Thermo-responsive smart materials

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While materials and nanoscience is currently still conducted within traditional areas that focus on "solid state", "soft matter" or biological systems, the development of the functional hybrid materials of the future requires a much more integrated, cross-disciplinary approach. Particularly promising routes towards novel materials and devices follow a soft nanotechnology approach, where bio-inspired fabrication strategies based on so-called bottom-up rather than top-down processes are used to assemble various nanoscaled building blocks into two- and three-dimensional materials and devices. In the soft nanotechnology approach to nanomaterials, the fabrication of structures is thus based on self-assembly without human intervention, where the instructions for assembly emerge from the intermolecular interactions between the synthons. However, traditional self-assembled materials based on colloids, block copolymers and surfactants suffer from the fact that the structures that emerge from a simple free energy minimization are often polydisperse and irregular. Quite in contrast, nature has excelled in making highly monodisperse, regular structures through the controlled self-assembly of biological molecules such as virus capsid proteins.

It is clear that the design and fabrication of future materials and devices for photonics, molecular electronics, or drug delivery would enormously benefit if we were capable of self-assembling synthetic nanostructures with the precision and reliability found in biological self-assembly. However, this requires control over their assembly into precise and predictable structures, which still remains the primary obstacle to the bottom-up construction of novel materials and devices. It can only be achieved if we understand the relationship between specific types of interactions and the resulting target structures, and subsequently develop the capability to engineer and control these interactions between the different building blocks. Progress in soft matter based materials science and nanotechnology thus critically depends on a sound understanding of the various intermolecular interactions acting in often highly complex systems.

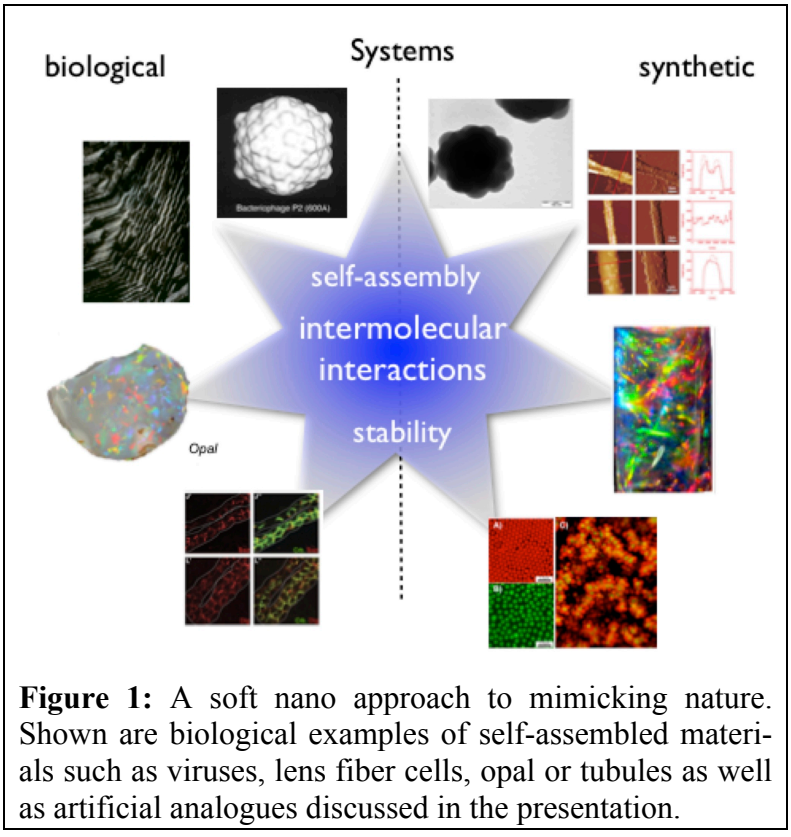

Figure 1: A soft nano approach to mimicking nature. Shown are biological examples of self-assembled materials such as viruses, lens fiber cells, opal or tubules as well as artificial analogues discussed in the presentation.

