Meso-scale porous structure of fractal porous silica studied by small-angle neutron scattering

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Fractal is a mathematical concept to understand self-similar structures observed in complex coastline, shapes of clouds and broccoli. It is also well-known that ideal fractal geometries in which self-similar patterns appear from zero to infinity in size generate infinite length, infinite surface area and zero volume in finite space. Therefore, we have expected that fractal porous materials with hierarchical structures over multi-decades have great potential as porous materials to produce huge surface area. Relation to this idea, we have created " fractal body "by a novel template method using alkyl ketene dimer (AKD) particles and a sol-gel synthesis of tetramethyl orthosilicate (TMOS) (Mayama and Tsujii, J. Chem. Phys. (2006)). We found that the prepared samples have highly developed hierarchical structures with mass fractal dimension D = 2.5 ~ 2.7 from ca. 100 nm to several tens micrometer determined by several experimental methods (Mayama and Tsujii, J. Chem. Phys. (2006), Ono et al., J. Colloid Interface Sci. (2009), Yamaguchi, Mayama et al., Eur. Phys. J. E, (2008)), but, we also found that the hierarchical structures from 10 to 100 nm was not highly structured.

To design the porous structures in 10-100 nm, we adopted other template materials using long and giant polymer chains such as polyethylene glycol (PEG) and DNA, where the polymers are burned out by calcinations of the sol-gel products at 500 degree centigrade for 2 hours and several nm ~ tens nm pores are obtained. In the sol-gel synthesis, we designed the composition of the sol solution by addition of PEG20000, PEG500000 and calf thymus DNA at different concentrations. We investigated the fractal dimension of the samples by SANS-U because fractal dimension can be directly determined by I (Q) ~ Q^(-D). As a result, we found that the dependences above 10 nm (Q =< 0.01 A^(-1)) and below 1 nm (Q => 0.1 A^(-1)) changes by mixing different molecular weight of PEG, which show that similar fractal geometries (D ~ 2.3) are structured from nm to several ten nm in pore size.