Synthetic Opals and Sandcastles: Exploring Water at the Nanoscale

Alvaro Blanco, F. Gallego-Gómez, V. Canalejas, C. López

Instituto de Ciencia de Materiales de Madrid and Unidad Asociada CSIC-UVigo, C/ Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain
ablanco@icmm.csic.es

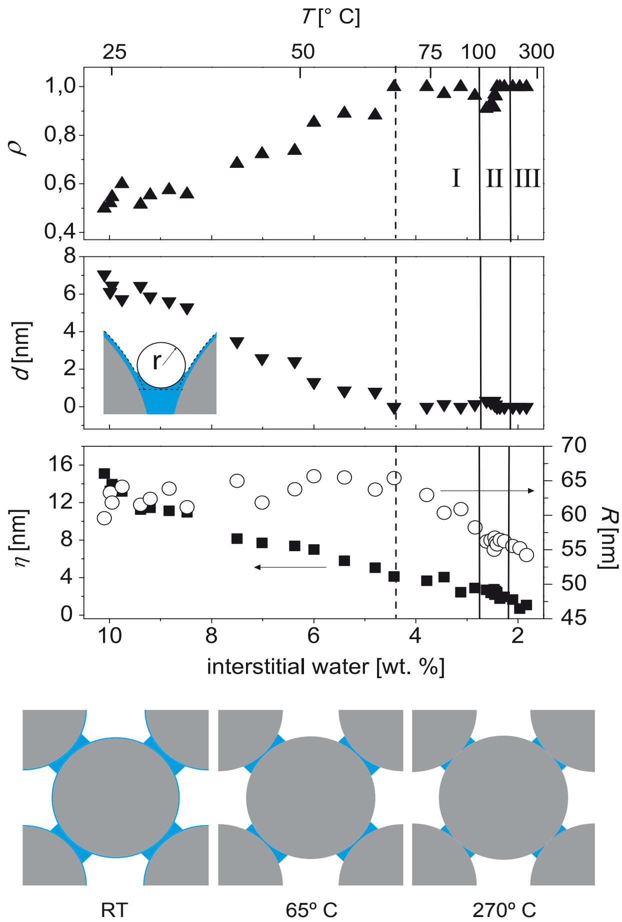
Humid granular media are everyday systems present in pharmaceutics, construction or agriculture. Sandcastles are built with wet sand, where water forms necks between grains, highly improving their mechanical stability [1]. Synthetic opals can be considered as sandcastles at the nanoscale. It is well known that the amorphous silica surface can adsorb a significant amount of water from the surrounding. The characteristics of systems based on silica structures can be greatly affected by the presence of adsorbed water, like the photonic properties of artificial opals formed by silica spheres. Previous work was focused on irreversible change of the water content in the spheres (e.g., by annealing at high temperatures) and its influence on the resulting silica opal [2]. However, studies on in situ water changes in the opal by e.g. due to alterations of the operating temperature or humidity are missing. In this direction, we have performed a complete characterization of water content in silica artificial opals for different conditions of composition, temperature and growth. We investigate the reversible modification of the water content in the opal (principally by moderate heating but also in vacuum) and the simultaneously changes in the photonic bandgap (PBG). We observe, due to removal of interstitial water, large blue-shifts up to 30 nm and a predominantly decrease of the bandgap width up to 7%. In this study, we make a novel use of the optical properties of the opal to infer quantitative information about water distribution within silica beads and dehydration phenomena from simple reflection spectra. Taking advantage on the well-defined opal morphology, our approach offers a simple tool for straightforward investigation on generic adsorption-desorption phenomena, which might be extrapolated to other humid granular media.

In addition, we also demonstrate that photoswitching can be induced by low cw-visible-irradiation in light-absorbing hydrophilic silica opals due to local heating, in which large and fast bandgap shift (15 nm in 5 milliseconds) is obtained (Figure 1) [3]. This very simple and cost-effective approach provides high switchability in conventional silica photonic crystals, promising an inexpensive solution for a number of applications.

References

[1] D. J. Hornbaker, et al., Nature, **387,** 765 (1997).
[2] H. Míguez et *al*. *Advanced Materials* **10**, 480 (1998).
[3] F. Gallego-Gómez et *al*. submitted (2011).

Figures



Water distribution as a function of humidity for different temperatures in an artificial opal formed by silica spheres of 335 nm.