I will show how we can create functional hybrid materials using self-assembly processes. I will in particular focus on the possibilities offered by responsive nanoparticles. Responsive nanoparticles such as thermo- or pH-sensitive microgels or magnetic

hybrid particles allow for a variation of the form, strength and range of the interaction potential almost at will. They are not only attractive models in basic research, but also of considerable technological importance to materials science and nanotechnology as building blocks for nanostructured responsive organic-inorganic hybrid sys-

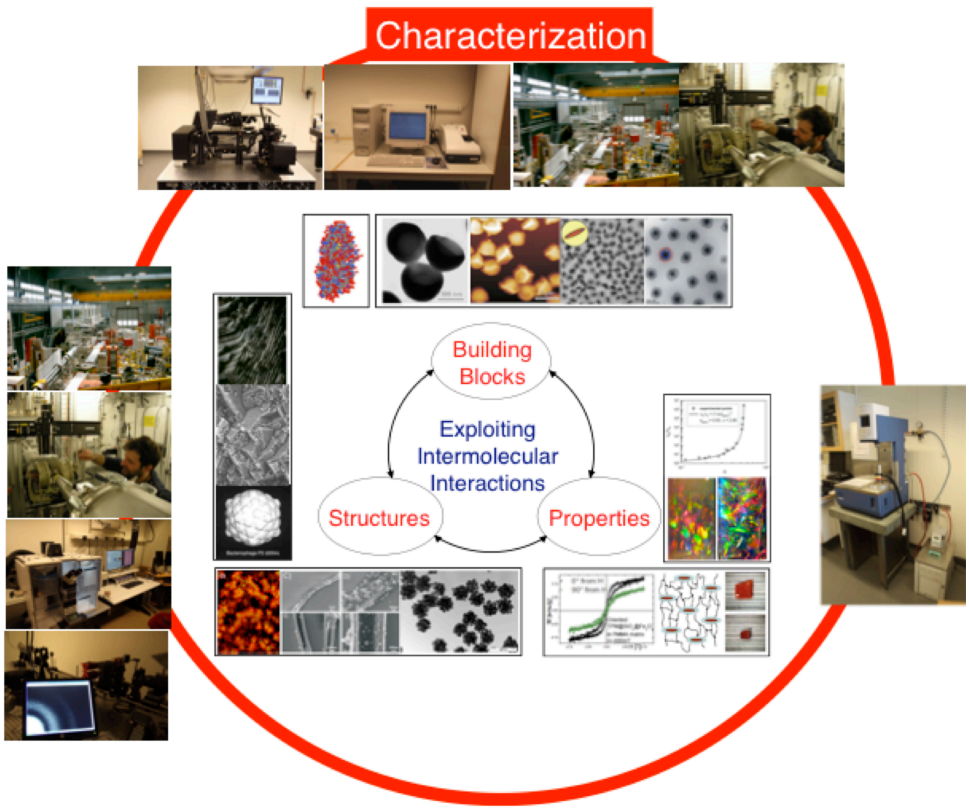

Figure 2: Combining responsive particles as building blocks with tuneable interaction forces and a multi-scale characterization platform to make and characterize hybrid structures and their materials properties.

tems. The combination of nanoscale inorganic moieties with organic polymers allows us to create materials with enhanced or even completely new properties. I will demonstrate how we can design and synthesize functionalized responsive nanoparticles that can be used to make adaptive polymer-colloid nanomaterials with tailored optical, magnetic and mechanical properties.

An important aspect of soft nanotechnology is the multi-scale characterization required by these hierarchical hybrid materials, where we have to determine not only the structure of and interactions between the nanoparticle building blocks, but also the resulting mesoscale structures and their optical, mechanical and magnetic properties. I will thus also introduce our experimental toolbox that combines real and reciprocal space techniques covering up to 8 orders in length scales, starting from almost atomic resolution.

References

A. Sánchez-Ferrer, M. Reufer, R. Mezzenga, P. Schurtenberger and H. Dietsch, Nanotechnology 21, 185603 (2010)
M. Hammond, H. Dietsch, O. Pravaz, and P. Schurtenberger, Macromolecules 43, 8340 (2010)
H. Dietsch, V. Malik, M. Reufer, C. Dagallier, A. Shalkevich, M. Saric, T. Gibaud, F. Cardinaux, F. Scheffold, A. Stradner, and P. Schurtenberger, Chimia 62, 805 (2008)