.647 |
| 21 | 0.315 | 0.394 | 0.374 | 0.564 |
| 22 | 0.347 | 0.537 | 0.303 | 0.445 |
| 23 | 0.459 | 0.379 | 0.363 | 0.498 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.472 | 0.363 | 0.458 | 0.479 |
| 25 | 0.299 | 0.474 | 0.451 | 0.586 |
| 26 | 0.673 | 0.254 | 0.401 | 0.411 |
| 27 | 0.493 | 0.493 | 0.411 | 0.254 |
| 28 | 0.301 | 0.472 | 0.47 | 0.428 |
| 29 | 0.381 | 0.394 | 0.458 | 0.479 |
| 30 | 0.458 | 0.401 | 0.398 | 0.425 |
| 31 | 0.624 | 0.436 | 0.479 | 0.352 |
| 32 | 0.441 | 0.401 | 0.374 | 0.668 |
| 33 | 0.352 | 0.317 | 0.568 | 0.425 |
| 34 | 0.709 | 0.352 | 0.88 | 0.627 |
| 35 | 0.557 | 0.325 | 0.352 | 0.479 |
| 36 | 0.459 | 0.451 | 0.599 | 0.606 |
| 37 | 0.389 | 0.441 | 0.394 | 0.352 |
| 38 | 0.29 | 0.379 | 0.436 | 0.389 |
| 39 | 0.602 | 0.284 | 0.424 | 0.458 |
| 40 | 0.424 | 0.412 | 0.49 | 0.513 |
| 41 | 0.374 | 0.374 | 0.43 | 0.458 |
| 42 | 0.563 | 0.374 | 0.303 | 0.352 |
| 43 | 0.349 | 0.249 | 0.428 | 0.684 |
| 44 | 0.303 | 0.349 | 0.325 | 0.513 |
| 45 | 0.564 | 0.354 | 0.573 | 0.627 |
| 46 | 0.547 | 0.381 | 0.539 | 0.494 |
| 47 | 0.401 | 0.411 | 0.347 | 0.401 |
| 48 | 0.472 | 0.459 | 0.493 | 0.662 |
| 49 | 0.5 | 0.424 | 0.374 | 0.684 |
| 50 | 0.282 | 0.401 | 0.493 | 0.635 |
| Average | 0.448 | 0.385 | 0.448 | 0.493 |
| SD | 0.122 | 0.069 | 0.100 | 0.105 |

Table A21 Measured values of PLA fiber segments electrospun at V=15kV, F=1.0 ml/hr, 18% PLA in ($CHCl_3$:DMF / 00:100) with various collecting distance.

| Solvent system | 18% PLA ($CHCl_3$:DMF / 00:100) | | | |
|---|---|---|---|---|
| Fiber Segment No | Fiber size (µm) | | | |
| | Collecting distance (cm) | | | |
| | 10 | 15 | 20 | 25 |
| 1 | 0.498 | 0.347 | 0.381 | 0.359 |
| 2 | 0.325 | 0.359 | 0.303 | 0.472 |
| 3 | 0.315 | 0.389 | 0.425 | 0.441 |
| 4 | 0.479 | 0.479 | 0.359 | 0.441 |
| 5 | 0.325 | 0.441 | 0.275 | 0.573 |
| 6 | 0.352 | 0.363 | 0.394 | 0.513 |
| 7 | 0.345 | 0.379 | 0.43 | 0.459 |
| 8 | 0.398 | 0.55 | 0.325 | 0.411 |
| 9 | 0.424 | 0.459 | 0.354 | 0.458 |
| 10 | 0.387 | 0.368 | 0.354 | 0.513 |
| 11 | 0.354 | 0.334 | 0.394 | 0.387 |
| 12 | 0.63 | 0.332 | 0.379 | 0.368 |
| 13 | 0.374 | 0.381 | 0.394 | 0.489 |
| 14 | 0.423 | 0.315 | 0.55 | 0.489 |
| 15 | 0.401 | 0.398 | 0.635 | 0.389 |
| 16 | 0.47 | 0.557 | 0.425 | 0.275 |
| 17 | 0.381 | 0.528 | 0.249 | 0.325 |
| 18 | 0.528 | 0.359 | 0.325 | 0.428 |
| 19 | 0.52 | 0.47 | 0.303 | 0.441 |
| 20 | 0.623 | 0.398 | 0.458 | 0.523 |
| 21 | 0.669 | 0.458 | 0.319 | 0.374 |
| 22 | 0.6 | 0.474 | 0.303 | 0.459 |
| 23 | 0.374 | 0.352 | 0.284 | 0.445 |

| | | | | |
|---|---|---|---|---|
| 24 | 0.368 | 0.394 | 0.303 | 0.394 |
| 25 | 0.459 | 0.334 | 0.43 | 0.398 |
| 26 | 0.374 | 0.319 | 0.401 | 0.374 |
| 27 | 0.394 | 0.352 | 0.332 | 0.389 |
| 28 | 0.387 | 0.412 | 0.334 | 0.368 |
| 29 | 0.489 | 0.354 | 0.352 | 0.363 |
| 30 | 0.498 | 0.389 | 0.448 | 0.349 |
| 31 | 0.49 | 0.5 | 0.425 | 0.334 |
| 32 | 0.325 | 0.299 | 0.586 | 0.256 |
| 33 | 0.381 | 0.379 | 0.268 | 0.448 |
| 34 | 0.463 | 0.394 | 0.381 | 0.363 |
| 35 | 0.578 | 0.6 | 0.569 | 0.412 |
| 36 | 0.424 | 0.401 | 0.513 | 0.354 |
| 37 | 0.354 | 0.315 | 0.363 | 0.424 |
| 38 | 0.394 | 0.347 | 0.325 | 0.299 |
| 39 | 0.379 | 0.411 | 0.412 | 0.387 |
| 40 | 0.528 | 0.412 | 0.401 | 0.389 |
| 41 | 0.284 | 0.5 | 0.282 | 0.352 |
| 42 | 0.533 | 0.363 | 0.368 | 0.599 |
| 43 | 0.441 | 0.301 | 0.463 | 0.368 |
| 44 | 0.504 | 0.368 | 0.352 | 0.412 |
| 45 | 0.568 | 0.394 | 0.563 | 0.354 |
| 46 | 0.401 | 0.315 | 0.334 | 0.441 |
| 47 | 0.539 | 0.459 | 0.474 | 0.352 |
| 48 | 0.374 | 0.441 | 0.401 | 0.533 |
| 49 | 0.49 | 0.325 | 0.474 | 0.472 |
| 50 | 0.363 | 0.445 | 0.317 | 0.334 |
| Average | 0.440 | 0.400 | 0.390 | 0.411 |
| SD | 0.092 | 0.071 | 0.088 | 0.072 |

# Appendix B

Raw data: Preparation of PLA-PEO bicomponent fiber by co-electrospinning

Table B1 Measured values of PLA-PEO bicomponent fiber segments electrospun at V=15 kV, $F_{PLA}$=0.5 ml/hr, $F_{PEO}$=0.5 ml/hr, 3% PEO in $CHCl_3$ with various PLA solvent system.

| Solvent system | Fixed 3% PEO (CHCl3) | | | |
|---|---|---|---|---|
| Fiber Segment No. | Fiber size (μm) | | | |
| | PLA solvent system | | | |
| | 8% PLA ($CHCl_3$:DMF) (75:25) | 12%PLA ($CHCl_3$:DMF) (50:50) | 16%PLA ($CHCl_3$:DMF) (25:75) | 19%PLA ($CHCl_3$:DMF) (00:100) |
| 1 | 2.71 | 1.44 | 0.6 | 0.85 |
| 2 | 2.22 | 1.25 | 0.42 | 0.98 |
| 3 | 2.05 | 1.29 | 1 | 1.26 |
| 4 | 1.74 | 1.29 | 0.82 | 0.98 |
| 5 | 2.27 | 1.44 | 0.93 | 1.21 |
| 6 | 1.57 | 1.4 | 1.74 | 1.35 |
| 7 | 1.62 | 1.25 | 1.45 | 0.92 |
| 8 | 2.81 | 1.25 | 0.86 | 1.14 |
| 9 | 2.27 | 1.62 | 1.62 | 1.27 |
| 10 | 2.59 | 1.53 | 2.67 | 1.06 |
| 11 | 2.2 | 1.36 | 1.3 | 1.25 |
| 12 | 1.79 | 1.29 | 0.51 | 0.96 |
| 13 | 2.05 | 1.4 | 0.36 | 1.08 |
| 14 | 2.23 | 2.02 | 0.35 | 0.88 |
| 15 | 2.7 | 1.4 | 1.11 | 1.01 |
| 16 | 1.41 | 1.61 | 0.16 | 0.82 |
| 17 | 2.1 | 1.96 | 0.85 | 1.11 |
| 18 | 1.91 | 1.44 | 1.59 | 1.01 |
| 19 | 2.9 | 1.53 | 1.1 | 1.2 |
| 20 | 2.6 | 2.04 | 1.1 | 1.14 |
| 21 | 2.49 | 1.76 | 1.16 | 1.1 |
| 22 | 2.05 | 1.53 | 0.22 | 1.07 |

| | | | | |
|---|---|---|---|---|
| 23 | 1.79 | 1.65 | 1.1 | 1.11 |
| 24 | 1.83 | 1.43 | 1.21 | 1.21 |
| 25 | 1.89 | 1.53 | 1.97 | 0.92 |
| 26 | 2.97 | 1.36 | 1.23 | 0.85 |
| 27 | 2.01 | 1.2 | 1.11 | 1.08 |
| 28 | 2.05 | 1.4 | 1.36 | 0.85 |
| 29 | 1.79 | 0.96 | 1.95 | 1.13 |
| 30 | 2.05 | 1.25 | 1.36 | 1.07 |
| 31 | 2.23 | 1.93 | 1.18 | 1.17 |
| 32 | 2.27 | 1.92 | 0.95 | 1.32 |
| 33 | 2.53 | 2.04 | 1.04 | 1.14 |
| 34 | 1.6 | 1.36 | 1.68 | 1 |
| 35 | 2.05 | 1.13 | 0.39 | 1 |
| 36 | 1.83 | 1.4 | 0.88 | 1.1 |
| 37 | 1.42 | 1.36 | 0.3 | 1.15 |
| 38 | 2.36 | 1.47 | 0.83 | 1.14 |
| 39 | 2.29 | 1.47 | 0.87 | 1.14 |
| 40 | 3.18 | 1.4 | 1.42 | 0.9 |
| 41 | 2.01 | 1.4 | 1.12 | 1.15 |
| 42 | 2.83 | 1.14 | 1.17 | 0.9 |
| 43 | 2.22 | 1.54 | 1.26 | 1.21 |
| 44 | 1.74 | 2.6 | 0.3 | 1.17 |
| 45 | 2 | 1.69 | 0.86 | 0.99 |
| 46 | 2 | 1.6 | 0.45 | 1.08 |
| 47 | 2.22 | 1.76 | 1.02 | 1.05 |
| 48 | 2.51 | 1.65 | 1.23 | 1.16 |
| 49 | 2.05 | 1.3 | 0.33 | 1.15 |
| 50 | 2.36 | 2.02 | 1.2 | 0.92 |
| Average | 2.167 | 1.521 | 1.034 | 1.074 |
| SD | 0.403 | 0.299 | 0.507 | 0.130 |

Table B2 Measured values of PLA-PEO bicomponent fiber segments electrospun at V=15kV, $F_{PLA}$=0.5 ml/hr, $F_{PEO}$=0.5 ml/hr, d=20cm, 8% PLA ($CHCl_3$:DMF/75:25) and 19% PLA ($CHCl_3$:DMF/00:100) with various PEO concentration.

| Solvent system | 8% PLA ($CHCl_3$:DMF/75:25) | | | 19% PLA ($CHCl_3$:DMF/00:100) | | |
|---|---|---|---|---|---|---|
| Fiber Segment No. | Fiber size (µm) | | | | | |
| | PEO concentration (%w/v) in $CHCl_3$ | | | | | |
| | 1% | 3% | 5% | 1% | 3% | 5% |
| 1 | 0.57 | 2.71 | 2.74 | 0.51 | 0.85 | 1.27 |
| 2 | 1.29 | 2.22 | 2.32 | 0.65 | 0.98 | 1.06 |
| 3 | 0.57 | 2.05 | 2.18 | 0.47 | 1.26 | 1.2 |
| 4 | 0.76 | 1.74 | 3.11 | 0.36 | 0.98 | 1.41 |
| 5 | 0.8 | 2.27 | 2.49 | 0.61 | 1.21 | 1.15 |
| 6 | 1.29 | 1.57 | 2.47 | 0.96 | 1.35 | 1.2 |
| 7 | 0.89 | 1.62 | 2.21 | 0.63 | 0.92 | 1.07 |
| 8 | 0.64 | 2.81 | 2.34 | 0.86 | 1.14 | 1.23 |
| 9 | 0.91 | 2.27 | 2.48 | 0.8 | 1.27 | 1.3 |
| 10 | 0.91 | 2.59 | 2.29 | 0.66 | 1.06 | 1.36 |
| 11 | 0.8 | 2.2 | 3.91 | 0.73 | 1.25 | 1.17 |
| 12 | 1.14 | 1.79 | 2.3 | 0.76 | 0.96 | 1.2 |
| 13 | 1.14 | 2.05 | 2.46 | 0.78 | 1.08 | 1.27 |
| 14 | 0.76 | 2.23 | 2.61 | 0.82 | 0.88 | 0.94 |
| 15 | 1.14 | 2.7 | 2.64 | 0.69 | 1.01 | 0.99 |
| 16 | 0.64 | 1.41 | 2.38 | 0.76 | 0.82 | 0.95 |
| 17 | 1.13 | 2.1 | 2 | 0.6 | 1.11 | 1.26 |
| 18 | 1.09 | 1.91 | 2.63 | 0.76 | 1.01 | 1.41 |
| 19 | 0.89 | 2.9 | 2.55 | 0.92 | 1.2 | 1.32 |
| 20 | 0.74 | 2.6 | 2.45 | 0.85 | 1.14 | 0.94 |
| 21 | 1.4 | 2.49 | 2.9 | 0.87 | 1.1 | 1.21 |
| 22 | 1.01 | 2.05 | 2.61 | 0.7 | 1.07 | 1.31 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 23 | 1.2 | 1.79 | 3.59 | 0.74 | 1.11 | 1.27 |
| 24 | 0.8 | 1.83 | 2.35 | 0.71 | 1.21 | 1.25 |
| 25 | 1.09 | 1.89 | 2.27 | 0.69 | 0.92 | 1.35 |
| 26 | 1.47 | 2.97 | 1.76 | 0.6 | 0.85 | 1.06 |
| 27 | 1.36 | 2.01 | 2.53 | 0.51 | 1.08 | 1.3 |
| 28 | 1.26 | 2.05 | 2.64 | 0.76 | 0.85 | 1.27 |
| 29 | 1.13 | 1.79 | 3.04 | 0.8 | 1.13 | 0.94 |
| 30 | 1.29 | 2.05 | 2.18 | 0.96 | 1.07 | 1.28 |
| 31 | 1.13 | 2.23 | 2.93 | 0.72 | 1.17 | 1.2 |
| 32 | 1.14 | 2.27 | 2.29 | 1.06 | 1.32 | 1.22 |
| 33 | 1.2 | 2.53 | 2.24 | 0.57 | 1.14 | 1.27 |
| 34 | 1.09 | 1.6 | 2.53 | 0.66 | 1 | 1.21 |
| 35 | 1.2 | 2.05 | 3.04 | 0.45 | 1 | 1.51 |
| 36 | 1.01 | 1.83 | 2.33 | 0.66 | 1.1 | 1.93 |
| 37 | 1.01 | 1.42 | 2.16 | 0.6 | 1.15 | 1.44 |
| 38 | 1.04 | 2.36 | 3.08 | 0.61 | 1.14 | 1.65 |
| 39 | 1.44 | 2.29 | 3.55 | 0.85 | 1.14 | 0.98 |
| 40 | 1.4 | 3.18 | 2.24 | 0.65 | 0.9 | 1.3 |
| 41 | 1.07 | 2.01 | 2.96 | 0.78 | 1.15 | 1.3 |
| 42 | 1.36 | 2.83 | 2.24 | 0.65 | 0.9 | 1.36 |
| 43 | 0.89 | 2.22 | 2.24 | 0.57 | 1.21 | 1.39 |
| 44 | 1.4 | 1.74 | 2.32 | 0.61 | 1.17 | 1.28 |
| 45 | 1.09 | 2 | 2.7 | 0.79 | 0.99 | 1.12 |
| 46 | 1.69 | 2 | 2.08 | 0.69 | 1.08 | 1.21 |
| 47 | 0.91 | 2.22 | 2.73 | 0.57 | 1.05 | 1.24 |
| 48 | 1.13 | 2.51 | 2.72 | 0.67 | 1.16 | 1.09 |
| 49 | 1.44 | 2.05 | 1.92 | 0.86 | 1.15 | 0.96 |
| 50 | 1.4 | 2.36 | 2.88 | 0.7 | 0.92 | 1.13 |
| Average | 1.083 | 2.167 | 2.552 | 0.705 | 1.074 | 1.235 |
| SD | 0.258 | 0.403 | 0.422 | 0.138 | 0.130 | 0.183 |

