Industrial Measurements at PETRA III via Science Link

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Under the project SCIENCE LINK, which ran from 2012-2014, 11 measurements for industrial companies were performed at PETRA III. The types of companies ranged from nanotechnology to agriculture, environmental science and cosmetics, and two examples are highlighted here.

Agriculture

Modern agriculture depends on the use of environmentally friendly fertiliser materials to ensure that healthy foods can be produced with a high efficiency. The small start-up company NanoGeo Finland Oy produces a natural fertiliser based on the common geological mineral Vermiculite. The production of fertiliser is based on the utilization of nanoscale structures and properties of the mineral – when vermiculite is heated its capability to absorb ammonium ions is increased. The absorption of ammonium results in the formation of ammoniumvermiculite, which is a fertiliser for plants. Furthermore, a source of ammonium for the fertiliser is ammonium-containing waste-water produced by human activity. This recovery of ammonium from waste-water for use in fertilisers is a very useful technique which benefits the environment as well agriculture.

To understand the structural changes that take place during the initial heating of NanoGeo's vermiculite, several samples were analysed at P02 which is dedicated to High Resolution Powder Diffraction at different pressures and temperatures. The ability to create extreme conditions is complemented by time resolved diffraction capabilities in order to explore the kinetics of physical processes during a phase transition, which is only possible at a synchrotron facility like DESY.

Powdered samples of the mineral were placed into glass capillaries and heated from 25 – 580°C. An XRD measurement was made every 2 – 3°C to observe the heat induced structural changes. The results are shown in Figure 1, and it was found that during the heating, crude vermiculite passes through five discrete structural transformations, involving three steps of reversible dehydration and two irreversible dehydroxylation steps resulting in decomposition of the vermiculite to talc and, finally a form of $Mg_2Si_2O_6$.

Results such as those shown in Figure 1 showed the temperatures of the structural changes of vermiculite required to create the best possible ammonium filter. This understanding has allowed NanoGeo to reduce the energy consumption of the manufacturing process of their filtering sands. Further measurements were performed on heated vermiculite before and after exposure to ammonia and chemical reactions governing ammonia absorption by vermiculite were identified.

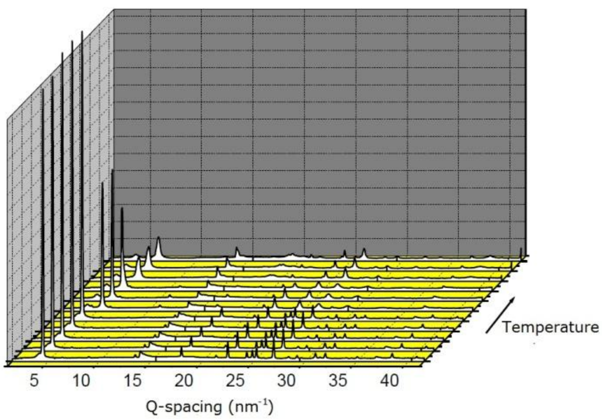

Figure 1: XRD data showing structural changes in Russian vermiculite during heating from 25°C – 580°C.

Nanotechnology

Dispersant agents are crucial to many diverse fields of application such as in paints, plastics, cosmetics and construction. In general, dispersant agents improve the homogeneity of a system of particles by being absorbed on to particle surfaces, and assist in compatibilisation of the surrounding medium and mediation of particle interactions. This improves colour strength and stability in paints and cosmetics, as well as mechanical properties in plastics and hardening and strength in construction. Evonik Industries produces many different systems which require the use of dispersants but until now the actual mode of action is only poorly understood.

To aid the understanding of these systems, a series of measurements were performed using SAXS at the Coherence Beamline P10. SAXS is sensitive to the size, structure, distribution, orientation and aggregation of particles in a solution and is a very useful technique for investigation of Evonik's materials. Figure 2a shows typical results from the measurements, from which valuable information could be obtained on how dispersant molecules influence the interactions between dispersed particles.

It was found that in low concentration the dispersant only insufficiently cover the surface of the scattering particles and hence cannot completely screen attractive interactions between the particles. For high dispersant concentrations, however, i.e. when a sufficient surface coverage of the particles by dispersant molecules is achieved, repulsive interactions between the scattering particles are induced, *i.e.* the system is sterically stabilized. This is shown schematically in Figure 2b. It is hoped that this improved understanding of the mode of action of the dispersant molecules can lead to an optimization of Evonik's products.

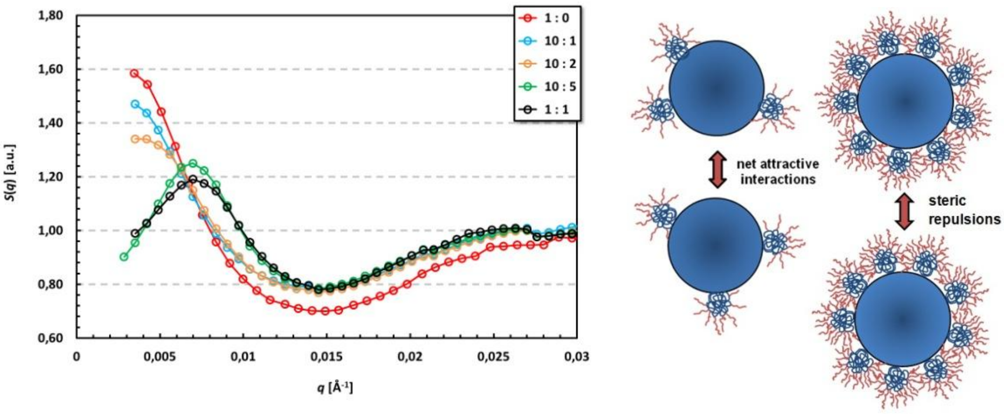

Figure 2a (left): Interparticle structure factor S(q) of the system SiO_2 – Dispersant in solution for different SiO_2 to dispersant ratios. S(q) was extracted from the experimental scattering data recorded at P10. Figure 2b (right): Diagram showing potential dispersant-nanoparticle relationship in both low and high dispersant-nanoparticle ratio systems.