# CHAPTER I
# INTRODUCTION

One of the most environmental concern problems is global warming. In comparison, carbon dioxide ($CO_2$) is the most emitted greenhouse gas which impacts on the climate change compare to water vapor ($H_2O$), methane ($CH_4$), nitrous oxide ($N_2O$) and ozone ($O_3$) (Karl and Trenberth, 2003). Nowadays, the quantitatively carbon dioxide ($CO_2$) increases intensely, not only from industries, but also from human activities. Nevertheless, the huge effect of $CO_2$ emission is generated from the power generation industries approximately more than 50 percent of whole industries (Larson *et al.*, 2011).

$CO_2$ capture and separation (CCSs) are one of the methods to reduce the amount of $CO_2$ released to the atmosphere. The CCSs include three technologies which are pre- and post-combustion and oxy-fuel combustion. The focus of this research is on the downstream $CO_2$ capture, which is referred to the post-combustion capture. $CO_2$ can be separated from flue gases after combustion with air or steam generated by the process itself. In addition, there are various types of post-combustion technologies which include chemical absorption, solid adsorption, membranes, cryogenics and $CO_2$ hydrates. Since the solid adsorbent has many benefits, such as high capacity in term of loading, low regeneration energy, various conditions of operating temperatures and no solution product of waste generated (Larson *et al.*, 2011).

Several adsorbents have been developed to capture $CO_2$ are silica, activated carbon, calcium oxides, hydrotalcites, lithium zirconate, and organic-inorganic hybrids (Choi *et al.*, 2009). In the present work, a porous carbon developed from polybenzoxazine is considered. Polybenzoxazine (abbreviated as PBZ) is a thermosetting polymer which is easily synthesized via ring opening polymerization. In comparison, the polybenzoxazine includes several preferential properties greater than the conventional phenolic resin in term of high thermal stability and outstanding mechanical properties, simple processability, poor water adsorption and near zero volume change after the curing process (Lorjai *et al.*, 2009).

In the previous study, the polybenzoxazine-derived activated carbon is synthesized from phenol, formaldehyde and diethylenetriamine (DETA) as precursors had been studied. The results revealed that it performed the $CO_2$ adsorption capacity of 1.65 mmol/g at carbonization temperature of 300 °C and showed higher $CO_2$ adsorption performance than the commercial activated carbon due to the high amount of nitrogen functionalities. However, the textural parameters show a low surface area of 267 $m^2$ /g and low total pore volume of 0.30 $cm^3$ /g (Hirikamol, 2013). To increase the surface area and porosity in the adsorbent structure, adding a blowing agent or using a sol-gel technique can help create more porosity and surface area of the polybenzoxazine.

By adding a blowing agent to polybenzoxazine during the curing step can create foam or porosity into the polymer matrix. Polymeric foam can be classified as a two phase material consisting of a dispersed phase of gas in a continuous phase of polymer matrix. In general, a blowing agent is used to generate the porous phase in the matrix material. The foaming agents can be divided into two classes which are chemical blowing agent (CBA) and physical blowing agent (PBA) (Zúñiga *et al.*, 2012). For the CBA, this blowing agent generates gases from a chemical reaction. For the PBA, it generates gases from a physical method which composes of evaporation, using the condition at elevated temperature or at reduced pressure and using other gases or chemicals such as nitrogen ($N_2$), carbon dioxide ($CO_2$) and hydrocarbons (HCs) (Lorjai *et al.*, 2009).

Another technique to create porosity in polybenzoxazine can be done via a sol-gel technique. The generation of porosity in polybenzoxazine hydrogel can be created when the solvent is removed from the gel structure and pores are created (Lorjai *et al.*, 2009). This porous polybenzoxazine is called aerogel and it is transformed to carbon aerogel by carbonization.

The purpose of this research was to design micro and mesopores structure of polybenzoxazine-based porous carbon for $CO_2$ capture using a sol-gel technique. The $CO_2$ adsorption effect between different types of polybenzoxazines was investigated. Two types of polybenzoxazines were prepared from phenol, formaldehyde and two different amine precursors, diethylenetriamine (DETA) and pentaethylenehexamine (PEHA). Moreover, the influences of benzoxazine content and loading PEG-PPG-

PEG block copolymer as non-ionic surfactant in aerogel material were investigated along with the generation of porosity in polybenzoxazine aerogels. The cured porous polybenzoxazine was then carbonized and activated to obtain the polybenzoxazine-derived activated carbon. Eventually, a simultaneous thermal analyzer (STA) was used to determine the $CO_2$ adsorption capacity.