Table B3 Measured values of PLA-PEO bicomponent fiber segments electrospun at V=15kV, d=20 cm, 8% PLA ($CHCl_3$:DMF/75:25) and 3% PEO ($CHCl_3$) with various PLA-PEO solution flow rate ratio.

| Solvent system | 8% PLA ($CHCl_3$:DMF / 75:25) : 3% PEO ($CHCl_3$) | | | | | | |
|---|---|---|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | | | | |
| | PLA:PEO flow rate ratio (ml/hr:ml/hr) | | | | | | |
| | 1.0:0.0 | 0.9:0.1 | 0.75:0.25 | 0.5:0.5 | 0.25:0.75 | 0.1:0.9 | 0.0:1.0 |
| 1 | 1.49 | 0.45 | 1.92 | 2.71 | 2.04 | 2.73 | 2.01 |
| 2 | 1.3 | 0.43 | 1.82 | 2.22 | 3.62 | 2.68 | 2.08 |
| 3 | 0.82 | 0.41 | 2.33 | 2.05 | 1.25 | 2.32 | 2.08 |
| 4 | 0.5 | 0.36 | 1.76 | 1.74 | 2.09 | 2.49 | 1.79 |
| 5 | 1.99 | 0.43 | 2.72 | 2.27 | 2.43 | 2.91 | 2.22 |
| 6 | 0.8 | 0.32 | 2.54 | 1.57 | 2.18 | 2.38 | 2.22 |
| 7 | 0.65 | 0.41 | 1.76 | 1.62 | 2.32 | 2.49 | 2.11 |
| 8 | 0.75 | 0.48 | 2.35 | 2.81 | 2 | 2.27 | 2.08 |
| 9 | 0.55 | 0.43 | 2.16 | 2.27 | 2.08 | 2.66 | 2.07 |
| 10 | 0.51 | 0.3 | 2.18 | 2.59 | 2 | 2.35 | 2.08 |
| 11 | 0.45 | 0.4 | 1.92 | 2.2 | 1.93 | 2.7 | 1.77 |
| 12 | 0.38 | 0.29 | 1.82 | 1.79 | 2.32 | 2.32 | 2.26 |
| 13 | 0.73 | 0.29 | 2.29 | 2.05 | 2.17 | 2.72 | 1.9 |
| 14 | 0.87 | 0.43 | 2 | 2.23 | 2.49 | 2.6 | 2.05 |
| 15 | 0.85 | 0.59 | 2.29 | 2.7 | 2 | 2.33 | 2.18 |
| 16 | 0.51 | 0.36 | 2 | 1.41 | 1.97 | 2.43 | 2.12 |
| 17 | 1.89 | 0.43 | 2.29 | 2.1 | 2 | 2.56 | 2.32 |
| 18 | 1.71 | 0.5 | 1.65 | 1.91 | 1.76 | 2.43 | 2.5 |
| 19 | 0.63 | 0.43 | 2 | 2.9 | 2.14 | 2.73 | 2.21 |
| 20 | 0.6 | 0.3 | 1.79 | 2.6 | 1.92 | 2.68 | 1.77 |
| 21 | 0.89 | 0.32 | 1.8 | 2.49 | 2.04 | 2.73 | 1.97 |
| 22 | 0.79 | 0.41 | 2.14 | 2.05 | 2.27 | 2.93 | 1.99 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23 | 1.14 | 0.51 | 2.15 | 1.79 | 1.93 | 2.58 | 1.96 |
| 24 | 0.63 | 0.36 | 1.79 | 1.83 | 2.5 | 2.29 | 2.09 |
| 25 | 1.64 | 0.32 | 1.52 | 1.89 | 1.93 | 2.64 | 2.17 |
| 26 | 0.85 | 0.3 | 1.92 | 2.97 | 2 | 2.79 | 1.97 |
| 27 | 0.64 | 0.36 | 2.15 | 2.01 | 1.96 | 2.32 | 2.19 |
| 28 | 0.3 | 0.36 | 2.32 | 2.05 | 2.14 | 2.89 | 2.11 |
| 29 | 0.5 | 0.3 | 2.04 | 1.79 | 2.29 | 2.32 | 1.92 |
| 30 | 0.61 | 0.38 | 2.15 | 2.05 | 2.26 | 2.82 | 2.16 |
| 31 | 0.66 | 0.4 | 1.9 | 2.23 | 1.84 | 2.33 | 1.9 |
| 32 | 0.98 | 0.43 | 2.4 | 2.27 | 2.18 | 2.79 | 1.76 |
| 33 | 0.78 | 0.41 | 1.69 | 2.53 | 2.04 | 2.43 | 1.9 |
| 34 | 0.92 | 0.36 | 2.24 | 1.6 | 2.09 | 2.49 | 2.4 |
| 35 | 0.6 | 0.43 | 1.93 | 2.05 | 1.92 | 2.77 | 2.33 |
| 36 | 0.65 | 0.54 | 1.79 | 1.83 | 2.34 | 2.72 | 1.71 |
| 37 | 0.85 | 0.5 | 1.8 | 1.42 | 3.08 | 2.49 | 1.83 |
| 38 | 1.06 | 0.28 | 2.24 | 2.36 | 3.12 | 2.27 | 2.25 |
| 39 | 0.71 | 0.26 | 2.21 | 2.29 | 1.97 | 2.8 | 1.92 |
| 40 | 0.57 | 0.48 | 2.08 | 3.18 | 2.14 | 2.35 | 1.97 |
| 41 | 1.9 | 0.45 | 1.9 | 2.01 | 1.9 | 2.6 | 2.26 |
| 42 | 0.72 | 0.51 | 2.33 | 2.83 | 3.15 | 2.51 | 1.87 |
| 43 | 0.57 | 0.32 | 1.53 | 2.22 | 2.5 | 2.32 | 1.99 |
| 44 | 0.57 | 0.29 | 1.84 | 1.74 | 1.67 | 2.24 | 1.92 |
| 45 | 0.64 | 0.26 | 1.86 | 2 | 1.78 | 2.51 | 1.72 |
| 46 | 0.58 | 0.32 | 2.43 | 2 | 2.77 | 2.78 | 2.13 |
| 47 | 0.93 | 0.32 | 2.8 | 2.22 | 1.97 | 2.66 | 1.8 |
| 48 | 0.42 | 0.41 | 1.97 | 2.51 | 2.05 | 2.43 | 1.99 |
| 49 | 0.55 | 0.38 | 1.92 | 2.05 | 1.63 | 2.35 | 2 |
| 50 | 1.07 | 0.36 | 2.49 | 2.36 | 2.04 | 2.89 | 2.28 |
| Average | 0.834 | 0.387 | 2.058 | 2.167 | 2.164 | 2.556 | 2.046 |
| SD | 0.405 | 0.078 | 0.287 | 0.403 | 0.410 | 0.203 | 0.184 |

Table B4 Measured values of PLA-PEO bicomponent fiber segments electrospun at V=15kV, d=20 cm, 19% PLA ($CHCl_3$:DMF/00:100) and 3% PEO ($CHCl_3$) with various PLA-PEO solution flow rate ratio.

| Solvent system | 19% PLA ($CHCl_3$:DMF / 00:100) : 3% PEO ($CHCl_3$) | | | | | | |
|---|---|---|---|---|---|---|---|
| Fiber Segment No | Fiber size (μm) | | | | | | |
| | PLA:PEO flow rate ratio (ml/hr:ml/hr) | | | | | | |
| | 1.0:0.0 | 0.9:0.1 | 0.75:0.25 | 0.5:0.5 | 0.25:0.75 | 0.1:0.9 | 0.0:1.0 |
| 1 | 0.2 | 0.13 | 0.22 | 0.85 | 0.82 | 1.04 | 2.01 |
| 2 | 0.23 | 0.18 | 0.22 | 0.98 | 1.14 | 1.4 | 2.08 |
| 3 | 0.15 | 0.1 | 0.22 | 1.26 | 0.92 | 1.4 | 2.08 |
| 4 | 0.11 | 0.11 | 0.45 | 0.98 | 1.15 | 1.44 | 1.79 |
| 5 | 0.19 | 0.1 | 0.58 | 1.21 | 0.86 | 1.54 | 2.22 |
| 6 | 0.3 | 0.14 | 0.16 | 1.35 | 1.14 | 1.61 | 2.22 |
| 7 | 0.18 | 0.18 | 0.2 | 0.92 | 1.11 | 1.52 | 2.11 |
| 8 | 0.18 | 0.1 | 0.2 | 1.14 | 1.08 | 1.14 | 2.08 |
| 9 | 0.21 | 0.1 | 0.36 | 1.27 | 1.1 | 1.76 | 2.07 |
| 10 | 0.18 | 0.13 | 0.22 | 1.06 | 1.22 | 1.29 | 2.08 |
| 11 | 0.41 | 0.11 | 0.8 | 1.25 | 1.35 | 1.2 | 1.77 |
| 12 | 0.28 | 0.18 | 0.2 | 0.96 | 1.13 | 1.44 | 2.26 |
| 13 | 0.33 | 0.08 | 0.16 | 1.08 | 1.17 | 0.96 | 1.9 |
| 14 | 0.28 | 0.1 | 0.25 | 0.88 | 0.99 | 1.3 | 2.05 |
| 15 | 0.21 | 0.18 | 0.2 | 1.01 | 1.16 | 1.44 | 2.18 |
| 16 | 0.24 | 0.1 | 1.08 | 0.82 | 1.45 | 2.04 | 2.12 |
| 17 | 0.23 | 0.11 | 0.22 | 1.11 | 1.04 | 1.36 | 2.32 |
| 18 | 0.25 | 0.1 | 0.47 | 1.01 | 0.99 | 1.79 | 2.5 |
| 19 | 0.23 | 0.14 | 0.35 | 1.2 | 0.74 | 1.47 | 2.21 |
| 20 | 0.21 | 0.13 | 0.21 | 1.14 | 0.79 | 1.29 | 1.77 |
| 21 | 0.3 | 0.14 | 0.16 | 1.1 | 1.1 | 1.2 | 1.97 |
| 22 | 0.26 | 0.18 | 0.95 | 1.07 | 1.25 | 2.09 | 1.99 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 23 | 0.24 | 0.08 | 0.14 | 1.11 | 1.76 | 1.44 | 1.96 |
| 24 | 0.25 | 0.11 | 0.14 | 1.21 | 1.13 | 1.65 | 2.09 |
| 25 | 0.26 | 0.18 | 1.11 | 0.92 | 0.82 | 1.4 | 2.17 |
| 26 | 0.21 | 0.08 | 0.36 | 0.85 | 1.06 | 1.29 | 1.97 |
| 27 | 0.21 | 0.13 | 0.16 | 1.08 | 1.08 | 1.4 | 2.19 |
| 28 | 0.21 | 0.1 | 0.86 | 0.85 | 0.99 | 1.61 | 2.11 |
| 29 | 0.2 | 0.14 | 0.22 | 1.13 | 1.23 | 1.36 | 1.92 |
| 30 | 0.25 | 0.08 | 0.36 | 1.07 | 0.76 | 1.6 | 2.16 |
| 31 | 0.38 | 0.11 | 0.22 | 1.17 | 1.02 | 1.44 | 1.9 |
| 32 | 0.18 | 0.14 | 0.28 | 1.32 | 1.23 | 1.65 | 1.76 |
| 33 | 0.33 | 0.1 | 1.4 | 1.14 | 1.4 | 1.13 | 1.9 |
| 34 | 0.43 | 0.14 | 0.22 | 1 | 1.1 | 1.47 | 2.4 |
| 35 | 0.19 | 0.18 | 1.16 | 1 | 1.28 | 1.79 | 2.33 |
| 36 | 0.19 | 0.1 | 0.35 | 1.1 | 1.17 | 1.65 | 1.71 |
| 37 | 0.24 | 0.13 | 0.2 | 1.15 | 1.08 | 1.54 | 1.83 |
| 38 | 0.2 | 0.1 | 0.22 | 1.14 | 1.27 | 1.62 | 2.25 |
| 39 | 0.21 | 0.14 | 0.35 | 1.14 | 1.14 | 1.43 | 1.92 |
| 40 | 0.22 | 0.18 | 0.61 | 0.9 | 1.55 | 1.43 | 1.97 |
| 41 | 0.21 | 0.08 | 0.21 | 1.15 | 1.2 | 1.6 | 2.26 |
| 42 | 0.13 | 0.1 | 1.1 | 0.9 | 1.07 | 1.8 | 1.87 |
| 43 | 0.26 | 0.13 | 0.38 | 1.21 | 1.16 | 2.04 | 1.99 |
| 44 | 0.21 | 0.1 | 0.2 | 1.17 | 1.14 | 1.65 | 1.92 |
| 45 | 0.13 | 0.18 | 0.36 | 0.99 | 1.08 | 1.69 | 1.72 |
| 46 | 0.28 | 0.1 | 0.16 | 1.08 | 1.11 | 1.69 | 2.13 |
| 47 | 0.23 | 0.08 | 0.51 | 1.05 | 1.27 | 1.53 | 1.8 |
| 48 | 0.25 | 0.14 | 0.38 | 1.16 | 1.23 | 1.6 | 1.99 |
| 49 | 0.2 | 0.13 | 0.43 | 1.15 | 0.8 | 1.62 | 2 |
| 50 | 0.23 | 0.11 | 0.29 | 0.92 | 1.14 | 1.47 | 2.28 |
| Average | 0.234 | 0.124 | 0.405 | 1.074 | 1.119 | 1.506 | 2.046 |
| SD | 0.064 | 0.032 | 0.316 | 0.130 | 0.194 | 0.236 | 0.184 |

