

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions (Synthesis and Characterization of Polybenzoxazine)

In this work, polybenzoxazine-based carbon aerogels from two different types of amine precursors (i.e., DETA and PEHA) were successfully synthesized by a sol-gel technique using xylene as a solvent, followed by carbonization in nitrogen and activation with CO₂. Comparing the preparation method, carbon aerogels derived from DETA and PEHA provided a higher surface area and pore volume compared to those PBZs derived activated carbon without using the sol-gel technique because the generation of porosity during aerogel preparation led to an increase in microporous range after carbonization and activation steps. Varying in benzoxazine concentration on carbon aerogel materials did not have a significant change on the textural properties for both kinds of PBZs. The DETA-derived PBZ provided good surface properties on carbon aerogels (312 - 376 m²/g at activated temperature of 800 °C) compared to the PEHA-derived PBZ carbon aerogels (44 - 114 m²/g at the same condition) due to the less influence on hydrogen bonding between shorter aliphatic chains of DETA-derived PBZ. The best condition of carbon aerogels was observed at higher activating temperature of 900 °C, with the surface area of 695 m²/g and pore volume of 0.396 cm³/g for 30 wt% of DETA-based carbon aerogel, due to more powerful generation of the microporosity at higher activated temperature. A similar result was observed for 30 wt% of PEHA-based carbon aerogel with a surface area of 304 m²/g and pore volume of 0.179 cm³/g at the same activating temperature. When the non-ionic surfactant was used, the surface area of 30 wt% of DETA-based carbon aerogel did not change, whereas it significantly increase from 304 m²/g (or 0.79 cm³/g of pore volume) for 30 wt% of PEHA-based carbon aerogel to 502 m²/g (or 0.285 cm³/g of pore volume) for 30 wt% of PEHA-based carbon aerogel with surfactant.

6.2 Conclusions (Carbon Materials from Polybenzoxazine for Carbon Dioxide Adsorption Application)

Polybenzoxazine aerogels from DETA-derived and PEHA-derived were successfully prepared via a sol-gel process using xylene as a solvent, followed by carbonization in nitrogen and activation with CO₂, and then carbon aerogels were formed. The CO₂ adsorption capacities of carbon aerogels from both polybenzoxazine were higher than those activated carbons from polybenzoxazine due to the generation of porosity during aerogel preparation, leading to an increase of the surface area and pore volume after the thermal treatments. The increasing of benzoxazine solutions on aerogel materials did not help improve the CO₂ adsorption capacity because all samples exhibited similar surface properties. The carbon aerogels with DETA-derived PBZ performed a higher CO₂ adsorption capacity (in the ranges of 1.46 – 1.59 mmol/g at 40 °C and 1 bar) than those carbon aerogels with PEHA-derived PBZ (1.27 – 1.34 mmol/g at 40 °C and 1 bar) at all operating temperatures of 40, 75, and 140 °C because the BET surface area and pore volume of the DETA-derived PBZ carbon aerogel were higher than carbon aerogels derived from PEHA. At higher activated temperature of 900 °C, the CO₂ adsorption performances of carbon aerogels increased significantly compared to the carbon aerogels activated at lower temperature of 800 °C because of the increasing of microporosity with providing double in the BET surface area for those carbon aerogels activated at 900 °C. When the non-ionic surfactant was used, PEHA-based carbon aerogel containing surfactant performed an increase in the CO₂ adsorption capacity (1.64 mmol/g at 40 °C and 1 bar) compared to the carbon aerogel from PEHA (1.40 mmol/g at 40 °C and 1 bar) because the non-ionic surfactant could help disperse the aggregated molecules of polybenzoxazine which led to the increase in the surface area and pore volume in the carbon aerogels. All carbon materials derived from polybenzoxazine could be regenerated completely at higher temperatures of 75 and 140 °C but cannot be completely regenerated at 40 °C because of the physisorption mechanism.

6.3 Recommendations

Polybenzoxazine-based aerogel can be synthesized from other amine reactants and preparation techniques to obtain polybenzoxazine-derived carbon aerogel with appropriate pore size and volume which will in turn improve the CO₂ adsorption performance. Other activation temperatures (temperatures greater than 900 °C) might improve the surface properties of the resulted activated carbon aerogel.

In addition, the varying surfactant types in polybenzoxazine-based carbon aerogel can also help improve the textural properties, leading to an increase in the CO₂ adsorption capacity. In the curing process, a vacuum oven is recommended to heat all samples from polybenzoxazine-based aerogel at the curing temperature to maintain the structural shape of aerogel network and prevent the aerogel from degradation.