2.3.5 Research Area "Nanostructured Optical Materials" (F. Marlow)

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Objective: Novel functional materials consist of a hierarchy of building blocks which have to be assembled by precise and tunable methods. In this research area we investigate fundamental aspects of processing steps, nanostructured building block formation, and the tuning of properties of optical materials.

Results: *Opals.* Nanostructures with length scales in the order of the wavelength of light have specific effects on electromagnetic fields. Photonic crystals (PhCs) are highly ordered versions of them. The self-assembly of these materials, especially of artificial opals, was investigated. The improvement and understanding of one well-defined opal fabrication method developed in this institute was the focus of the research. We found that the opal lattice is strongly aligned in opals fabricated by this method (Fig. 1). This is considered as an important step to mono-crystalline opal films which are, up to now, not existing. The current opal films can be understood as intergrowth structures of two different fcc lattices, each of them interrupted by stacking faults. We found out that the fcc-fcc twinning leads to relatively big domains which are not limiting to potential applications.

The detailed understanding of the opal self-assembly process is another topic of our research. The opal formation can be divided in two temporal phases: the wet assembly and the drying. Both are of different relevance for the quality of the opals. We have followed the second phase by optical spectroscopy in-situ and found significant rearrangement processes during and after water extinction. Optical microscopy, SEM[56], optical spectroscopy[59], and neutron scattering[57,60] have been used for opal film characterization.

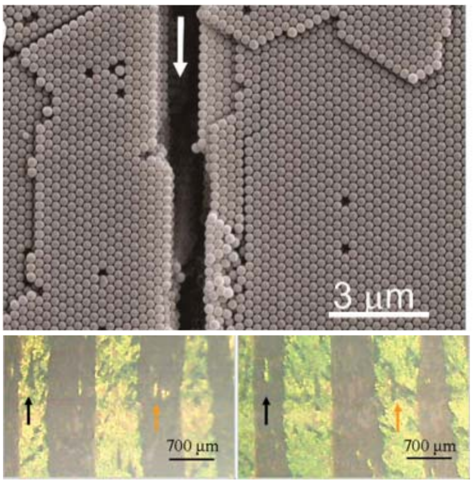

Fig. 1: Opals fabricated by the capillary deposition method (CDM). White arrow: growth direction. SEM images and optical images from two directions.[56, 59]

Core-shell particles. Core-shell particles are interesting building blocks for photonic crystals, catalysis, drug release, and corrosion protection. Their internal structure (shell thickness and composition) can, for example, be used to tune the band structure of PhCs and they are a way to avoid the inversion step which is needed for many PhC applications.[62] Moreover, it turned out that opals made from hollow shells can nearly avoid all cracks. This surprising improvement is ascribed to the enhanced mechanical flexibility of hollow spheres in comparison with solid ones.[65]

NPAs. Nano particle aggregates (NPAs) are also building blocks for photonic crystals, but they can also serve as micro lenses or special scattering particles.[61,63,64] An efficient fabrication method was developed which delivers strongly monodisperse NPAs. Also the shape tuning of NPAs was investigated.

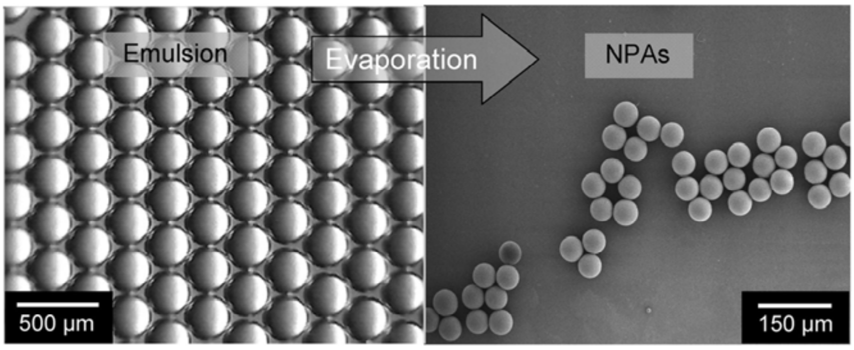

Fig. 2: The NPA fabrication process. The highly monodisperse emulsion is fabricated in a micro fluidic T-junction set-up. The drying leads to the solid NPAs.[61]

DSSCs. Dye-sensitized solar cells are a promising alternative type of solar cells. After 20 years of slow progress with these cells, the interest has increased in the last years again. We also started with works on the fabrication, characterization, and modeling of these solar cells. The key issue is the use of modified semiconductor electrodes and an improved understanding of the charge transport mechanisms in these solar cells.