Table B5 Measured values of PLA-PEO bicomponent fiber segments electrospun at, $F_{PLA}$=0.5 ml/hr, $F_{PEO}$=0.5 ml/hr, d=20 cm, [PLA 8% (CHCl3:DMF/75:25) / PEO 3% $CHCl_3$] and [19% PLA ($CHCl_3$:DMF/00:100) / 3% PEO ($CHCl_3$)] with various applied voltage.

| Solvent system | 8% PLA ($CHCl_3$:DMF/75:25) / PEO 3% $CHCl_3$ | | | | 19%PLA ($CHCl_3$:DMF/00:100) / PEO 3% $CHCl_3$ | | | |
|---|---|---|---|---|---|---|---|---|
| Fiber Segment No. | Fiber size (µm) | | | | | | | |
| | Applied voltage (kV) | | | | | | | |
| | 10 | 15 | 20 | 25 | 10 | 15 | 20 | 25 |
| 1 | 2.32 | 2.71 | 1.8 | 3.06 | 0.71 | 0.85 | 0.7 | 0.45 |
| 2 | 3.44 | 2.22 | 1.93 | 2.4 | 0.72 | 0.98 | 0.9 | 0.26 |
| 3 | 2.68 | 2.05 | 2.29 | 1.82 | 0.57 | 1.26 | 0.96 | 1.07 |
| 4 | 3.29 | 1.74 | 2.6 | 2.58 | 0.58 | 0.98 | 1.2 | 1.2 |
| 5 | 3.22 | 2.27 | 2.27 | 2.04 | 0.7 | 1.21 | 0.9 | 1.25 |
| 6 | 1.97 | 1.57 | 2.29 | 1.8 | 0.86 | 1.35 | 1.37 | 1.26 |
| 7 | 2.6 | 1.62 | 2.33 | 2.35 | 0.9 | 0.92 | 0.9 | 1.1 |
| 8 | 2.49 | 2.81 | 1.82 | 3.04 | 1.01 | 1.14 | 1.1 | 1 |
| 9 | 1.96 | 2.27 | 2.27 | 2.68 | 1.09 | 1.27 | 1.17 | 1.17 |
| 10 | 2.15 | 2.59 | 2.24 | 1.69 | 0.96 | 1.06 | 0.93 | 0.93 |
| 11 | 2.32 | 2.2 | 2.16 | 2.26 | 0.75 | 1.25 | 1.05 | 1.09 |
| 12 | 3.12 | 1.79 | 3.04 | 2.26 | 1.21 | 0.96 | 1 | 1.14 |
| 13 | 2.6 | 2.05 | 2.18 | 1.92 | 0.82 | 1.08 | 1.27 | 1.2 |
| 14 | 3.12 | 2.23 | 1.8 | 2.6 | 0.86 | 0.88 | 1.17 | 0.86 |
| 15 | 2.26 | 2.7 | 3.22 | 1.82 | 1.07 | 1.01 | 0.93 | 1.15 |
| 16 | 2.54 | 1.41 | 1.69 | 2.15 | 0.6 | 0.82 | 0.92 | 1.2 |
| 17 | 3.28 | 2.1 | 1.82 | 2.04 | 1 | 1.11 | 0.95 | 1.23 |
| 18 | 2.14 | 1.91 | 2.29 | 2.51 | 0.98 | 1.01 | 0.9 | 1.22 |
| 19 | 2.56 | 2.9 | 1.61 | 2.72 | 1.06 | 1.2 | 1.02 | 1.12 |
| 20 | 2.73 | 2.6 | 2.66 | 3.07 | 1.1 | 1.14 | 0.99 | 1.17 |
| 21 | 2.96 | 2.49 | 2.95 | 2.64 | 0.95 | 1.1 | 1.03 | 1.05 |
| 22 | 2.7 | 2.05 | 2.38 | 1.4 | 1 | 1.07 | 1.02 | 1.29 |
| 23 | 2.33 | 1.79 | 2.66 | 2.08 | 0.78 | 1.11 | 1.14 | 1.21 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 24 | 2.95 | 1.83 | 1.79 | 2.02 | 0.78 | 1.21 | 1.07 | 1.28 |
| 25 | 2.51 | 1.89 | 1.86 | 2.82 | 0.96 | 0.92 | 0.96 | 1.15 |
| 26 | 2.93 | 2.97 | 2.38 | 2.93 | 1.41 | 0.85 | 1.25 | 1.15 |
| 27 | 3.55 | 2.01 | 1.93 | 3.37 | 1.06 | 1.08 | 1.03 | 1.07 |
| 28 | 2.6 | 2.05 | 1.9 | 2.09 | 1.14 | 0.85 | 1.08 | 1.17 |
| 29 | 2.78 | 1.79 | 1.97 | 2.73 | 0.58 | 1.13 | 0.83 | 1.23 |
| 30 | 3.34 | 2.05 | 1.77 | 2.56 | 0.99 | 1.07 | 0.9 | 1.09 |
| 31 | 2.73 | 2.23 | 1.76 | 1.9 | 1.15 | 1.17 | 1.14 | 1.28 |
| 32 | 3.16 | 2.27 | 2.53 | 2.15 | 0.99 | 1.32 | 1.09 | 1.37 |
| 33 | 1.93 | 2.53 | 1.9 | 2.86 | 1.09 | 1.14 | 1.03 | 1.29 |
| 34 | 2.24 | 1.6 | 2.04 | 2.35 | 1.2 | 1 | 1.46 | 1.2 |
| 35 | 2.88 | 2.05 | 2.09 | 1.53 | 0.8 | 1 | 0.85 | 1.2 |
| 36 | 3.21 | 1.83 | 1.43 | 2 | 1.27 | 1.1 | 0.65 | 1.23 |
| 37 | 3.57 | 1.42 | 2.4 | 2.38 | 1.05 | 1.15 | 1.14 | 1.16 |
| 38 | 2.73 | 2.36 | 1.93 | 2.6 | 0.95 | 1.14 | 1.06 | 1.16 |
| 39 | 3.18 | 2.29 | 2.09 | 2.93 | 1.01 | 1.14 | 0.92 | 1.27 |
| 40 | 2.68 | 3.18 | 2.15 | 1.62 | 1.03 | 0.9 | 0.96 | 1.17 |
| 41 | 2.78 | 2.01 | 2.73 | 2.04 | 1.08 | 1.15 | 1.04 | 1.13 |
| 42 | 2.96 | 2.83 | 2.97 | 2.56 | 0.99 | 0.9 | 1.18 | 1.06 |
| 43 | 2.17 | 2.22 | 2.29 | 3.06 | 0.85 | 1.21 | 0.99 | 1.06 |
| 44 | 2.53 | 1.74 | 2.48 | 2.04 | 1.19 | 1.17 | 0.96 | 1.34 |
| 45 | 3.66 | 2 | 2.24 | 2.08 | 1.05 | 0.99 | 1.05 | 1.07 |
| 46 | 3.12 | 2 | 2.16 | 2.04 | 0.81 | 1.08 | 1.06 | 0.69 |
| 47 | 3.29 | 2.22 | 2.21 | 2.04 | 0.95 | 1.05 | 1.1 | 1.2 |
| 48 | 3.52 | 2.51 | 2.04 | 2.56 | 1 | 1.16 | 0.86 | 1.32 |
| 49 | 2.51 | 2.05 | 2.24 | 2.56 | 0.71 | 1.15 | 1.27 | 1.39 |
| 50 | 2.82 | 2.36 | 1.86 | 2.04 | 0.76 | 0.92 | 1.14 | 1.17 |
| Average | 2.782 | 2.167 | 2.189 | 2.336 | 0.943 | 1.074 | 1.032 | 1.130 |
| SD | 0.455 | 0.403 | 0.384 | 0.453 | 0.188 | 0.130 | 0.152 | 0.203 |

# Appendix C

Raw data of TGA

Table C1: PLA electrospun fiber

Curve Name:

!&Ruttapon_SP1

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 50.0042 | 50 | 100 | 552 | 233.984 | 234 | 98.0713 |
| 23 | 57.6869 | 57.6667 | 100.023 | 575 | 241.659 | 241.667 | 97.2071 |
| 46 | 65.3487 | 65.3333 | 99.9508 | 598 | 249.316 | 249.333 | 95.7728 |
| 69 | 72.9422 | 73 | 99.9105 | 621 | 256.954 | 257 | 93.6502 |
| 92 | 80.6363 | 80.6667 | 99.8689 | 644 | 264.612 | 264.667 | 90.5603 |
| 115 | 88.3437 | 88.3333 | 99.8445 | 667 | 272.221 | 272.333 | 86.0036 |
| 138 | 96.0401 | 96 | 99.7817 | 690 | 279.838 | 280 | 79.7829 |
| 161 | 103.695 | 103.667 | 99.7293 | 713 | 287.453 | 287.667 | 71.4055 |
| 184 | 111.365 | 111.333 | 99.6918 | 736 | 295.062 | 295.333 | 60.4673 |
| 207 | 119.007 | 119 | 99.6405 | 759 | 302.646 | 303 | 46.9934 |
| 230 | 126.675 | 126.667 | 99.5851 | 782 | 310.256 | 310.667 | 30.6555 |
| 253 | 134.303 | 134.333 | 99.553 | 805 | 318.031 | 318.333 | 15.741 |
| 276 | 141.925 | 142 | 99.4885 | 828 | 325.943 | 326 | 9.44652 |
| 299 | 149.547 | 149.667 | 99.4598 | 851 | 333.744 | 333.667 | 8.63832 |
| 322 | 157.256 | 157.333 | 99.4276 | 874 | 341.475 | 341.333 | 8.25766 |
| 345 | 164.941 | 165 | 99.3785 | 897 | 349.157 | 349 | 7.97541 |
| 368 | 172.621 | 172.667 | 99.3388 | 920 | 356.827 | 356.667 | 7.74604 |
| 391 | 180.285 | 180.333 | 99.3263 | 943 | 364.51 | 364.333 | 7.55465 |
| 414 | 187.959 | 188 | 99.2709 | 966 | 372.188 | 372 | 7.32645 |
| 437 | 195.624 | 195.667 | 99.2401 | 989 | 379.851 | 379.667 | 7.08862 |
| 460 | 203.285 | 203.333 | 99.1996 | 1012 | 387.514 | 387.333 | 6.88782 |
| 483 | 210.96 | 211 | 99.0984 | 1035 | 395.169 | 395 | 6.69189 |
| 506 | 218.639 | 218.667 | 98.9412 | 1058 | 402.819 | 402.667 | 6.4918 |
| 529 | 226.314 | 226.333 | 98.6271 | 1081 | 410.492 | 410.333 | 6.29417 |

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 1104 | 418.123 | 418 | 6.13052 | 1748 | 598.942 | 600 | 2.85278 |
| 1127 | 425.763 | 425.667 | 5.98419 | 1771 | 598.968 | 600 | 2.79833 |
| 1150 | 433.421 | 433.333 | 5.81938 | 1794 | 599 | 600 | 2.70553 |
| 1173 | 441.055 | 441 | 5.6663 | 1817 | 599.014 | 600 | 2.65381 |
| 1196 | 448.682 | 448.667 | 5.51829 | 1840 | 599.02 | 600 | 2.57179 |
| 1219 | 456.312 | 456.333 | 5.37278 | 1863 | 599.047 | 600 | 2.51529 |
| 1242 | 463.931 | 464 | 5.22264 | 1886 | 599.055 | 600 | 2.44607 |
| 1265 | 471.554 | 471.667 | 5.06718 | 1909 | 599.064 | 600 | 2.36822 |
| 1288 | 479.182 | 479.333 | 4.90063 | 1932 | 599.099 | 600 | 2.32209 |
| 1311 | 486.812 | 487 | 4.76208 | 1955 | 599.109 | 600 | 2.24268 |
| 1334 | 494.458 | 494.667 | 4.63154 | 1978 | 599.137 | 600 | 2.18983 |
| 1357 | 502.1 | 502.333 | 4.53008 | 2001 | 599.163 | 600 | 2.11703 |
| 1380 | 509.734 | 510 | 4.42832 | 2024 | 599.161 | 600 | 2.08049 |
| 1403 | 517.373 | 517.667 | 4.36364 | 2047 | 599.182 | 600 | 2.00153 |
| 1426 | 525.029 | 525.333 | 4.25642 | 2070 | 599.198 | 600 | 1.96289 |
| 1449 | 532.662 | 533 | 4.19686 | 2093 | 599.216 | 600 | 1.89031 |
| 1472 | 540.32 | 540.667 | 4.08632 | 2116 | 599.221 | 600 | 1.84397 |
| 1495 | 547.961 | 548.333 | 4.01661 | 2139 | 599.25 | 600 | 1.78678 |
| 1518 | 555.601 | 556 | 3.90392 | 2162 | 599.262 | 600 | 1.71981 |
| 1541 | 563.24 | 563.667 | 3.80911 | 2185 | 599.274 | 600 | 1.65216 |
| 1564 | 570.897 | 571.333 | 3.69027 | 2208 | 599.287 | 600 | 1.62474 |
| 1587 | 578.53 | 579 | 3.56035 | 2231 | 599.307 | 600 | 1.5339 |
| 1610 | 586.186 | 586.667 | 3.44522 | | | | |
| 1633 | 593.807 | 594.333 | 3.33758 | | | | |
| 1656 | 599.234 | 600 | 3.22048 | | | | |
| 1679 | 598.848 | 600 | 3.12327 | | | | |
| 1702 | 598.886 | 600 | 3.03679 | | | | |
| 1725 | 598.948 | 600 | 2.95143 | | | | |

Results:

? Onset 273.46 °C

Endset 321.45 °C

Sample:

Ruttapon_SP1, 2.3324 mg

Table C2: PLA:PEO bicomponent filber (flow rate ratio 0.9:0.1 ml/hr:ml/hr)

Curve Name:

