Nanostructure carbon formation in sol-gel polymerization of resorcinol and formaldehyde

Katarzyna Gaca, Jan Sefcik, Peter J. Hall

Department of Chemical and Process Engineering, University of Strathclyde, Glasgow, United Kingdom

E-mail: katarzyna.gaca@strath.ac.uk

Organic gels based on formaldehyde and resorcinol (RF) were first synthesised in a sol-gel process in 1980s and since then they have become increasingly important. Being electrically conductive and having very large surface areas, RF aerogels are ideal novel materials for electrodes in electrochemical double-layer supercapacitors, making their research of great importance in terms of energy storage and management. They are also used to produce electrodes for batteries and for capacitive deionization units, as well as materials for hydrogen fuel storage due to their porosity and highly developed surface areas. Among their other applications, one can mention filters and absorbing media, as well as catalyst supporting materials.

Previous research proved that RF gels properties can be tailored to match specific requirements by changing the conditions of synthesis, allowing them to cover a wide range of applications. The sol-gel process is a convenient and environmental friendly synthesis method in which numerous factors can be changed independently, influencing the structural properties of the final product. The key to successful synthesis design targeted at certain final properties of the RF gel is to understand its mechanism. The objective of this research is to investigate the reactions which lead to formation of RF gels and thus to enable to control the structure of final product - both its pore size and surface area – in a predictable manner. The investigated factors are ratios of resorcinol to formaldehyde and to catalyst (sodium carbonate), dilution of the reactants and temperature of synthesis. Dynamic Light Scattering was employed to examine the particle growth in the early stages of the sol-gel process. The results proved that regardless of the temperature and resorcinol to catalyst ratio, the hydrodynamic radii of particles before gelation were 3-6 nm. This finding proves that previous assumptions towards the role of the catalyst call for revision, as the amount of catalyst appears not to affect these values. ^{13}C and ^{1}H Nuclear Magnetic Resonance was used to analyse the composition of formaldehyde aqueous solutions at a variety of dilutions, giving to understanding of the influence dilution has on the chemical structure of the formed gel.