doi:10.2533/chimia.2009.78

Polymer and Colloid Highlights

Division of Polymers and Colloids

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Novel Anisotropic Porous Materials through Self-Assembly of Super-Paramagnetic Particles

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Keywords: Colloidal stability · Porous materials · Self-assembly· Superparamagnetic nanoparticles

In this work, we show how the combination of colloid and polymer science and engineering can be effectively utilized to rationally design novel porous materials with uniquely controlled pore structure and many promising applications, for example in the field of chromatography.

The preparation of porous materials requires two steps. First, polymer nanoparticles with controlled size are prepared and stabilized by electrostatic repulsive interactions. The strength of these interactions can be decreased by increasing the ionic strength in the solution. Afterwards, colloidal instability is induced, leading to self-assembly of particles into irregular fractal clusters, the density of which decreases as their size increases. At high enough concentrations these fractal clusters percolate and form a space filling network, called a gel, where particles occupy only a few percent of the overall available space.

Through a combination of characterization techniques (*e.g.* light scattering and rheology), and mathematical modeling (*e.g.* Monte Carlo simulations), we can monitor, control and quantitatively describe the aggregation process and the onset of a gel phase. Particle size and volume fractions can be used to tune the properties of the gel.

To provide an additional and unique control over the pore size distribution, we have also encapsulated super-paramagnetic nanocrystals into polymer particles. In this way, magnetic fields can be used to fine-tune the self-assembly of magnetic particles. In fact, magnetic particles form chain-like structures in the presence of an external magnetic field due to dipolar interactions. The combination of chain formation with random fractal growth can be used to obtain a pore structure oriented in the direction of the magnetic field. By applying a magnetic field at different times during the gelation process, the aspect ratio of clusters can be manipulated, and the formation of chains of clusters can be induced at different stages of the gelation process, thus affecting the final structure. Therefore, by balancing magnetic with non-magnetic self-assembly of clusters, the pore size distribution and orientation and the material morphology can be controlled.

In order to obtain a processable material, a post-polymerization treatment is eventually applied to covalently link the particles together and transform a soft colloidal gel into a hard porous scaffold.

Received: November 25, 2008

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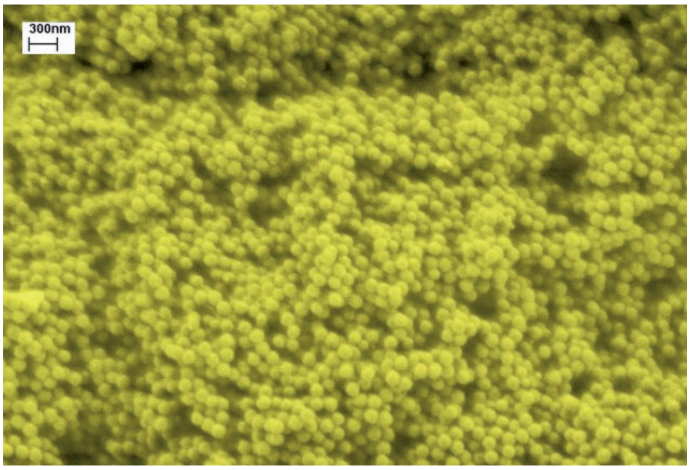
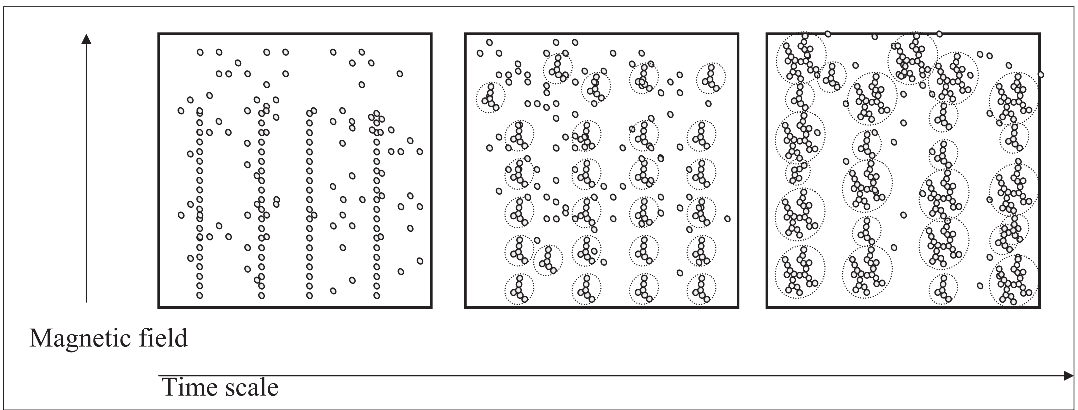
SEM picture of a (non-magnetic) crosslinked gel used as a chromatographic stationary phase.





Schematics of the porous material formation and structure by applying a magnetic field at different time steps during the gelation process

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