!&Ruttapon_sample7

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 49.9438 | 50 | 100 | 552 | 235.151 | 234 | 99.7851 |
| 23 | 57.52 | 57.6667 | 100.014 | 575 | 241.127 | 241.667 | 99.6725 |
| 46 | 65.0781 | 65.3333 | 99.9976 | 598 | 248.415 | 249.333 | 99.7075 |
| 69 | 72.6355 | 73 | 99.9862 | 621 | 256.388 | 257 | 99.6733 |
| 92 | 80.3182 | 80.6667 | 99.9758 | 644 | 264.248 | 264.667 | 99.5895 |
| 115 | 88.0127 | 88.3333 | 99.9696 | 667 | 272.137 | 272.333 | 99.4818 |
| 138 | 95.7445 | 96 | 99.958 | 690 | 279.826 | 280 | 99.325 |
| 161 | 103.405 | 103.667 | 99.946 | 713 | 287.473 | 287.667 | 99.0607 |
| 184 | 111.064 | 111.333 | 99.94 | 736 | 295.069 | 295.333 | 98.5888 |
| 207 | 118.708 | 119 | 99.9204 | 759 | 302.705 | 303 | 97.6753 |
| 230 | 126.358 | 126.667 | 99.9083 | 782 | 310.423 | 310.667 | 95.8816 |
| 253 | 134.01 | 134.333 | 99.8998 | 805 | 318.088 | 318.333 | 92.8428 |
| 276 | 141.609 | 142 | 99.9043 | 828 | 325.578 | 326 | 87.8881 |
| 299 | 149.209 | 149.667 | 99.9002 | 851 | 333.073 | 333.667 | 79.6804 |
| 322 | 156.943 | 157.333 | 99.8895 | 874 | 340.574 | 341.333 | 67.0842 |
| 345 | 164.633 | 165 | 99.8755 | 897 | 348.041 | 349 | 49.9882 |
| 368 | 172.318 | 172.667 | 99.8787 | 920 | 355.582 | 356.667 | 29.9438 |
| 391 | 180.01 | 180.333 | 99.8655 | 943 | 363.402 | 364.333 | 11.8322 |
| 414 | 187.68 | 188 | 99.8595 | 966 | 371.493 | 372 | 3.31976 |
| 437 | 195.347 | 195.667 | 99.8477 | 989 | 379.469 | 379.667 | 2.29574 |
| 460 | 203.02 | 203.333 | 99.8221 | 1012 | 387.256 | 387.333 | 2.13692 |
| 483 | 210.699 | 211 | 99.8112 | 1035 | 394.978 | 395 | 2.01967 |
| 506 | 218.388 | 218.667 | 99.7968 | 1058 | 402.722 | 402.667 | 1.92592 |
| 529 | 226.391 | 226.333 | 99.8165 | 1081 | 410.335 | 410.333 | 1.82546 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1104 | 417.98 | 418 | 1.74252 |
| 1127 | 425.653 | 425.667 | 1.70926 |
| 1150 | 433.313 | 433.333 | 1.649 |
| 1173 | 440.991 | 441 | 1.58095 |
| 1196 | 448.635 | 448.667 | 1.55341 |
| 1219 | 456.271 | 456.333 | 1.50861 |
| 1242 | 463.932 | 464 | 1.44142 |
| 1265 | 471.59 | 471.667 | 1.43843 |
| 1288 | 479.257 | 479.333 | 1.3688 |
| 1311 | 486.904 | 487 | 1.36826 |
| 1334 | 494.553 | 494.667 | 1.2986 |
| 1357 | 502.188 | 502.333 | 1.27396 |
| 1380 | 509.849 | 510 | 1.22794 |
| 1403 | 517.49 | 517.667 | 1.20482 |
| 1426 | 525.153 | 525.333 | 1.15944 |
| 1449 | 532.842 | 533 | 1.15048 |
| 1472 | 540.471 | 540.667 | 1.1227 |
| 1495 | 548.113 | 548.333 | 1.09658 |
| 1518 | 555.758 | 556 | 1.08759 |
| 1541 | 563.411 | 563.667 | 1.08759 |
| 1564 | 571.177 | 571.333 | 1.05302 |
| 1587 | 578.724 | 579 | 1.05251 |
| 1610 | 586.342 | 586.667 | 1.02567 |
| 1633 | 594.002 | 594.333 | 1.01743 |
| 1656 | 599.505 | 600 | 1.0119 |
| 1679 | 599.307 | 600 | 1.0043 |
| 1702 | 599.336 | 600 | 0.98567 |
| 1725 | 599.322 | 600 | 0.98234 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1748 | 599.322 | 600 | 0.98234 |
| 1771 | 599.337 | 600 | 0.94727 |
| 1794 | 599.343 | 600 | 0.94792 |
| 1817 | 599.359 | 600 | 0.93843 |
| 1840 | 599.35 | 600 | 0.94725 |
| 1863 | 599.361 | 600 | 0.91225 |
| 1886 | 599.797 | 600 | 0.912173 |
| 1909 | 599.44 | 600 | 0.902754 |
| 1932 | 599.1 | 600 | 0.877092 |
| 1955 | 599.255 | 600 | 0.894146 |
| 1978 | 599.378 | 600 | 0.878755 |
| 2001 | 599.419 | 600 | 0.87709 |
| 2024 | 599.432 | 600 | 0.87656 |
| 2047 | 599.434 | 600 | 0.842024 |
| 2070 | 599.426 | 600 | 0.842006 |
| 2093 | 599.429 | 600 | 0.807266 |
| 2116 | 599.424 | 600 | 0.806923 |
| 2139 | 599.436 | 600 | 0.812875 |
| 2162 | 599.443 | 600 | 0.806892 |
| 2185 | 599.448 | 600 | 0.806923 |
| 2208 | 599.451 | 600 | 0.781544 |
| 2231 | 599.449 | 600 | 0.771839 |

Results:

Texts:

!&Ruttapon_sample7

Ruttapon_sample7, 2.8503 mg

Sample:

Ruttapon_sample7, 2.8503 mg

Table C3: PLA:PEO bicomponent filber (flow rate ratio 0.75:0.25 ml/hr:ml/hr)

Curve Name:

!&Ruttapon_sample2

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 49.9366 | 50 | 100 | 552 | 235.198 | 234 | 98.6679 |
| 23 | 57.4905 | 57.6667 | 100.002 | 575 | 241.171 | 241.667 | 98.3608 |
| 46 | 65.0556 | 65.3333 | 99.9005 | 598 | 248.466 | 249.333 | 98.3539 |
| 69 | 72.7137 | 73 | 99.8414 | 621 | 256.432 | 257 | 98.1572 |
| 92 | 80.4009 | 80.6667 | 99.7747 | 644 | 264.285 | 264.667 | 97.8242 |
| 115 | 88.0912 | 88.3333 | 99.7053 | 667 | 272.174 | 272.333 | 97.2801 |
| 138 | 95.7668 | 96 | 99.6535 | 690 | 279.857 | 280 | 96.4301 |
| 161 | 103.423 | 103.667 | 99.6031 | 713 | 287.512 | 287.667 | 95.1555 |
| 184 | 111.087 | 111.333 | 99.5462 | 736 | 295.099 | 295.333 | 93.187 |
| 207 | 118.749 | 119 | 99.4889 | 759 | 302.775 | 303 | 90.136 |
| 230 | 126.412 | 126.667 | 99.4198 | 782 | 310.538 | 310.667 | 85.5649 |
| 253 | 134.062 | 134.333 | 99.3791 | 805 | 318.279 | 318.333 | 78.8523 |
| 276 | 141.701 | 142 | 99.3425 | 828 | 325.863 | 326 | 69.0443 |
| 299 | 149.348 | 149.667 | 99.2765 | 851 | 333.481 | 333.667 | 55.4406 |
| 322 | 157.047 | 157.333 | 99.2292 | 874 | 341.124 | 341.333 | 37.4498 |
| 345 | 164.729 | 165 | 99.1759 | 897 | 348.825 | 349 | 17.8409 |
| 368 | 172.418 | 172.667 | 99.1403 | 920 | 356.598 | 356.667 | 5.26019 |
| 391 | 180.076 | 180.333 | 99.1058 | 943 | 364.394 | 364.333 | 3.87305 |
| 414 | 187.748 | 188 | 99.0561 | 966 | 372.124 | 372 | 3.33629 |
| 437 | 195.428 | 195.667 | 98.9792 | 989 | 379.806 | 379.667 | 2.81966 |
| 460 | 203.095 | 203.333 | 98.9134 | 1012 | 387.488 | 387.333 | 2.32929 |
| 483 | 210.767 | 211 | 98.8901 | 1035 | 395.165 | 395 | 1.88149 |
| 506 | 218.445 | 218.667 | 98.7886 | 1058 | 402.899 | 402.667 | 1.42315 |
| 529 | 226.446 | 226.333 | 98.7595 | 1081 | 410.521 | 410.333 | 0.90227 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1104 | 418.168 | 418 | 0.41434 |
| 1127 | 425.836 | 425.667 | 0.10983 |
| 1150 | 433.511 | 433.333 | -0.12737 |
| 1173 | 441.206 | 441 | -0.33872 |
| 1196 | 448.879 | 448.667 | -0.54195 |
| 1219 | 456.543 | 456.333 | -0.76522 |
| 1242 | 464.22 | 464 | -1.02234 |
| 1265 | 471.878 | 471.667 | -1.20635 |
| 1288 | 479.56 | 479.333 | -1.47157 |
| 1311 | 487.212 | 487 | -1.65314 |
| 1334 | 494.852 | 494.667 | -1.89743 |
| 1357 | 502.495 | 502.333 | -2.09006 |
| 1380 | 510.133 | 510 | -2.23944 |
| 1403 | 517.763 | 517.667 | -2.4098 |
| 1426 | 525.388 | 525.333 | -2.50147 |
| 1449 | 533.07 | 533 | -2.51727 |
| 1472 | 540.697 | 540.667 | -2.63791 |
| 1495 | 548.342 | 548.333 | -2.6887 |
| 1518 | 556.001 | 556 | -2.70574 |
| 1541 | 563.675 | 563.667 | -2.70575 |
| 1564 | 571.438 | 571.333 | -2.77182 |
| 1587 | 579.014 | 579 | -2.70598 |
| 1610 | 586.656 | 586.667 | -2.75782 |
| 1633 | 594.34 | 594.333 | -2.77339 |
| 1656 | 599.992 | 600 | -2.76936 |
| 1679 | 600.006 | 600 | -2.74627 |
| 1702 | 599.984 | 600 | -2.77333 |
| 1725 | 599.968 | 600 | -2.77339 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1748 | 599.958 | 600 | -2.77339 |
| 1771 | 599.957 | 600 | -2.77339 |
| 1794 | 599.957 | 600 | -2.83278 |
| 1817 | 599.979 | 600 | -2.79056 |
| 1840 | 599.962 | 600 | -2.77339 |
| 1863 | 599.965 | 600 | -2.77339 |
| 1886 | 600.401 | 600 | -2.77339 |
| 1909 | 600.033 | 600 | -2.8347 |
| 1932 | 599.694 | 600 | -2.84103 |
| 1955 | 599.845 | 600 | -2.8002 |
| 1978 | 599.941 | 600 | -2.77341 |
| 2001 | 599.979 | 600 | -2.77339 |
| 2024 | 599.991 | 600 | -2.77467 |
| 2047 | 599.977 | 600 | -2.77339 |
| 2070 | 599.972 | 600 | -2.78666 |
| 2093 | 599.987 | 600 | -2.84095 |
| 2116 | 599.972 | 600 | -2.84103 |
| 2139 | 599.967 | 600 | -2.82047 |
| 2162 | 599.973 | 600 | -2.77344 |
| 2185 | 599.973 | 600 | -2.77339 |
| 2208 | 599.974 | 600 | -2.81699 |
| 2231 | 599.97 | 600 | -2.84103 |

Results:

Texts:

!&Ruttapon_sample2

Ruttapon_sample2, 1.4783 mg

Sample:

Ruttapon_sample2, 1.4783 mg

Table C4: PLA:PEO bicomponent filber (flow rate ratio 0.5:0.5 ml/hr:ml/hr)

Curve Name:

!&Ruttapon_SP2

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 50.0838 | 50 | 100 | 552 | 234.069 | 234 | 99.0922 |
| 23 | 57.6635 | 57.6667 | 100.029 | 575 | 241.752 | 241.667 | 98.9833 |
| 46 | 65.1567 | 65.3333 | 100.003 | 598 | 249.423 | 249.333 | 98.7639 |
| 69 | 72.843 | 73 | 99.935 | 621 | 257.093 | 257 | 98.4378 |
| 92 | 80.5551 | 80.6667 | 99.9248 | 644 | 264.759 | 264.667 | 98.0104 |
| 115 | 88.2487 | 88.3333 | 99.9083 | 667 | 272.435 | 272.333 | 97.2612 |
| 138 | 95.9039 | 96 | 99.8673 | 690 | 280.097 | 280 | 96.1124 |
| 161 | 103.584 | 103.667 | 99.8242 | 713 | 287.754 | 287.667 | 94.2347 |
| 184 | 111.264 | 111.333 | 99.8097 | 736 | 295.4 | 295.333 | 91.064 |
| 207 | 118.92 | 119 | 99.7437 | 759 | 302.99 | 303 | 85.9606 |
| 230 | 126.593 | 126.667 | 99.6959 | 782 | 310.556 | 310.667 | 77.5769 |
| 253 | 134.243 | 134.333 | 99.6707 | 805 | 318.083 | 318.333 | 63.4895 |
| 276 | 141.878 | 142 | 99.6442 | 828 | 325.651 | 326 | 44.8915 |
| 299 | 149.509 | 149.667 | 99.6083 | 851 | 333.391 | 333.667 | 27.4908 |
| 322 | 157.245 | 157.333 | 99.5743 | 874 | 341.326 | 341.333 | 20.3584 |
| 345 | 164.951 | 165 | 99.567 | 897 | 349.151 | 349 | 19.5916 |
| 368 | 172.636 | 172.667 | 99.5183 | 920 | 356.867 | 356.667 | 19.1989 |
| 391 | 180.314 | 180.333 | 99.5067 | 943 | 364.558 | 364.333 | 18.8727 |
| 414 | 187.987 | 188 | 99.4429 | 966 | 372.241 | 372 | 18.5231 |
| 437 | 195.677 | 195.667 | 99.4549 | 989 | 379.882 | 379.667 | 18.0068 |
| 460 | 203.354 | 203.333 | 99.4108 | 1012 | 387.552 | 387.333 | 17.3111 |
| 483 | 211.019 | 211 | 99.364 | 1035 | 395.228 | 395 | 16.1053 |
| 506 | 218.706 | 218.667 | 99.2756 | 1058 | 402.879 | 402.667 | 13.8581 |
| 529 | 226.383 | 226.333 | 99.2238 | 1081 | 410.548 | 410.333 | 10.4489 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1104 | 418.194 | 418 | 6.75574 |
| 1127 | 425.852 | 425.667 | 4.12447 |
| 1150 | 433.497 | 433.333 | 3.17108 |
| 1173 | 441.143 | 441 | 2.93806 |
| 1196 | 448.77 | 448.667 | 2.79534 |
| 1219 | 456.411 | 456.333 | 2.65983 |
| 1242 | 464.046 | 464 | 2.5007 |
| 1265 | 471.674 | 471.667 | 2.36117 |
| 1288 | 479.288 | 479.333 | 2.21974 |
| 1311 | 486.917 | 487 | 2.12565 |
| 1334 | 494.543 | 494.667 | 2.0371 |
| 1357 | 502.172 | 502.333 | 1.95087 |
| 1380 | 509.786 | 510 | 1.89068 |
| 1403 | 517.405 | 517.667 | 1.87609 |
| 1426 | 525.024 | 525.333 | 1.82472 |
| 1449 | 532.632 | 533 | 1.78796 |
| 1472 | 540.255 | 540.667 | 1.75904 |
| 1495 | 547.883 | 548.333 | 1.72773 |
| 1518 | 555.501 | 556 | 1.7128 |
| 1541 | 563.13 | 563.667 | 1.70125 |
| 1564 | 570.76 | 571.333 | 1.65839 |
| 1587 | 578.376 | 579 | 1.6392 |
| 1610 | 585.998 | 586.667 | 1.60483 |
| 1633 | 593.614 | 594.333 | 1.61201 |
| 1656 | 598.977 | 600 | 1.61852 |
| 1679 | 598.461 | 600 | 1.56907 |
| 1702 | 598.49 | 600 | 1.58919 |
| 1725 | 598.512 | 600 | 1.56431 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1748 | 598.496 | 600 | 1.58357 |
| 1771 | 598.52 | 600 | 1.58707 |
| 1794 | 598.56 | 600 | 1.54068 |
| 1817 | 598.559 | 600 | 1.55228 |
| 1840 | 598.553 | 600 | 1.55476 |
| 1863 | 598.562 | 600 | 1.54119 |
| 1886 | 598.558 | 600 | 1.58472 |
| 1909 | 598.568 | 600 | 1.53991 |
| 1932 | 598.573 | 600 | 1.57713 |
| 1955 | 598.59 | 600 | 1.53950 |
| 1978 | 598.589 | 600 | 1.55244 |
| 2001 | 598.598 | 600 | 1.53950 |
| 2024 | 598.597 | 600 | 1.55759 |
| 2047 | 598.616 | 600 | 1.54034 |
| 2070 | 598.617 | 600 | 1.55304 |
| 2093 | 598.614 | 600 | 1.56082 |
| 2116 | 598.626 | 600 | 1.53976 |
| 2139 | 598.63 | 600 | 1.57201 |
| 2162 | 598.642 | 600 | 1.53980 |
| 2185 | 598.655 | 600 | 1.51538 |
| 2208 | 598.654 | 600 | 1.53948 |
| 2231 | 598.664 | 600 | 1.51057 |

