Self-organization of nanoparticles into highly ordered lattices with protein nanocages as an atomically precise ligand shell

Michael Rütten[1], Hendrik Böhler[1], Laurin Lang[1,2], Tobias Beck[1,2]

[1]Universität Hamburg, Department of Chemistry, Institute of Physical Chemistry, Grindelallee 117, 20146 Hamburg, Germany, tobias.beck@chemie.uni-hamburg.de [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

In nature, molecules can function as a matrix to organize inorganic components into ordered hybrid materials such as bone or nacre. These materials have inspired researchers to create novel composite materials based on biomolecules and inorganic building blocks such as nanoparticles.[1] However, the controlled assembly of inorganic components and nanoparticles into highly ordered structures still represents a major challenge.

We have established a novel method for the self-organization of biomolecular building blocks and nanoparticles. Here, protein containers, engineered with opposite surface charge, are used as an atomically precise ligand shell for the assembly of inorganic nanoparticles.[2] The assembly of protein-nanoparticle composites through supramolecular interactions yields highly ordered nanoparticle superlattices with unprecedented precision (Fig. 1A). The structure of the protein scaffold can be tuned with external stimuli such as metal ion concentration.[3] Importantly, these composite materials show catalytic activity inside the porous material.[4]

Towards the formation of defined biohybrid materials, we demonstrated that the highly specific cargo-loading mechanism of the bacterial nanocompartment encapsulin can be employed for encapsulation of artificial cargo such as inorganic nanoparticles.[5] For this purpose, gold nanoparticles were decorated with cargo-loading peptides. By supramolecular interactions between the peptides and peptide-binding pockets on the inner container surface, nanoparticles are encapsulated with extremely high efficiency (Fig. 1B).

Recently, the interactions of gold nanoparticles and fluorescent molecules inside ordered lattices were studied with confocal lifetime imaging. The gold nanoparticles show strong plasmon-exciton interactions and induce drastic shortening of fluorescent lifetimes. [6]

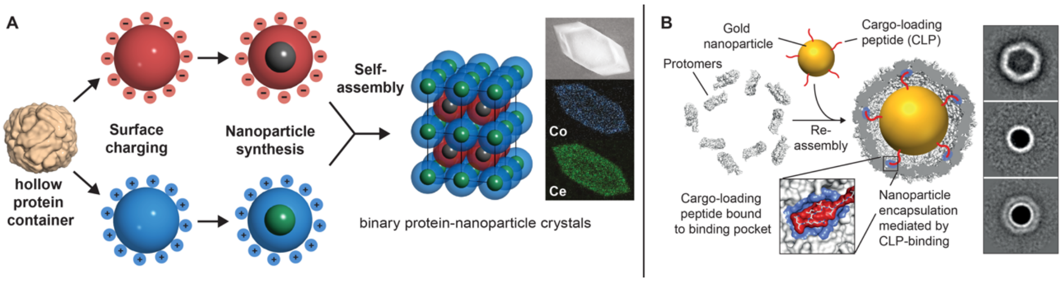

Figure 1. A) General strategy for the assembly of binary protein-nanoparticle crystals based on charged protein containers. B) Efficient encapsulation of functionalized gold nanoparticles into the encapsulin protein container. *Right panel:* TEM class averages of empty containers, gold nanoparticles and encapsulated gold nanoparticles.

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