Dissolution kinetics and interface dynamics of industrial silicates

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Cement composition has not drastically changed in the last two millennia, since the invention of hydraulic lime empowered the Roman Empire, and yet many fundamental mechanisms associated with cement hydration are still poorly understood.
While research into alternative cementitious binders is constantly growing, a paradigm shift in the construction industry is not expected to occur in the short to medium term. Therefore, in the next few years, research into conventional binders based on ordinary Portland cement (OPC) and alternative ones will likely run in parallel, with possible transfer of knowledge from one system to the other. If cement mineralogy has to be included among those “high-tech” fields within the realm of materials science, then it is necessary to deploy innovative techniques with the aim of focussing research towards the basic mechanisms associated with cement hydration and reconcile the macroscopic properties with the behaviour observed at the smallest scales. Cement mineralogy and chemistry will cover a relevant role in a world where fundamental societal issues related to demographic growth and climate change must be urgently tackled. From this point of view, the need of providing housing and infrastructures in a scenario in which urban population is predicted to drastically increase, especially in the developing countries where nearly one billion people are currently living in slums (UN-habitat, 2013), has to be reconciled with a drastic cut of the global warming potential associated with building materials, hence the need of a knowledge-based design of cement-based materials.

From this perspective, since the use of alternative binders is often associated with slower hardening processes, with crucial economic drawbacks, the study of the fundamental reaction mechanisms is urgently needed. Modern concrete also contain different chemical additives, which improve various properties of the material. But a clear scientific understanding of the complex inorganic-organic interaction is again missing.
The proposed research will tackle the kinetics of early age hydration kinetics by means of a detailed investigation of alite (the main constituent of OPC) dissolution. Alite will be synthesized at the Finger-Institut für Baustoffkunde (Bauhaus-Universität Weimar) and its hydration behaviour will be analyzed by a combination of methods, including optical emission spectroscopy, X-ray micro-tomography, confocal microscopy and X-ray powder diffraction, by which the time variation of the particle-size distribution, the time-dependent surface topology and the rate of alite dissolution will be monitored. In particular, the effect of organic additives on the dissolution kinetics and interface dynamics will be assessed.
The results of this research will clarify the basic mechanisms of early age cement hydration and will likely have an impact on the study of the solid-liquid interface of industrial minerals.

International partnership:
The research will be carried out in *co-tutelle de these* regime, based on a bilateral agreement between CRUI and the German equivalent (HRK), in collaboration with the group lead by Prof. Horst-Michael Ludwig of the Bauhaus-Universität Weimar, which will ensure the possibility of using a wide range of research facilities. This is a worldwide recognized group in the field of cement chemistry and mineralogy, also participating to the NANOCEM consortium.
Dr. Thomas Sowoidnich will act as supervisor from this institution.

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References
UN-Habitat, United Nations Human Settlements Programme (2013) State of World’s Cities 2012/2013