Results:

Onset 294.24 °C

Onset 397.04 °C

Endset 426.19 °C

Sample:

Ruttapon_SP2, 2.0136 mg

Table C5: PLA:PEO bicomponent filber (flow rate ratio 0.25:0.75 ml/hr:ml/hr)

Curve Name:

!&Ruttapon_sample4

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 50.012 | 50 | 100 | 552 | 235.381 | 234 | 98.3552 |
| 23 | 57.5597 | 57.6667 | 99.9837 | 575 | 241.344 | 241.667 | 97.8076 |
| 46 | 64.94 | 65.3333 | 99.9516 | 598 | 248.63 | 249.333 | 97.3722 |
| 69 | 72.6778 | 73 | 99.8913 | 621 | 256.585 | 257 | 96.6333 |
| 92 | 80.429 | 80.6667 | 99.8308 | 644 | 264.453 | 264.667 | 95.6636 |
| 115 | 88.1146 | 88.3333 | 99.7741 | 667 | 272.312 | 272.333 | 94.3668 |
| 138 | 95.8074 | 96 | 99.7142 | 690 | 279.983 | 280 | 92.5753 |
| 161 | 103.491 | 103.667 | 99.6804 | 713 | 287.62 | 287.667 | 90.0283 |
| 184 | 111.176 | 111.333 | 99.6249 | 736 | 295.177 | 295.333 | 86.4609 |
| 207 | 118.842 | 119 | 99.5951 | 759 | 302.794 | 303 | 81.4002 |
| 230 | 126.523 | 126.667 | 99.5389 | 782 | 310.492 | 310.667 | 74.532 |
| 253 | 134.205 | 134.333 | 99.4796 | 805 | 318.164 | 318.333 | 65.3407 |
| 276 | 141.843 | 142 | 99.4357 | 828 | 325.651 | 326 | 53.2615 |
| 299 | 149.495 | 149.667 | 99.4153 | 851 | 333.277 | 333.667 | 39.2679 |
| 322 | 157.199 | 157.333 | 99.3537 | 874 | 341.178 | 341.333 | 31.4518 |
| 345 | 164.886 | 165 | 99.3092 | 897 | 349.011 | 349 | 30.493 |
| 368 | 172.578 | 172.667 | 99.255 | 920 | 356.741 | 356.667 | 30.1163 |
| 391 | 180.246 | 180.333 | 99.2185 | 943 | 364.443 | 364.333 | 29.7887 |
| 414 | 187.927 | 188 | 99.1739 | 966 | 372.122 | 372 | 29.3512 |
| 437 | 195.618 | 195.667 | 99.1143 | 989 | 379.795 | 379.667 | 28.6961 |
| 460 | 203.282 | 203.333 | 99.0292 | 1012 | 387.482 | 387.333 | 27.612 |
| 483 | 210.952 | 211 | 98.9639 | 1035 | 395.169 | 395 | 25.7489 |
| 506 | 218.631 | 218.667 | 98.8366 | 1058 | 402.883 | 402.667 | 22.5678 |
| 529 | 226.64 | 226.333 | 98.67 | 1081 | 410.478 | 410.333 | 17.605 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1104 | 418.126 | 418 | 11.3651 |
| 1127 | 425.818 | 425.667 | 5.70838 |
| 1150 | 433.548 | 433.333 | 2.33245 |
| 1173 | 441.264 | 441 | 1.40333 |
| 1196 | 448.932 | 448.667 | 1.21308 |
| 1219 | 456.571 | 456.333 | 1.12198 |
| 1242 | 464.223 | 464 | 1.05563 |
| 1265 | 471.86 | 471.667 | 1.02179 |
| 1288 | 479.511 | 479.333 | 0.92676 |
| 1311 | 487.134 | 487 | 0.91907 |
| 1334 | 494.758 | 494.667 | 0.83182 |
| 1357 | 502.39 | 502.333 | 0.79338 |
| 1380 | 510.009 | 510 | 0.77851 |
| 1403 | 517.653 | 517.667 | 0.74643 |
| 1426 | 525.279 | 525.333 | 0.71069 |
| 1449 | 532.967 | 533 | 0.67097 |
| 1472 | 540.577 | 540.667 | 0.63260 |
| 1495 | 548.207 | 548.333 | 0.59614 |
| 1518 | 555.841 | 556 | 0.58389 |
| 1541 | 563.487 | 563.667 | 0.58388 |
| 1564 | 571.23 | 571.333 | 0.53631 |
| 1587 | 578.782 | 579 | 0.53522 |
| 1610 | 586.385 | 586.667 | 0.49777 |
| 1633 | 594.053 | 594.333 | 0.48657 |
| 1656 | 599.56 | 600 | 0.48432 |
| 1679 | 599.33 | 600 | 0.46828 |
| 1702 | 599.347 | 600 | 0.43810 |
| 1725 | 599.343 | 600 | 0.40246 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1748 | 599.356 | 600 | 0.389250 |
| 1771 | 599.378 | 600 | 0.340710 |
| 1794 | 599.389 | 600 | 0.322460 |
| 1817 | 599.413 | 600 | 0.328360 |
| 1840 | 599.425 | 600 | 0.329180 |
| 1863 | 599.44 | 600 | 0.291956 |
| 1886 | 599.89 | 600 | 0.286195 |
| 1909 | 599.527 | 600 | 0.243288 |
| 1932 | 599.194 | 600 | 0.243282 |
| 1955 | 599.346 | 600 | 0.218311 |
| 1978 | 599.463 | 600 | 0.243264 |
| 2001 | 599.513 | 600 | 0.194641 |
| 2024 | 599.537 | 600 | 0.193891 |
| 2047 | 599.525 | 600 | 0.145987 |
| 2070 | 599.525 | 600 | 0.129047 |
| 2093 | 599.54 | 600 | 0.097315 |
| 2116 | 599.547 | 600 | 0.050993 |
| 2139 | 599.554 | 600 | 0.063019 |
| 2162 | 599.572 | 600 | 0.053243 |
| 2185 | 599.564 | 600 | 0.048657 |
| 2208 | 599.566 | 600 | 0.000112 |
| 2231 | 599.579 | 600 | 0.000004 |

Results:

Texts:

!&Ruttapon_sample4

Ruttapon_sample4, 2.0552 mg

Sample:

Ruttapon_sample4, 2.0552 mg

Table C6: PLA:PEO bicomponent filber (flow rate ratio 0.1:0.9 ml/hr:ml/hr)

Curve Name:

!&Ruttapon_sample8

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 50.1986 | 50 | 100 | 552 | 235.699 | 234 | 98.8574 |
| 23 | 57.6263 | 57.6667 | 100.05 | 575 | 241.668 | 241.667 | 98.1787 |
| 46 | 64.8288 | 65.3333 | 100.071 | 598 | 248.959 | 249.333 | 97.4497 |
| 69 | 72.3679 | 73 | 100.064 | 621 | 256.896 | 257 | 96.3933 |
| 92 | 80.248 | 80.6667 | 100.031 | 644 | 264.767 | 264.667 | 94.9376 |
| 115 | 88.0358 | 88.3333 | 100.009 | 667 | 272.615 | 272.333 | 93.0247 |
| 138 | 95.8051 | 96 | 99.9787 | 690 | 280.284 | 280 | 90.4289 |
| 161 | 103.537 | 103.667 | 99.972 | 713 | 287.913 | 287.667 | 87.1086 |
| 184 | 111.261 | 111.333 | 99.9578 | 736 | 295.487 | 295.333 | 83.2732 |
| 207 | 118.985 | 119 | 99.9307 | 759 | 303.145 | 303 | 79.1321 |
| 230 | 126.691 | 126.667 | 99.9095 | 782 | 310.901 | 310.667 | 74.8733 |
| 253 | 134.395 | 134.333 | 99.8916 | 805 | 318.636 | 318.333 | 70.9034 |
| 276 | 142.062 | 142 | 99.8904 | 828 | 326.244 | 326 | 67.4815 |
| 299 | 149.734 | 149.667 | 99.8622 | 851 | 333.942 | 333.667 | 64.7429 |
| 322 | 157.453 | 157.333 | 99.8554 | 874 | 341.674 | 341.333 | 63.1617 |
| 345 | 165.137 | 165 | 99.8244 | 897 | 349.394 | 349 | 62.4316 |
| 368 | 172.846 | 172.667 | 99.7914 | 920 | 357.076 | 356.667 | 61.9412 |
| 391 | 180.525 | 180.333 | 99.7627 | 943 | 364.767 | 364.333 | 61.4169 |
| 414 | 188.206 | 188 | 99.738 | 966 | 372.423 | 372 | 60.6222 |
| 437 | 195.895 | 195.667 | 99.6804 | 989 | 380.082 | 379.667 | 59.4649 |
| 460 | 203.571 | 203.333 | 99.6131 | 1012 | 387.74 | 387.333 | 57.5736 |
| 483 | 211.263 | 211 | 99.5615 | 1035 | 395.397 | 395 | 54.4935 |
| 506 | 218.95 | 218.667 | 99.4245 | 1058 | 403.108 | 402.667 | 49.2686 |
| 529 | 226.952 | 226.333 | 99.2488 | 1081 | 410.643 | 410.333 | 40.4685 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1104 | 418.209 | 418 | 27.4044 |
| 1127 | 425.907 | 425.667 | 14.7874 |
| 1150 | 433.657 | 433.333 | 7.0306 |
| 1173 | 441.436 | 441 | 4.33298 |
| 1196 | 449.128 | 448.667 | 4.03063 |
| 1219 | 456.797 | 456.333 | 3.9467 |
| 1242 | 464.465 | 464 | 3.88467 |
| 1265 | 472.135 | 471.667 | 3.84423 |
| 1288 | 479.827 | 479.333 | 3.8066 |
| 1311 | 487.486 | 487 | 3.7675 |
| 1334 | 495.153 | 494.667 | 3.72934 |
| 1357 | 502.817 | 502.333 | 3.70216 |
| 1380 | 510.501 | 510 | 3.69042 |
| 1403 | 518.179 | 517.667 | 3.66507 |
| 1426 | 525.846 | 525.333 | 3.65197 |
| 1449 | 533.556 | 533 | 3.68217 |
| 1472 | 541.201 | 540.667 | 3.65202 |
| 1495 | 548.874 | 548.333 | 3.62322 |
| 1518 | 556.535 | 556 | 3.63278 |
| 1541 | 564.219 | 563.667 | 3.65197 |
| 1564 | 571.972 | 571.333 | 3.6197 |
| 1587 | 579.542 | 579 | 3.65197 |
| 1610 | 587.161 | 586.667 | 3.62238 |
| 1633 | 594.823 | 594.333 | 3.64915 |
| 1656 | 600.353 | 600 | 3.64467 |
| 1679 | 599.974 | 600 | 3.63763 |
| 1702 | 599.955 | 600 | 3.65196 |
| 1725 | 599.917 | 600 | 3.65197 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1748 | 599.862 | 600 | 3.65197 |
| 1771 | 599.825 | 600 | 3.65197 |
| 1794 | 599.808 | 600 | 3.65270 |
| 1817 | 599.774 | 600 | 3.68065 |
| 1840 | 599.727 | 600 | 3.69041 |
| 1863 | 599.704 | 600 | 3.69041 |
| 1886 | 600.099 | 600 | 3.69041 |
| 1909 | 599.692 | 600 | 3.69041 |
| 1932 | 599.304 | 600 | 3.69041 |
| 1955 | 599.428 | 600 | 3.70887 |
| 1978 | 599.5 | 600 | 3.73305 |
| 2001 | 599.517 | 600 | 3.72886 |
| 2024 | 599.497 | 600 | 3.72812 |
| 2047 | 599.459 | 600 | 3.72885 |
| 2070 | 599.427 | 600 | 3.73111 |
| 2093 | 599.414 | 600 | 3.72885 |
| 2116 | 599.383 | 600 | 3.72885 |
| 2139 | 599.364 | 600 | 3.74054 |
| 2162 | 599.378 | 600 | 3.76727 |
| 2185 | 599.358 | 600 | 3.7673 |
| 2208 | 599.357 | 600 | 3.7673 |
| 2231 | 599.354 | 600 | 3.7673 |

Results:

Texts:

!&Ruttapon_sample8

Ruttapon_sample8, 2.6013 mg

Sample:

Ruttapon_sample8, 2.6013 mg

Table C7: PEO bicomponent filber

Curve Name:

