Aggregation of silica colloids: From suspension to rock

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Silica colloid is a very common binder material occupying the pore spaces of sedimentary rocks, frequently appeared in clay-rich bentonite and typically as agate, opal. Silica has fairly low solubility (Log K of amorphous silica and quartz are -2.702 and -3.740, respectively), so that it can be saturated easily in the mineral-water equilibrium system. Most interesting feature of silica colloid is its spherical shape due to amorphous state and various types of aggregation. Such a uniformity of silica colloid sometimes allow to construct the colloidal crystal which is well-known as opal. If the solution is in high-pH condition such as in the presence of $Ca(OH)_2$, silica can be slightly dissolved and subsequently precipitate Ca-silicate hydrate (C-S-H). Satoh et al. (2018) investigated this alteration process of silica by transmission electron microscopy (TEM) applied for the system of synthetic silica fume (940 nm) and aqueous solutions, and discussed aggregation models that is applicable for powder technology.

We newly carried out the aggregation experiments using colloidal materials focusing on (1) natural silica colloid in the geothermal system and (2) synthetic silica in the various pore spaces. Natural colloidal silica is produced in the circulation system at the geothermal power plant and accumulated as silica scale. Kinetic process of this accumulation was measured by ex-situ interferometry using steel and chalcedony plates to be 0.003 and 0.03 nm/s, respectively. TEM and FESEM observations of these silica aggregates revealed that silica particle has core (<10 nm) and mantling structure (100-1000 nm), and their growth may had continued after aggregation like sintering. Resultant silica scale is porous and lower density (~ 1.55 g/cm^3) than homogeneous a-SiO_2 (2.196) but hard. Since the porosity of close-packing of equal spheres is 0.260 (packing density, 0.740), porosity of obtained silica scale, 0.296 may reflect that colloidal aggregation of silica scale is randomly formed. Synthetic colloidal silica was used for solidifying experiment with various sandy materials and alkalis. These different experiments suggest that the aggregation of silica particles requires condensation space (supersaturation) and overgrowth (volume increase). We evaluate the observation results of aggregation structures of various colloids in nano-scale. This knowledge is important to consider the solidification process of geomaterials as well as to control the colloidal particles.

Reference

Satoh, H., Kimura, Y., and Furukawa, E. (2018) Direct transmission electron microscopy visualization of the cement reaction by colloidal aggregation of fumed silica. Industrial & Engineering Chemistry Research, **57** , 79-83.

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