CHAPTER II
LITERATURE REVIEW

Recently, electrospinning process has become the well-known method to produce non-woven membranes of nanofibers. This process was first studied by Zeleny in 1914 and patented by Formhals in 1934. In 1964, Taylor showed that the equilibrium shape of suspended menicus at a critical voltage was a cone with a semi-vertical angle of 49.3°. When the applied voltage exceeded this critical voltage, a stable jet of liquid could be ejected. The research work of Taylor and others on electrically driven jets of the liquid inspired scientists to apply the same concept to polymeric systems.

Great efforts have been made to study the effects of processing parameters on the structure and morphology of electrospun fibers. For example, Doshi and Reneker(1995) correlated the electrospinning process and the physical properties of electrospun polymeric nanofiber. They found that by reducing the surface tension, fibers could be produced without beads. A higher net charge density of the polymer solution could also yield thinner fibers with no beads. In addition, they reported that at very low viscosity the solution was too dilute to form a stable jet and the jet broke. At very high viscosity, it was difficult to form fibers due to the drying of the solution at the tip.

J.M. Deitzel *et al.* (2001) evaluated systematically the effects of two of the most important processing parameters: spinning voltage and solution concentration, on the morphology of the PEO fibers formed. They found that spinning voltage was strongly correlated with an increase in the number of bead defects forming along the electrospun fibers, and that current measurements may be used to signal the onset of the processing voltage at which the bead defect density increases substantially. Solution concentration has been found to most strongly affect fiber size, with fiber diameter increasing with increasing solution concentration according to a power law relationship. Similar results were also observed by E.R. Kenawy *et al.* (2003). They also indicated that the average fiber diameters of the electrospun poly(ethylene-co-vinyl alcohol) fibers increase with increasing polymer concentration.

Effects of solution properties and processing parameters on the structure and morphology of the electrospun biodegradable membrane like poly(D-lactic acid) and poly(L-lactic acid) were investigated by X. Zong *et al.* (2002). Results obtained demonstrated that the morphology of electrospun polymer fibers depended on the strength of the electric field, the solution viscosity (e.g. concentration), the charge density of the solution (by salt addition), and the solution feeding rate. It was shown that higher concentration and higher charge density of the solution favored the formation of uniform nanofibers without bead-like textures. The diameter of the nanofibers increased with electrospinning voltage as well as feeding rate of the solution. The addition of a small amount of salts or antibiotic drugs was found to greatly change the morphology of electrospun PDLA fibers from beads-on-fiber structure to uniform fiber-structure. The diameters of the nanofibers also decreased with the addition of salts. In addition, different salts exhibited different effects on the morphology of the electrospun fibers. B. Kim *et al.* (2005) explained the effect of salt on morphology of poly(acrylic acid) nanofibers that the characteristic morphology change of PAA nanofibers may be caused by the chain conformation and conductivity changes of PAA solutions with changes of ionic strength.

Furthermore, X. Zong and co-workers (2002) observed that the electrospinning of crystallizable PLLA resulted in a decrease of glass transition and crystallization temperatures, but an increase in the crystallization rate. Electrospinning was found to significantly retard the crystallization of PLLA. This is corresponding with the result from Deitzel *et al.* (2001). They point out that although the presence of some molecular orientation, the crystalline structure of the electrospun PEO fibers was not well developed in spite of the good crystallization ability of pure PEO, especially when under elongational flow.

Zhang *et al.* (2005) studied the effects of instrument parameters including electric voltage, tip–target distance, flow rate and solution parameters such as concentration on the morphology of electrospun poly(vinyl alcohol) fibers. Results showed that, when PVA with higher degree of hydrolysis (DH) of 98% was used, tip–target distance exhibited no significant effect on the fiber morphology, however the morphological structure can be slightly changed by changing the solution flow rate. At high voltages above 10 kV, electrospun PVA fibers exhibited a broad diameter distribution. With increasing solution concentration, the morphology was changed from beaded fiber to uniform fiber and the average fiber diameter could be increased from 87 ± 14 nm to 246 ± 50 nm. It was also found that additions of sodium chloride and ethanol had significant effects on the fiber diameter and the morphology of electrospun PVA fibers because of the different solution conductivity, surface tension and viscosity.

The effect of molecular weight is very important due to the molecular weight of polymer may have a significant effect on the rheological properties, electrical conductivity, dielectric strength and on surface tension in the solution. A. Koski *et al.* (2004) studied the effect of molecular weight on fibrous PVA produced by electrospinning. It was observed that for each molecular weight, a fibrous structure was stabilized above a minimum concentration. The average fiber diameter was between 250 nm and 2 μm. The fiber diameter increases with M_W and concentration. At low concentrations and/or M_W, the cross-section of the fibers was circular. As the solution concentration increases, the fiber diameter and interfiber spacing increase and there is gradual shift from circular to flat fibers.