!&Ruttapon_SP3

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 50.0818 | 50 | 100 | 552 | 233.973 | 234 | 100.014 |
| 23 | 57.6656 | 57.6667 | 100.059 | 575 | 241.656 | 241.667 | 99.9972 |
| 46 | 64.9434 | 65.3333 | 100.081 | 598 | 249.314 | 249.333 | 100.008 |
| 69 | 72.0438 | 73 | 100.14 | 621 | 256.979 | 257 | 99.9768 |
| 92 | 79.9099 | 80.6667 | 100.142 | 644 | 264.665 | 264.667 | 99.9762 |
| 115 | 87.8626 | 88.3333 | 99.9631 | 667 | 272.335 | 272.333 | 99.9412 |
| 138 | 95.6782 | 96 | 100.057 | 690 | 280.001 | 280 | 99.9332 |
| 161 | 103.425 | 103.667 | 100.049 | 713 | 287.684 | 287.667 | 99.906 |
| 184 | 111.174 | 111.333 | 100.076 | 736 | 295.369 | 295.333 | 99.8981 |
| 207 | 118.873 | 119 | 100.052 | 759 | 303.012 | 303 | 99.8708 |
| 230 | 126.56 | 126.667 | 100.058 | 782 | 310.689 | 310.667 | 99.8582 |
| 253 | 134.242 | 134.333 | 100.051 | 805 | 318.352 | 318.333 | 99.8065 |
| 276 | 141.906 | 142 | 100.054 | 828 | 326.008 | 326 | 99.7795 |
| 299 | 149.578 | 149.667 | 100.053 | 851 | 333.677 | 333.667 | 99.704 |
| 322 | 157.262 | 157.333 | 100.049 | 874 | 341.335 | 341.333 | 99.5956 |
| 345 | 164.925 | 165 | 100.044 | 897 | 349.013 | 349 | 99.3937 |
| 368 | 172.593 | 172.667 | 100.029 | 920 | 356.676 | 356.667 | 98.9875 |
| 391 | 180.254 | 180.333 | 100.036 | 943 | 364.333 | 364.333 | 98.2823 |
| 414 | 187.926 | 188 | 100.026 | 966 | 372.017 | 372 | 97.183 |
| 437 | 195.613 | 195.667 | 100.037 | 989 | 379.663 | 379.667 | 95.4639 |
| 460 | 203.277 | 203.333 | 100.039 | 1012 | 387.331 | 387.333 | 92.7452 |
| 483 | 210.949 | 211 | 100.04 | 1035 | 394.997 | 395 | 88.4368 |
| 506 | 218.634 | 218.667 | 100.016 | 1058 | 402.656 | 402.667 | 81.4644 |
| 529 | 226.309 | 226.333 | 100.012 | 1081 | 410.27 | 410.333 | 69.2979 |

| Index | Ts | Tr | Value |
|---|---|---|---|
| | [°C] | [°C] | [%] |
| 1104 | 417.862 | 418 | 51.2574 |
| 1127 | 425.506 | 425.667 | 30.679 |
| 1150 | 433.215 | 433.333 | 13.6301 |
| 1173 | 440.994 | 441 | 5.96062 |
| 1196 | 448.71 | 448.667 | 5.08078 |
| 1219 | 456.384 | 456.333 | 4.99484 |
| 1242 | 464.042 | 464 | 4.92801 |
| 1265 | 471.684 | 471.667 | 4.8743 |
| 1288 | 479.327 | 479.333 | 4.82302 |
| 1311 | 486.972 | 487 | 4.78884 |
| 1334 | 494.622 | 494.667 | 4.7544 |
| 1357 | 502.257 | 502.333 | 4.7524 |
| 1380 | 509.901 | 510 | 4.71743 |
| 1403 | 517.547 | 517.667 | 4.71719 |
| 1426 | 525.184 | 525.333 | 4.71719 |
| 1449 | 532.822 | 533 | 4.70937 |
| 1472 | 540.456 | 540.667 | 4.66896 |
| 1495 | 548.09 | 548.333 | 4.67486 |
| 1518 | 555.724 | 556 | 4.66403 |
| 1541 | 563.343 | 563.667 | 4.67332 |
| 1564 | 570.976 | 571.333 | 4.6293 |
| 1587 | 578.595 | 579 | 4.61205 |
| 1610 | 586.22 | 586.667 | 4.61867 |
| 1633 | 593.816 | 594.333 | 4.6273 |
| 1656 | 599.21 | 600 | 4.62824 |
| 1679 | 598.719 | 600 | 4.6225 |
| 1702 | 598.721 | 600 | 4.61161 |
| 1725 | 598.738 | 600 | 4.62809 |

| Index | Ts | Tr | Value |
|---|---|---|---|
| | [°C] | [°C] | [%] |
| 1748 | 598.704 | 600 | 4.61154 |
| 1771 | 598.715 | 600 | 4.64478 |
| 1794 | 598.734 | 600 | 4.61576 |
| 1817 | 598.729 | 600 | 4.64672 |
| 1840 | 598.731 | 600 | 4.62591 |
| 1863 | 598.734 | 600 | 4.64677 |
| 1886 | 598.713 | 600 | 4.6459 |
| 1909 | 598.714 | 600 | 4.64679 |
| 1932 | 598.719 | 600 | 4.6701 |
| 1955 | 598.721 | 600 | 4.64679 |
| 1978 | 598.719 | 600 | 4.68163 |
| 2001 | 598.725 | 600 | 4.67808 |
| 2024 | 598.715 | 600 | 4.68735 |
| 2047 | 598.719 | 600 | 4.68274 |
| 2070 | 598.732 | 600 | 4.71316 |
| 2093 | 598.727 | 600 | 4.69673 |
| 2116 | 598.741 | 600 | 4.71717 |
| 2139 | 598.745 | 600 | 4.72813 |
| 2162 | 598.744 | 600 | 4.7172 |
| 2185 | 598.751 | 600 | 4.72698 |
| 2208 | 598.756 | 600 | 4.75238 |
| 2231 | 598.762 | 600 | 4.73649 |

Results:

? Onset 398.88 °C

Endset 435.49 °C

Texts:

!&Ruttapon_SP3

Ruttapon_SP3, 2.8407 mg

Table C8: PLA:PEO bicomponent filber (PEO phase removal.

Curve Name: !&Ruttapon_SP3

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 50.0816 | 50 | 100 | 575 | 241.799 | 241.667 | 99.1911 |
| 23 | 57.7427 | 57.6667 | 100.044 | 598 | 249.469 | 249.333 | 98.898 |
| 46 | 65.3473 | 65.3333 | 100.029 | 621 | 257.125 | 257 | 98.5421 |
| 69 | 72.9592 | 73 | 100.017 | 644 | 264.795 | 264.667 | 98.1386 |
| 92 | 80.629 | 80.6667 | 100.015 | 667 | 272.472 | 272.333 | 97.6011 |
| 115 | 88.3627 | 88.3333 | 100.027 | 690 | 280.122 | 280 | 96.9185 |
| 138 | 96.0917 | 96 | 100.015 | 713 | 287.785 | 287.667 | 95.9596 |
| 161 | 103.747 | 103.667 | 100.011 | 736 | 295.44 | 295.333 | 94.5344 |
| 184 | 111.403 | 111.333 | 100.032 | 759 | 303.048 | 303 | 92.1929 |
| 207 | 119.05 | 119 | 100.011 | 782 | 310.633 | 310.667 | 88.3789 |
| 230 | 126.697 | 126.667 | 100.005 | 805 | 318.127 | 318.333 | 82.2978 |
| 253 | 134.339 | 134.333 | 100.003 | 828 | 325.561 | 326 | 72.2214 |
| 276 | 141.914 | 142 | 99.9953 | 851 | 332.917 | 333.667 | 56.7073 |
| 299 | 149.507 | 149.667 | 99.9865 | 874 | 340.302 | 341.333 | 36.2938 |
| 322 | 157.278 | 157.333 | 99.9836 | 897 | 348.065 | 349 | 16.4619 |
| 345 | 164.995 | 165 | 99.9794 | 920 | 356.359 | 356.667 | 8.49994 |
| 368 | 172.691 | 172.667 | 99.9678 | 943 | 364.422 | 364.333 | 7.3179 |
| 391 | 180.375 | 180.333 | 99.9701 | 966 | 372.261 | 372 | 6.91524 |
| 414 | 188.052 | 188 | 99.9377 | 989 | 379.97 | 379.667 | 6.63357 |
| 437 | 195.738 | 195.667 | 99.9181 | 1012 | 387.651 | 387.333 | 6.40851 |
| 460 | 203.415 | 203.333 | 99.8873 | 1035 | 395.305 | 395 | 6.17533 |
| 483 | 211.089 | 211 | 99.83 | 1058 | 402.964 | 402.667 | 5.89047 |
| 506 | 218.772 | 218.667 | 99.7522 | 1081 | 410.637 | 410.333 | 5.57151 |
| 529 | 226.441 | 226.333 | 99.6201 | 1104 | 418.265 | 418 | 5.26412 |
| 552 | 234.111 | 234 | 99.4281 | 1127 | 425.907 | 425.667 | 5.01764 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1150 | 433.567 | 433.333 | 4.83601 |
| 1173 | 441.209 | 441 | 4.6909 |
| 1196 | 448.862 | 448.667 | 4.58086 |
| 1219 | 456.507 | 456.333 | 4.4671 |
| 1242 | 464.146 | 464 | 4.35691 |
| 1265 | 471.789 | 471.667 | 4.23836 |
| 1288 | 479.438 | 479.333 | 4.12983 |
| 1311 | 487.089 | 487 | 4.05356 |
| 1334 | 494.753 | 494.667 | 3.9964 |
| 1357 | 502.407 | 502.333 | 3.96557 |
| 1380 | 510.064 | 510 | 3.93866 |
| 1403 | 517.693 | 517.667 | 3.91113 |
| 1426 | 525.343 | 525.333 | 3.88376 |
| 1449 | 532.964 | 533 | 3.87714 |
| 1472 | 540.621 | 540.667 | 3.84584 |
| 1495 | 548.241 | 548.333 | 3.82317 |
| 1518 | 555.886 | 556 | 3.81425 |
| 1541 | 563.518 | 563.667 | 3.82138 |
| 1564 | 571.151 | 571.333 | 3.79815 |
| 1587 | 578.755 | 579 | 3.77374 |
| 1610 | 586.341 | 586.667 | 3.77883 |
| 1633 | 593.931 | 594.333 | 3.78609 |
| 1656 | 599.275 | 600 | 3.77664 |
| 1679 | 598.618 | 600 | 3.76166 |
| 1702 | 598.607 | 600 | 3.77339 |
| 1725 | 598.622 | 600 | 3.76415 |
| 1748 | 598.561 | 600 | 3.77338 |
| 1771 | 598.535 | 600 | 3.77262 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1794 | 598.529 | 600 | 3.77395 |
| 1817 | 598.504 | 600 | 3.80086 |
| 1840 | 598.476 | 600 | 3.78117 |
| 1863 | 598.469 | 600 | 3.80094 |
| 1886 | 598.449 | 600 | 3.8258 |
| 1909 | 598.435 | 600 | 3.80099 |
| 1932 | 598.442 | 600 | 3.82529 |
| 1955 | 598.437 | 600 | 3.82232 |
| 1978 | 598.441 | 600 | 3.8282 |
| 2001 | 598.453 | 600 | 3.82849 |
| 2024 | 598.432 | 600 | 3.8601 |
| 2047 | 598.438 | 600 | 3.83252 |
| 2070 | 598.431 | 600 | 3.85594 |
| 2093 | 598.434 | 600 | 3.86782 |
| 2116 | 598.437 | 600 | 3.88051 |
| 2139 | 598.445 | 600 | 3.87724 |
| 2162 | 598.43 | 600 | 3.88358 |
| 2185 | 598.453 | 600 | 3.89191 |
| 2208 | 598.446 | 600 | 3.91036 |
| 2231 | 598.443 | 600 | 3.8836 |

Results:

? Onset 315.12 °C

Endset 353.23 °C

Texts:

!&Ruttapon_SP3

Ruttapon_SP3, 3.6307 mg

Sample:

Ruttapon_SP3, 3.6307 mg

Table C9: PLA:PEO bicomponent filber (Porous surface system before PEO phase removal)

Curve Name:

!&Ruttapon_SP5

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 50.1447 | 50 | 100 | 552 | 234.303 | 234 | 99.2252 |
| 23 | 57.8578 | 57.6667 | 100.081 | 575 | 241.98 | 241.667 | 98.7309 |
| 46 | 65.3837 | 65.3333 | 100.106 | 598 | 249.649 | 249.333 | 98.0999 |
| 69 | 73.1021 | 73 | 100.112 | 621 | 257.3 | 257 | 97.2996 |
| 92 | 80.8364 | 80.6667 | 100.13 | 644 | 264.966 | 264.667 | 96.3587 |
| 115 | 88.5517 | 88.3333 | 100.15 | 667 | 272.642 | 272.333 | 95.1535 |
| 138 | 96.2181 | 96 | 100.159 | 690 | 280.29 | 280 | 93.7211 |
| 161 | 103.883 | 103.667 | 100.157 | 713 | 287.963 | 287.667 | 91.8907 |
| 184 | 111.571 | 111.333 | 100.188 | 736 | 295.618 | 295.333 | 89.4498 |
| 207 | 119.246 | 119 | 100.156 | 759 | 303.222 | 303 | 85.6925 |
| 230 | 126.916 | 126.667 | 100.174 | 782 | 310.841 | 310.667 | 80.2101 |
| 253 | 134.56 | 134.333 | 100.154 | 805 | 318.414 | 318.333 | 71.7853 |
| 276 | 142.191 | 142 | 100.141 | 828 | 325.981 | 326 | 59.7554 |
| 299 | 149.845 | 149.667 | 100.161 | 851 | 333.564 | 333.667 | 44.6368 |
| 322 | 157.559 | 157.333 | 100.156 | 874 | 341.356 | 341.333 | 32.043 |
| 345 | 165.256 | 165 | 100.15 | 897 | 349.256 | 349 | 29.0313 |
| 368 | 172.94 | 172.667 | 100.131 | 920 | 357.018 | 356.667 | 28.5812 |
| 391 | 180.605 | 180.333 | 100.145 | 943 | 364.72 | 364.333 | 28.2965 |
| 414 | 188.275 | 188 | 100.127 | 966 | 372.405 | 372 | 27.9751 |
| 437 | 195.941 | 195.667 | 100.139 | 989 | 380.06 | 379.667 | 27.4982 |
| 460 | 203.628 | 203.333 | 100.098 | 1012 | 387.713 | 387.333 | 26.7818 |
| 483 | 211.291 | 211 | 100.014 | 1035 | 395.366 | 395 | 25.5008 |
| 506 | 218.977 | 218.667 | 99.8908 | 1058 | 403.015 | 402.667 | 23.1548 |
| 529 | 226.64 | 226.333 | 99.6174 | 1081 | 410.67 | 410.333 | 19.2279 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1104 | 418.302 | 418 | 13.7918 |
| 1127 | 425.947 | 425.667 | 8.25938 |
| 1150 | 433.63 | 433.333 | 4.88029 |
| 1173 | 441.295 | 441 | 4.05088 |
| 1196 | 448.947 | 448.667 | 3.96482 |
| 1219 | 456.597 | 456.333 | 3.90046 |
| 1242 | 464.242 | 464 | 3.84642 |
| 1265 | 471.891 | 471.667 | 3.80125 |
| 1288 | 479.539 | 479.333 | 3.74896 |
| 1311 | 487.191 | 487 | 3.70404 |
| 1334 | 494.837 | 494.667 | 3.70255 |
| 1357 | 502.481 | 502.333 | 3.70255 |
| 1380 | 510.133 | 510 | 3.69741 |
| 1403 | 517.766 | 517.667 | 3.68524 |
| 1426 | 525.4 | 525.333 | 3.69613 |
| 1449 | 533.026 | 533 | 3.6824 |
| 1472 | 540.661 | 540.667 | 3.68542 |
| 1495 | 548.28 | 548.333 | 3.69326 |
| 1518 | 555.911 | 556 | 3.67862 |
| 1541 | 563.519 | 563.667 | 3.69115 |
| 1564 | 571.156 | 571.333 | 3.6738 |
| 1587 | 578.75 | 579 | 3.66398 |
| 1610 | 586.354 | 586.667 | 3.71186 |
| 1633 | 593.942 | 594.333 | 3.72321 |
| 1656 | 599.282 | 600 | 3.72445 |
| 1679 | 598.719 | 600 | 3.71715 |
| 1702 | 598.726 | 600 | 3.74881 |
| 1725 | 598.716 | 600 | 3.74805 |

| Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|
| 1748 | 598.69 | 600 | 3.74877 |
| 1771 | 598.69 | 600 | 3.79248 |
| 1794 | 598.721 | 600 | 3.77853 |
| 1817 | 598.712 | 600 | 3.79503 |
| 1840 | 598.693 | 600 | 3.80871 |
| 1863 | 598.693 | 600 | 3.84137 |
| 1886 | 598.687 | 600 | 3.88319 |
| 1909 | 598.688 | 600 | 3.87549 |
| 1932 | 598.686 | 600 | 3.88203 |
| 1955 | 598.687 | 600 | 3.88768 |
| 1978 | 598.695 | 600 | 3.93348 |
| 2001 | 598.705 | 600 | 3.93396 |
| 2024 | 598.674 | 600 | 3.98716 |
| 2047 | 598.689 | 600 | 3.98123 |
| 2070 | 598.687 | 600 | 3.98259 |
| 2093 | 598.697 | 600 | 3.99963 |
| 2116 | 598.699 | 600 | 4.0265 |
| 2139 | 598.707 | 600 | 4.06193 |
| 2162 | 598.704 | 600 | 4.0728 |
| 2185 | 598.714 | 600 | 4.07539 |
| 2208 | 598.703 | 600 | 4.09176 |
| 2231 | 598.714 | 600 | 4.07284 |

