CHAPTER I
INTRODUCTION

Electrochemical capacitors or known as supercapacitors are important energy storage devices at the present because of huge demand of electrical energy. Due to the great properties of supercapacitors that could reach the optimum point such as high power density, high energy density, long life cycle, fast charge and discharge rate, and light weight (Rekesh *et al.*, 2009). Many researchers try to develop supercapacitors in order obtain higher efficiency.

Normally, supercarpacitors can be divided into two types mainly by mechanism of storing charges; the electrical double-layer capacitors (EDLCs) and the pseudocapacitors (Prasad *et al.*, 2013). EDLCs store energy by electrostatic or physical separation of charge at the interface between electrode and electrolyte. In contrast, faradic redox reaction of electroactive materials is a main mechanism for storing charges in pseudocapacitors. EDLCs can be improved capacitance by choosing electrode materials which have good properties which are relatively high electrical conductivity, high surface areas, and acceptable cost (Pandolfo and Hollenkamp, 2006). For electrode materials, carbons were interested due to high conductivity, high surface area, good corrosion resistance, high temperature stability, relatively low cost, and have many types of carbon. Normally, graphene was incorporated into the electrodes due to high electrical conductivity and surface areas.

Graphene is a two-dimensional structure carbon which has excellent electrical, chemical, and mechanical properties. Normally, graphene cannot be synthesized by direct method. Due to graphene has high specific surface area causing the restacking and forming to graphite through van der Waals interactions (Cai *et al.*, 2008). To overcome this problem, many methods for synthesizing graphene have been created especially chemical exfoliation because it is easy to scale up (Wu *et al.*, 2010). Nevertheless, complex steps and hazard chemicals was involved in the process so prepared graphene form pyrolysis carbon precursors was interested. From the high electrical conductivity of carbon that requires to be used as electrode, chemical structure of carbon precursor needs to be concerned. In previous work, Worsley and coworker (2010) prepared graphene aerogels via sol-gel polymerization derived from resor-

cinol, formaldehyde, and sodium carbonate as catalyst. The conductivity of graphene aerogel equal to $1 \times 10^2\ S/m$. To increase electrical conductivity and obtain graphene-like carbon structure, choosing carbon precursor which contain high aromatic contents was critical concern.

The polycondensation of resocinal and formaldehyde has been generally used for the carbon aerogels preparation because the physical properties of carbon aerogels can be easily controlled via modification of preparation conditions, for instance, concentrations, pHs, reaction times, and temperatures. However, carbon aerogels are generally obtained by supercritical drying which is inappropriate for commercialization due to high cost. Therefore, ambient drying process has been focused instead to obtain carbon aerogels (Lee *et al.*, 2010) and the carbon obtained via ambient drying is generally called "carbon xerogel". In this work, polybenzoxazine, a novel type of phenolic resin, was selected as a precursor for the preparation of carbon xerogels owing to its unique characteristics, e.g., excellent dimensional stability, low shrinkage upon polymerization and low water adsorption. Furthermore, the molecular design flexibility allows the tailoring of the cured materials properties in order to fit desired applications (Ghosh *et al.*, 2007) which suitable for electrode materials that required high electrical conductivity. In order to design morphology of carbon xerogels, soft template method was used to prepare. Wang *et al.* (2008) used F127 as a soft template to prepare ordered mesoporous carbon.

In this work, carbon xerogel was prepared by using polybenzoxazine as a precursor via sol-gel process to be used as an electrode material in supercapacitors. Polybenzoxazine based on phenol, methylenedianiline, and formaldehyde. In addition, CTAB was also used as a soft templating agent to make sol-gel structure looser and increase mobility of aromatic molecules to rearrange themselves during pyrolysis process. Varying pyrolysis temperature was studied for observing the effect of temperature to carbon structure. Heat treatment was required to increase hydrophilic of carbon xerogels. The transformation of carbon xerogels to graphene-like carbon structure was investigated at different pyrolysis temperature. The electrical conductivity of carbon xerogels which related to changing of carbon xerogels structure also examined.