

CHAPTER 1

INTRODUCTION

Carbons have many allotropes due to their valency such as graphite, graphene and carbon nanotube. The forms of carbon are attractive for electronic applications because of their properties such as thermal stability and conductivity.

Graphene is a single carbon layer of graphite structure, describing its nature by analogy to a polycyclic aromatic hydrocarbon of quasi-infinite size (Fitzer *et al.*, 1995) as according to the IUPAC definition from 1995. Graphene is the subset of graphite, carbon nanotube and fullerene. In this material, carbon atoms are arranged in a regular hexagonal pattern. It is a one-atom thick layer of the layered mineral graphite. This two-dimensional material constitutes a new carbon including layers of carbon atoms forming six-membered rings (Geim *et al.*, 2007). Ideally graphene is a single-layer material, but graphene samples with two or more layers are being investigated with equal interest. Graphenes can be defined in to three different types: single-layer graphene (SG), bi-layer graphene (BG) and few-layer graphene (number of layers ≤ 10). Graphene exhibits large specific surface area and unique electrical, mechanical and thermal properties (Novoselov *et al.*, 2004, Geim *et al.*, 2007, Geim, 2009, Rao *et al.*, 2009, Segal, 2009). It shows excellent physical and chemical properties, making it promising for variety of applications in the areas such as solar-cells (Wang *et al.*, 2007), energy storage (Stoller *et al.*, 2008), field effect transistors (Ponomarenko *et al.*, 2008), catalyst support (Si *et al.*, 2008), sensors (Schedin *et al.*, 2007), and nanocomposites (Stankovich *et al.*, 2006).

The first preparation of single-layer graphene was reported by Novoselov and coworker (2004). In 2007, Black and coworker reported the direct chemical exfoliation of graphite into graphene without a graphene oxide step. The first preparation of graphite oxide was achieved by oxidative treatment of graphite by employing Hummers procedure (Hummers *et al.*, 1958) A chemical method to prepare single-layer graphene involves reduction of single-layer graphene oxide dispersion in dimethylformamide with hydrazine hydrate (Park *et al.*, 2009), or sodium and ethanol (Choucair *et al.*, 2009). At the same time, single-layer graphene have been exfoliated in N-methylpyrrolidone (Hernandez *et al.*, 2008) or a

surfactant/water solution using ultrasonication (Lotya *et al.*, 2009). Besides, chemical vapor deposition was used to prepare single-layer graphene by decomposing a variety of hydrocarbons on films or sheets, the number of layers varying with the hydrocarbon and reaction parameters of transition metal (Reina *et al.*, 2009). The thermal exfoliation of graphitic oxide is an important method to prepare few-layer graphene at high temperatures (Schniepp *et al.*, 2006, Subrahmanyam *et al.*, 2008). Another method of preparing few-layer graphene is by reacting single-layer graphene oxide in water with hydrazine hydrate at the refluxing temperature (Rao *et al.*, 2009) or by microwave treatment (Stankovich *et al.*, 2007). The effect of heating nanodiamond at different temperatures has been studied by Enoki and coworker (1998, 2000). Annealing of nanodiamond at high temperatures in an inert atmosphere produces few-layer graphenes (Subrahmanyam *et al.*, 2008, Andersson *et al.*, 1998).

Because the preparations of conductive carbon, almost transform of graphite to graphene, are complicated and expensive process. Therefore, novel carbons have been developed including partially ordered carbon. Partially ordered carbon has been widely studied and used in various applications such as gas separation, catalyst supports, and electrode material. It has been conventionally prepared by pyrolysis and physical or chemical activation of organic precursors such as polymers in which the pore size and pore structure can be controlled during the process at very high temperature in inert atmosphere.

Polybenzoxazine as a novel developed class of thermosetting resins derived from phenolic resin. It possesses various good properties like high thermal stability, easy processability and very high char yield. A method for preparing a desired benzoxazine compound comprises of preparing a substantially homogeneous reaction mixture that includes a phenolic compound, a primary amine and an aldehyde. It has been synthesized from inexpensive raw materials and polymerized by a ring-opening addition reaction (Ishida *et al.*, 1996, Ishida, 2011). The ways of producing benzoxazine monomer based on the functional group of reactants. They are mono-functional, di-functional and multifunctional group (Ghosh *et al.*, 2007). Because of the benzoxazine monomer are resulting in linear and branch structure. It may cause reduce the properties of benzoxazine. In 2005, Takeichi and colleague synthesized

high molecular weight polybenzoxazine precursors from aromatic or aliphatic diamine and bisphenol-A with para-formaldehyde.

In this work benzoxazines precursors based on aniline, methylenedianiline and tetraethylenepentamine were synthesized in order to study the changing ordered structure of partially ordered carbon. Benzoxazines precursors were polymerized to be polybenzoxazine and then pyrolyzed to obtain partially ordered carbon. Heat treatment, at various pyrolyzed temperatures, has been used to enhance the ordered structure of partially ordered carbon. Moreover, silver nitrate was loaded in benzoxazine precursor in order to study the effect of silver ion on carbon morphology. Finally, polybenzoxazine and partially ordered carbon were characterized to study their properties.