Results:

Texts:

!&Ruttapon_SP5

Ruttapon_SP5, 2.1607 mg

Sample:

Ruttapon_SP5, 2.1607 mg

Table C10: PLA:PEO bicomponent filber (Porous surface system after PEO phase removal)

Curve Name:

!&Ruttapon_sample10

Curve Values:

| Index | Ts [°C] | Tr [°C] | Value [%] | Index | Ts [°C] | Tr [°C] | Value [%] |
|---|---|---|---|---|---|---|---|
| 0 | 49.9804 | 50 | 100 | 552 | 235.279 | 234 | 97.7605 |
| 23 | 57.5695 | 57.6667 | 99.9808 | 575 | 241.256 | 241.667 | 97.3148 |
| 46 | 65.1189 | 65.3333 | 99.8888 | 598 | 248.544 | 249.333 | 97.162 |
| 69 | 72.7848 | 73 | 99.7836 | 621 | 256.509 | 257 | 96.8343 |
| 92 | 80.4573 | 80.6667 | 99.7047 | 644 | 264.372 | 264.667 | 96.4213 |
| 115 | 88.1194 | 88.3333 | 99.6447 | 667 | 272.243 | 272.333 | 95.9137 |
| 138 | 95.819 | 96 | 99.547 | 690 | 279.918 | 280 | 95.2753 |
| 161 | 103.512 | 103.667 | 99.4978 | 713 | 287.571 | 287.667 | 94.3965 |
| 184 | 111.18 | 111.333 | 99.4177 | 736 | 295.156 | 295.333 | 93.1289 |
| 207 | 118.831 | 119 | 99.3744 | 759 | 302.816 | 303 | 91.1546 |
| 230 | 126.489 | 126.667 | 99.2878 | 782 | 310.526 | 310.667 | 87.7671 |
| 253 | 134.15 | 134.333 | 99.2058 | 805 | 318.224 | 318.333 | 82.7759 |
| 276 | 141.771 | 142 | 99.1455 | 828 | 325.731 | 326 | 75.3742 |
| 299 | 149.443 | 149.667 | 99.0758 | 851 | 333.268 | 333.667 | 64.3472 |
| 322 | 157.148 | 157.333 | 98.9987 | 874 | 340.857 | 341.333 | 48.6947 |
| 345 | 164.819 | 165 | 98.885 | 897 | 348.458 | 349 | 30.2388 |
| 368 | 172.508 | 172.667 | 98.8249 | 920 | 356.223 | 356.667 | 14.8092 |
| 391 | 180.162 | 180.333 | 98.7066 | 943 | 364.137 | 364.333 | 7.84515 |
| 414 | 187.835 | 188 | 98.5946 | 966 | 371.952 | 372 | 5.75681 |
| 437 | 195.505 | 195.667 | 98.5186 | 989 | 379.684 | 379.667 | 4.91098 |
| 460 | 203.181 | 203.333 | 98.3738 | 1012 | 387.394 | 387.333 | 4.35092 |
| 483 | 210.847 | 211 | 98.2828 | 1035 | 395.075 | 395 | 3.8333 |
| 506 | 218.516 | 218.667 | 98.1132 | 1058 | 402.808 | 402.667 | 3.31178 |
| 529 | 226.529 | 226.333 | 98.0087 | 1081 | 410.429 | 410.333 | 2.71766 |

| Index | Ts | Tr | Value |
|---|---|---|---|
| | [°C] | [°C] | [%] |
| 1104 | 418.077 | 418 | 2.22123 |
| 1127 | 425.748 | 425.667 | 1.88027 |
| 1150 | 433.414 | 433.333 | 1.60758 |
| 1173 | 441.079 | 441 | 1.37652 |
| 1196 | 448.731 | 448.667 | 1.20714 |
| 1219 | 456.383 | 456.333 | 1.02394 |
| 1242 | 464.039 | 464 | 0.871237 |
| 1265 | 471.692 | 471.667 | 0.747502 |
| 1288 | 479.372 | 479.333 | 0.611907 |
| 1311 | 487.019 | 487 | 0.502984 |
| 1334 | 494.673 | 494.667 | 0.353159 |
| 1357 | 502.33 | 502.333 | 0.229679 |
| 1380 | 509.993 | 510 | 0.139017 |
| 1403 | 517.649 | 517.667 | 0.028886 |
| 1426 | 525.311 | 525.333 | -0.001879 |
| 1449 | 533.013 | 533 | -0.081946 |
| 1472 | 540.645 | 540.667 | -0.20033 |
| 1495 | 548.293 | 548.333 | -0.29688 |
| 1518 | 555.95 | 556 | -0.33936 |
| 1541 | 563.612 | 563.667 | -0.33939 |
| 1564 | 571.372 | 571.333 | -0.47410 |
| 1587 | 578.942 | 579 | -0.47514 |
| 1610 | 586.568 | 586.667 | -0.59394 |
| 1633 | 594.233 | 594.333 | -0.61090 |
| 1656 | 599.831 | 600 | -0.67112 |
| 1679 | 599.771 | 600 | -0.70345 |
| 1702 | 599.778 | 600 | -0.74663 |
| 1725 | 599.773 | 600 | -0.81446 |

| Index | Ts | Tr | Value |
|---|---|---|---|
| | [°C] | [°C] | [%] |
| 1748 | 599.759 | 600 | -0.88239 |
| 1771 | 599.766 | 600 | -0.95013 |
| 1794 | 599.777 | 600 | -1.01347 |
| 1817 | 599.778 | 600 | -1.0334 |
| 1840 | 599.766 | 600 | -1.05673 |
| 1863 | 599.781 | 600 | -1.08605 |
| 1886 | 600.232 | 600 | -1.15372 |
| 1909 | 599.863 | 600 | -1.20718 |
| 1932 | 599.526 | 600 | -1.22181 |
| 1955 | 599.67 | 600 | -1.25256 |
| 1978 | 599.769 | 600 | -1.26412 |
| 2001 | 599.813 | 600 | -1.28969 |
| 2024 | 599.826 | 600 | -1.35451 |
| 2047 | 599.819 | 600 | -1.35757 |
| 2070 | 599.803 | 600 | -1.42511 |
| 2093 | 599.821 | 600 | -1.42544 |
| 2116 | 599.82 | 600 | -1.49328 |
| 2139 | 599.818 | 600 | -1.47329 |
| 2162 | 599.836 | 600 | -1.49336 |
| 2185 | 599.817 | 600 | -1.49332 |
| 2208 | 599.825 | 600 | -1.5612 |
| 2231 | 599.82 | 600 | -1.59891 |

Results:

Texts:

!&Ruttapon_sample10

Ruttapon_sample10, 1.4732 mg

Sample:

Ruttapon_sample10, 1.4732 mg

# APPENDIX D

Raw data of Air filtration testing

**Calculation of filtration efficiency**

(Refer form 2.5.6 Air filtration testing) In this research, the filtration efficiency was measured by the total particulate matter collection with micro balance analytical 5 digit (Mettler Toledo, Model MS105 from Switzerland), comparison before and after analyzing. The weight of total particle matter was calculated by using the following equation

$$W_c = W_a - W_b$$

$W_c$ = The weight of total particulate matter.

$W_b$ = The weight of air filter media before testing

$W_a$ = The weight of air filter media after testing.

The filtration efficiency percentage was calculated by using the following equation.

$$\%\ \text{Filtration efficiency} = \frac{W_C}{W_T} \times 100$$

$W_T$ = The total weight particulate matter in each air volume

Table D1 The weight of S/M/S before and after air filter testing

| S/M/S | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Volume of air | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection |
| 1 | 1 | 0.08955 | 0.09034 | 0.00082 | 2 | 0.07752 | 0.07912 | 0.00148 | 4 | 0.09162 | 0.09423 | 0.00258 | 8 | 0.08806 | 0.09122 | 0.00316 |
| | | 0.08952 | 0.09036 | | | 0.07750 | 0.07891 | | | 0.09168 | 0.09421 | | | 0.08806 | 0.09123 | |
| | | 0.08951 | 0.09033 | | | 0.07748 | 0.07890 | | | 0.09161 | 0.09421 | | | 0.08805 | 0.09121 | |
| | | 0.08953 | 0.09034 | | | 0.07750 | 0.07898 | | | 0.09164 | 0.09422 | | | 0.08806 | 0.09122 | |
| 2 | | 0.09144 | 0.09277 | 0.00130 | | 0.08956 | 0.09121 | 0.00160 | | 0.07788 | 0.07993 | 0.00208 | | 0.08292 | 0.08699 | 0.00406 |
| | | 0.09146 | 0.09271 | | | 0.08957 | 0.09120 | | | 0.07783 | 0.07994 | | | 0.08297 | 0.08699 | |
| | | 0.09140 | 0.09271 | | | 0.08957 | 0.09110 | | | 0.07789 | 0.07996 | | | 0.08290 | 0.08698 | |
| | | 0.09143 | 0.09273 | | | 0.08957 | 0.09117 | | | 0.07787 | 0.07994 | | | 0.08293 | 0.08699 | |
| 3 | | 0.08122 | 0.08212 | 0.00091 | | 0.09337 | 0.09482 | 0.00143 | | 0.09014 | 0.09261 | 0.00244 | | 0.08769 | 0.09104 | 0.00333 |
| | | 0.08122 | 0.08214 | | | 0.09338 | 0.09477 | | | 0.09013 | 0.09258 | | | 0.08772 | 0.09101 | |
| | | 0.08122 | 0.08212 | | | 0.09331 | 0.09476 | | | 0.09015 | 0.09256 | | | 0.08774 | 0.09108 | |
| | | 0.08122 | 0.08213 | | | 0.09335 | 0.09478 | | | 0.09014 | 0.09258 | | | 0.08772 | 0.09104 | |

Table D2 The weight of S/M/NF(T1)/S before and after air filter testing

| S/M/NF(T1)/S | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection |
| 1 | 1 | 0.09052 | 0.09252 | 0.00204 | 2 | 0.09172 | 0.09532 | 0.00362 | 4 | 0.0861 | 0.09006 | 0.00397 | 8 | 0.0861 | 0.09151 | 0.00541 |
| | | 0.09051 | 0.09255 | | | 0.09171 | 0.09536 | | | 0.08606 | 0.09006 | | | 0.08606 | 0.09146 | |
| | | 0.09047 | 0.09255 | | | 0.09172 | 0.09534 | | | 0.08608 | 0.09004 | | | 0.08608 | 0.09149 | |
| | | 0.09050 | 0.09254 | | | 0.09172 | 0.09534 | | | 0.08608 | 0.09005 | | | 0.08608 | 0.09149 | |
| 2 | | 0.08803 | 0.09018 | 0.00215 | | 0.08726 | 0.09052 | 0.00328 | | 0.07584 | 0.07989 | 0.00408 | | 0.07584 | 0.08089 | 0.00508 |
| | | 0.08803 | 0.09019 | | | 0.08724 | 0.09054 | | | 0.07583 | 0.07993 | | | 0.07583 | 0.08093 | |
| | | 0.08803 | 0.09016 | | | 0.08726 | 0.09053 | | | 0.07583 | 0.07991 | | | 0.07583 | 0.08091 | |
| | | 0.08803 | 0.09018 | | | 0.08725 | 0.09053 | | | 0.07583 | 0.07991 | | | 0.07583 | 0.08091 | |
| 3 | | 0.08849 | 0.09013 | 0.00165 | | 0.07962 | 0.08363 | 0.00399 | | 0.08404 | 0.08855 | 0.00449 | | 0.08404 | 0.08895 | 0.00489 |
| | | 0.08850 | 0.09015 | | | 0.07965 | 0.08365 | | | 0.08404 | 0.08855 | | | 0.08404 | 0.08895 | |
| | | 0.08845 | 0.09012 | | | 0.07963 | 0.08359 | | | 0.08408 | 0.08854 | | | 0.08408 | 0.08894 | |
| | | 0.08848 | 0.09013 | | | 0.07963 | 0.08362 | | | 0.08405 | 0.08855 | | | 0.08405 | 0.08895 | |

