Nanoparticulate construction materials via flame spray synthesis: Enhanced reactivity of nano-Portland cement and improved hardness of nano-gypsum

S. C. Halim¹, N. Osterwalder¹, S. Loher¹, R. N. Grass¹, T. J. Brunner¹, L. K. Limbach¹, M. Bohner² and W. J. Stark¹

¹Chemistry and Applied Biosciences, ETH Zurich, CH-8093, Zurich, Switzerland
²Dr Robert Mathys Foundation, CH-2544, Bettlach, Switzerland

Keywords: nanoparticle applications, combustion aerosols, physical properties, surface reaction.

Gypsum is one of the oldest known construction materials today accounting for a worldwide production of an estimated 100 million metric tons of calcium sulfate. Portland cement, on the other hand, represents one of the largest volume chemicals globally with an annual production of over 2.1 billion tons. Both materials are widespread due to their mechanical properties and the versatile fields of applications.

In this work, nano-sized anhydrous calcium sulfate (anhydrite) and nanoparticles with a typical Portland cement composition (68% CaO, 22% SiO₂, 5.8% Al₂O₃, 2.6% Fe₂O₃, 1.5% MgO) were produced in a one-step preparation route based on flame spray synthesis. Latter has established itself as a reliable production process for mixed oxide nanoparticles of high phase homogeneity (Maedler, 2002; Stark, 2003; Stark, 2002). This continuous high temperature gas process uses suitable organic derivatives of the desired metals as homogeneous mixtures. The precursors are directly sprayed into a flame where they are rapidly converted into the corresponding mixed oxides.

The in-situ prepared gypsum and Portland cement nanoparticles were characterized with respect to particle size, crystal phases, morphology, and mechanical properties.

After compaction and hardening by the addition of water, the anhydrite nanoparticles reacted to nano-gypsum which was confirmed by X-ray diffraction, diffuse reflectance IR spectroscopy and thermal analysis. Mechanical properties were investigated in terms of Vickers hardness and revealed an up to three times higher hardness of nano-gypsum if compared to conventional micron-sized construction material (Osterwalder, 2006). The improved mechanical properties of nano-gypsum could in part be traced back to the presence of calcium sulfate nano-needles in the nano-gypsum as showed by electron microscopy (Figure 1).

The hardening process of the flame-derived Portland cement was followed in situ using isothermal calorimetry. The 20-50 nm sized Portland cement displayed an over 10 times faster hardening if compared to conventional cement (micrometer sized starting material, see Figure 2), yet showed poorer mechanical properties (Halim, 2007).

This work was supported by the Gebert Rüf Foundation, grant no. GRS-048/04, and ETH Zurich.

References