

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

Carbon xerogel was successfully synthesized by using BA-teta-derived polybenzoxazine as a carbon precursor. Polybenzoxazine (PBZ)-based carbon xerogels with different properties were obtained by varying different synthesis parameters. By taking advantage of phase separation phenomena during the sol-gel process, morphology, porous characteristics, density and the rate of cluster growth during the sol-gel process, of PBZ xerogel and its porous carbon, were depended on the precursor concentrations and the types of solvents used. The spherical particles with microporous property obtained from self-micelle-like formation model were observed by using isopropanol as the solvent. By using dioxane as the solvent, carbon xerogel showed the characteristics of mesoporous carbon due to the interconnection of small clusters of benzoxazine. Comparing the rate of cluster growth between DMF and dioxane system, rate of cluster growth in dioxane system was slower than that of DMF system implying the good miscibility between PBZ and dioxane. Without the need of supercritical CO₂ drying method, PBZ-based xerogel was sufficiently strong to withstand the pore collapse during the ambient pressure drying method.

Carbon xerogel with mesoporous properties obtained from dioxane system was used as a carbon template confinement to control the size of ZSM-5 into nano-scale. Using this novel template confinement as a hard template, highly crystalline nanosized ZSM-5 was successfully synthesized at 150 °C for 6 h with 5 h aging time via microwave irradiation. The resulting ZSM-5 with crystal sizes of 27-70 nm exhibited the mesoporous properties and high external surface area.

By using non-ionic surfactant (Synperonic NP30) and cationic surfactant (CTAB), the carbon xerogels derived from PBZ with tunable pore structure were successfully synthesized as well. When CTAB was used as a surfactant, mesoporous carbon xerogels with wide range of mesopore diameters (15.57-36.07 nm) were obtained by changing the concentrations of CTAB. Moreover, the carbon xerogel nanospheres with the size of 50-200 nm were obtained through emulsion process since the concentration of CTAB was equal to or exceeded 0.030 M (CMC). On the

other hand, when the Synperonic NP30 concentrations were increased, the properties of the obtained carbon xerogels were shifted from mesoporous material for reference carbon xerogel to obviously microporous material at higher concentrations of Synperonic NP30 (0.009-0.180 M). Furthermore, the carbon xerogel microspheres with size of about 2.5 μm were obtained through the emulsion process when the concentration of Synperonic NP30 reached 0.180 M (CMC).

In order to produce mesoporous carbon xerogel with both well distribution of uniform pore and extremely high pore volume, colloidal silica nanoparticles were used as pore-generating hard template. After removal of silica template from carbon xerogel structure, the specific surface area of carbon xerogel was obviously improved up to 518-899 m^2/g and the amounts of pore volume were also significantly increased from 0 cm^3/g and 0.18 cm^3/g to 1.04-4.26 cm^3/g and 1.34-6.05 cm^3/g for mesopore volume and total pore volume, respectively, depending on the content of silica loadings. An average mesopore diameter of all mesoporous carbon xerogel was identical with an average diameter of silica nanoparticles – about 24 nm.

Hence, all results demonstrated that polybenzoxazine is an excellent candidate for producing carbon xerogel with tailorable properties by changing various either synthesis parameters or synthesis pathways.

However, due to the excellent molecular design flexibility of PBZ, the effects of both amine derivative species and phenol derivative species on cluster growth behavior during the sol-gel process and on properties of PBZ-based carbon xerogel should be further studied for understanding the control parameters of PBZ-based carbon xerogel. The new synthesis technique like microwave heating technique should also be studied in order to decrease the preparation time of carbon xerogel. Moreover, the versatile performance of PBZ-based carbon xerogel should be examined in several applications such as catalyst-supporting material, electrodes for supercapacitors, and adsorbents, for further use in industrial scale.