Table D3 The weight of S/M/NF(T2)/S before and after air filter testing

| S/M/NF(T2)/S | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection |
| 1 | 1 | 0.08962 | 0.09238 | 0.00273 | 2 | 0.09639 | 0.10050 | 0.00413 | 4 | 0.09810 | 0.10292 | 0.00480 | 8 | 0.09777 | 0.10388 | 0.00610 |
| | | 0.08964 | 0.09235 | | | 0.09642 | 0.10055 | | | 0.09814 | 0.10291 | | | 0.09775 | 0.10388 | |
| | | 0.08963 | 0.09234 | | | 0.09642 | 0.10058 | | | 0.09810 | 0.10292 | | | 0.09781 | 0.10387 | |
| | | 0.08963 | 0.09236 | | | 0.09641 | 0.10054 | | | 0.09811 | 0.10292 | | | 0.09778 | 0.10388 | |
| 2 | | 0.09986 | 0.10197 | 0.00209 | | 0.09548 | 0.09943 | 0.00391 | | 0.09216 | 0.09727 | 0.00510 | | 0.09770 | 0.10296 | 0.00592 |
| | | 0.09986 | 0.10193 | | | 0.09552 | 0.09943 | | | 0.09217 | 0.09725 | | | 0.09770 | 0.10292 | |
| | | 0.09984 | 0.10193 | | | 0.09552 | 0.09940 | | | 0.09211 | 0.09722 | | | 0.09770 | 0.10497 | |
| | | 0.09985 | 0.10194 | | | 0.09551 | 0.09942 | | | 0.09215 | 0.09725 | | | 0.09770 | 0.10362 | |
| 3 | | 0.08998 | 0.09221 | 0.00222 | | 0.09628 | 0.10042 | 0.00414 | | 0.09159 | 0.09681 | 0.00526 | | 0.09247 | 0.09868 | 0.00624 |
| | | 0.08998 | 0.09221 | | | 0.09629 | 0.10041 | | | 0.09161 | 0.09687 | | | 0.09246 | 0.09871 | |
| | | 0.08998 | 0.09218 | | | 0.09626 | 0.10043 | | | 0.09161 | 0.09691 | | | 0.09244 | 0.09871 | |
| | | 0.08998 | 0.09220 | | | 0.09628 | 0.10042 | | | 0.09160 | 0.09686 | | | 0.09246 | 0.09870 | |

Table D4 The weight of S/M/NF(T3)/S before and after air filter testing

| S/M/NF(T3)/S | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection |
| 1 | 1 | 0.09796 | 0.10017 | 0.00217 | 2 | 0.10209 | 0.10631 | 0.00423 | 4 | 0.09660 | 0.10192 | 0.00533 | 8 | 0.09790 | 0.10416 | 0.00626 |
| | | 0.09801 | 0.10016 | | | 0.10207 | 0.10632 | | | 0.09662 | 0.10194 | | | 0.09786 | 0.10414 | |
| | | 0.09799 | 0.10015 | | | 0.10209 | 0.10630 | | | 0.09657 | 0.10192 | | | 0.09789 | 0.10413 | |
| | | 0.09799 | 0.10016 | | | 0.10208 | 0.10631 | | | 0.09660 | 0.10193 | | | 0.09788 | 0.10414 | |
| 2 | | 0.10498 | 0.10734 | 0.00237 | | 0.10312 | 0.10801 | 0.00485 | | 0.09475 | 0.09974 | 0.00495 | | 0.09433 | 0.10029 | 0.00595 |
| | | 0.10499 | 0.10738 | | | 0.10314 | 0.10798 | | | 0.09482 | 0.09974 | | | 0.09430 | 0.10027 | |
| | | 0.10501 | 0.10738 | | | 0.10314 | 0.10797 | | | 0.09482 | 0.09975 | | | 0.09433 | 0.10024 | |
| | | 0.10499 | 0.10737 | | | 0.10313 | 0.10799 | | | 0.09480 | 0.09974 | | | 0.09432 | 0.10027 | |
| 3 | | 0.10355 | 0.10598 | 0.00238 | | 0.09662 | 0.10140 | 0.00476 | | 0.09212 | 0.09759 | 0.00543 | | 0.09782 | 0.10366 | 0.00580 |
| | | 0.10359 | 0.10598 | | | 0.09662 | 0.10141 | | | 0.09218 | 0.09758 | | | 0.09780 | 0.10352 | |
| | | 0.10363 | 0.10596 | | | 0.09668 | 0.10140 | | | 0.09216 | 0.09757 | | | 0.09780 | 0.10364 | |
| | | 0.10359 | 0.10597 | | | 0.09664 | 0.10140 | | | 0.09215 | 0.09758 | | | 0.09781 | 0.10361 | |

Table D5 The weight of S/M/C-shape PLA/S before and after air filter testing

| S/M/C-shape PLA/S | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection |
| 1 | 1 | 0.09795 | 0.10016 | 0.00217 | 2 | 0.09683 | 0.10031 | 0.00350 | 4 | 0.09227 | 0.09822 | 0.00591 | 8 | 0.09359 | 0.10038 | 0.00678 |
| | | 0.09798 | 0.10013 | | | 0.09684 | 0.10034 | | | 0.09228 | 0.09817 | | | 0.09357 | 0.10037 | |
| | | 0.09797 | 0.10013 | | | 0.09679 | 0.10032 | | | 0.09231 | 0.09819 | | | 0.09358 | 0.10033 | |
| | | 0.09797 | 0.10014 | | | 0.09682 | 0.10032 | | | 0.09229 | 0.09819 | | | 0.09358 | 0.10036 | |
| 2 | | 0.09574 | 0.09777 | 0.00199 | | 0.09683 | 0.10000 | 0.00318 | | 0.09409 | 0.10028 | 0.00616 | | 0.09322 | 0.10030 | 0.00708 |
| | | 0.09576 | 0.09774 | | | 0.09684 | 0.10001 | | | 0.09408 | 0.10022 | | | 0.09320 | 0.10026 | |
| | | 0.09577 | 0.09773 | | | 0.09679 | 0.10000 | | | 0.09409 | 0.10023 | | | 0.09320 | 0.10029 | |
| | | 0.09576 | 0.09775 | | | 0.09682 | 0.10000 | | | 0.09409 | 0.10024 | | | 0.09321 | 0.10028 | |
| 3 | | 0.09440 | 0.09568 | 0.00128 | | 0.09748 | 0.10062 | 0.00320 | | 0.09545 | 0.10069 | 0.00524 | | 0.09359 | 0.09980 | 0.00622 |
| | | 0.09442 | 0.09566 | | | 0.09740 | 0.10065 | | | 0.09545 | 0.10068 | | | 0.09357 | 0.09979 | |
| | | 0.09442 | 0.09573 | | | 0.09745 | 0.10066 | | | 0.09545 | 0.10069 | | | 0.09358 | 0.09980 | |
| | | 0.09441 | 0.09569 | | | 0.09744 | 0.10064 | | | 0.09545 | 0.10069 | | | 0.09358 | 0.09980 | |

Table D6 The weight of S/M/M/S before and after air filter testing

| S/M/M/S | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection | Air volume (Liter) | Weight (g) (before) | Weight (g) (After) | Weight (g) Collection |
| 1 | 1 | 0.11030 | 0.11143 | 0.00116 | 2 | 0.10201 | 0.10385 | 0.00182 | 4 | 0.10390 | 0.10797 | 0.00400 | 8 | 0.10505 | 0.11007 | 0.00500 |
| | | 0.11027 | 0.11146 | | | 0.10201 | 0.10381 | | | 0.10397 | 0.10798 | | | 0.10505 | 0.11004 | |
| | | 0.11031 | 0.11148 | | | 0.10200 | 0.10383 | | | 0.10400 | 0.10791 | | | 0.10505 | 0.11003 | |
| | | 0.11029 | 0.11146 | | | 0.10201 | 0.10383 | | | 0.10396 | 0.10795 | | | 0.10505 | 0.11005 | |
| 2 | | 0.11174 | 0.11311 | 0.00138 | | 0.11226 | 0.11479 | 0.00252 | | 0.11135 | 0.11586 | 0.00450 | | 0.11442 | 0.11981 | 0.00539 |
| | | 0.11177 | 0.11311 | | | 0.11225 | 0.11479 | | | 0.11139 | 0.11588 | | | 0.11448 | 0.11985 | |
| | | 0.11172 | 0.11316 | | | 0.11226 | 0.11474 | | | 0.11139 | 0.11589 | | | 0.11446 | 0.11987 | |
| | | 0.11174 | 0.11313 | | | 0.11226 | 0.11477 | | | 0.11138 | 0.11588 | | | 0.11445 | 0.11984 | |
| 3 | | 0.11292 | 0.11451 | 0.00158 | | 0.10915 | 0.11188 | 0.00273 | | 0.10962 | 0.11368 | 0.00406 | | 0.11029 | 0.11541 | 0.00511 |
| | | 0.11295 | 0.11452 | | | 0.10918 | 0.11189 | | | 0.10962 | 0.11367 | | | 0.11030 | 0.11539 | |
| | | 0.11295 | 0.11452 | | | 0.10915 | 0.11191 | | | 0.10961 | 0.11368 | | | 0.11030 | 0.11543 | |
| | | 0.11294 | 0.11452 | | | 0.10916 | 0.11189 | | | 0.10962 | 0.11368 | | | 0.11030 | 0.11541 | |

Table D7 Filtration efficiency of S/M/S

| S/M/S | | | |
|---|---|---|---|
| Air volume (Liters) | Weight collection(g) | Total weight(g) | %Efficiency |
| 1 | 0.00082 | 0.00344 | 23.76 |
| | 0.00130 | 0.00344 | 37.83 |
| | 0.00091 | 0.00344 | 26.48 |
| | average | | 29.36 |
| | SD | | 7.46 |
| 2 | 0.00148 | 0.00672 | 21.99 |
| | 0.00160 | 0.00672 | 23.87 |
| | 0.00143 | 0.00672 | 21.29 |
| | average | | 22.38 |
| | SD | | 1.33 |
| 4 | 0.00258 | 0.01104 | 23.37 |
| | 0.00208 | 0.01104 | 18.81 |
| | 0.00244 | 0.01104 | 22.13 |
| | average | | 21.44 |
| | SD | | 2.36 |
| 6 | 0.00316 | 0.01527 | 20.72 |
| | 0.00406 | 0.01527 | 26.57 |
| | 0.00333 | 0.01527 | 21.79 |
| | average | | 23.02 |
| | SD | | 3.12 |

Table D8 Filtration efficiency of S/M/NF(T1)/S

| S/M/NF(T1)/S | | | |
|---|---|---|---|
| Air volume (Liters) | Weight collection(g) | Total weight(g) | %Efficiency |
| 1 | 0.00204 | 0.00344 | 59.36 |
| | 0.00215 | 0.00344 | 62.46 |
| | 0.00165 | 0.00344 | 48.11 |
| | average | | 56.64 |
| | SD | | 7.55 |
| 2 | 0.00362 | 0.00672 | 53.95 |
| | 0.00328 | 0.00672 | 48.78 |
| | 0.00399 | 0.00672 | 59.40 |
| | average | | 54.04 |
| | SD | | 5.31 |
| 4 | 0.00397 | 0.01104 | 35.99 |
| | 0.00408 | 0.01104 | 36.93 |
| | 0.00449 | 0.01104 | 40.70 |
| | average | | 37.87 |
| | SD | | 2.49 |
| 6 | 0.00541 | 0.01527 | 35.41 |
| | 0.00508 | 0.01527 | 33.25 |
| | 0.00489 | 0.01527 | 32.05 |
| | average | | 33.57 |
| | SD | | 1.70 |

Table D9 Filtration efficiency of S/M/NF(T2)/S

| S/M/NF(T2)/S | | | |
|---|---|---|---|
| Air volume (Liters) | Weight collection(g) | Total weight(g) | %Efficiency |
| 1 | 0.00273 | 0.00344 | 79.34 |
| | 0.00209 | 0.00344 | 60.81 |
| | 0.00222 | 0.00344 | 64.60 |
| | average | | 68.25 |
| | SD | | 9.79 |
| 2 | 0.00413 | 0.00672 | 61.54 |
| | 0.00391 | 0.00672 | 58.26 |
| | 0.00414 | 0.00672 | 61.69 |
| | average | | 60.50 |
| | SD | | 1.94 |
| 4 | 0.00480 | 0.01104 | 43.51 |
| | 0.00510 | 0.01104 | 46.20 |
| | 0.00526 | 0.01104 | 47.64 |
| | average | | 45.78 |
| | SD | | 2.10 |
| 6 | 0.00610 | 0.01527 | 39.95 |
| | 0.00592 | 0.01527 | 38.75 |
| | 0.00624 | 0.01527 | 40.89 |
| | average | | 39.86 |
| | SD | | 1.07 |

Table D10 Filtration efficiency of S/M/NF(T3)/S

| S/M/NF(T3)/S | | | |
|---|---|---|---|
| Air volume (Liters) | Weight collection(g) | Total weight(g) | %Efficiency |
| 1 | 0.00217 | 0.00344 | 63.24 |
| | 0.00237 | 0.00344 | 69.06 |
| | 0.00238 | 0.00344 | 69.35 |
| | average | | 67.22 |
| | SD | | 3.45 |
| 2 | 0.00423 | 0.00672 | 62.93 |
| | 0.00485 | 0.00672 | 72.26 |
| | 0.00476 | 0.00672 | 70.92 |
| | average | | 68.70 |
| | SD | | 5.04 |
| 4 | 0.00533 | 0.01104 | 48.28 |
| | 0.00495 | 0.01104 | 44.81 |
| | 0.00543 | 0.01104 | 49.15 |
| | average | | 47.41 |
| | SD | | 2.30 |
| 6 | 0.00626 | 0.01527 | 41.00 |
| | 0.00595 | 0.01527 | 38.94 |
| | 0.00580 | 0.01527 | 37.98 |
| | average | | 39.31 |
| | SD | | 1.54 |

Table D11 Filtration efficiency of S/M/C-shape PLA/S

| S/M/NF(C-shape PLA)/S | | | |
|---|---|---|---|
| Air volume (Liters) | Weight collection(g) | Total weight(g) | %Efficiency |
| 1 | 0.00217 | 0.00344 | 63.24 |
| | 0.00199 | 0.00344 | 57.90 |
| | 0.00128 | 0.00344 | 37.15 |
| | average | | 52.76 |
| | SD | | 13.78 |
| 2 | 0.00350 | 0.00672 | 52.16 |
| | 0.00318 | 0.00672 | 47.39 |
| | 0.00320 | 0.00672 | 47.64 |
| | average | | 49.07 |
| | SD | | 2.68 |
| 4 | 0.00591 | 0.01104 | 53.50 |
| | 0.00616 | 0.01104 | 55.77 |
| | 0.00524 | 0.01104 | 47.43 |
| | average | | 52.23 |
| | SD | | 4.31 |
| 6 | 0.00678 | 0.01527 | 44.40 |
| | 0.00708 | 0.01527 | 46.34 |
| | 0.00622 | 0.01527 | 40.71 |
| | average | | 43.82 |
| | SD | | 2.86 |

Table D12 Filtration efficiency of S/M/M/S

| S/M/M/S | | | |
|---|---|---|---|
| Air volume (Liters) | Weight collection(g) | Total weight(g) | %Efficiency |
| 1 | 0.00116 | 0.00344 | 33.85 |
| | 0.00138 | 0.00344 | 40.25 |
| | 0.00158 | 0.00344 | 45.88 |
| | average | | 39.99 |
| | SD | | 6.02 |
| 2 | 0.00182 | 0.00672 | 27.15 |
| | 0.00252 | 0.00672 | 37.47 |
| | 0.00273 | 0.00672 | 40.69 |
| | average | | 35.10 |
| | SD | | 7.08 |
| 4 | 0.00400 | 0.01104 | 36.20 |
| | 0.00450 | 0.01104 | 40.76 |
| | 0.00406 | 0.01104 | 36.78 |
| | average | | 37.91 |
| | SD | | 2.48 |
| 6 | 0.00500 | 0.01527 | 32.72 |
| | 0.00539 | 0.01527 | 35.30 |
| | 0.00511 | 0.01527 | 33.49 |
| | average | | 33.84 |
| | SD | | 1.32 |

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