Designing mesoporous materials for a sustainable society

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Materials science plays a crucial role in meeting many of the UN's sustainable development goals, and mesoporous materials, characterized by a large specific surface area (>500 m^2/g) and pores in the range of 2 – 50 nm, are anticipated to play a critical role to reach them. For example, development of noble-metal-free catalysts for water splitting and recombination enables storage of sustainable energy from wind- and solar power, and carriers of antimicrobial peptides and therapeutic ions are needed to reduce the usage of antibiotics. The materials are synthesized using soft-templating with micelles in sol-gel or hydrothermal syntheses which enable controlled characteristics for the different applications. In this talk, I will focus on how understanding and controlling the material formation processes enable optimization of material characteristics.

Mesoporous silica film can be used as drug delivery systems from implants, catalysts, and sensors. By combining in situ IR-spectroscopy with small angle x-ray scattering, insights to both the formation of the silica network and the micelle evolution are obtained. By adding hydrophobized substrates to the synthesis solution when the micelles are slightly silicated, it is possible to grow films with an available surface area per substrate area is up to 170 m^2/m^2. By careful tailoring of the substrate functionalization, it is possible to grow homogeneous films on silicon wafers, titanium screws, and glass beads. The films are biocompatible and can be used to deliver both hydrophilic and hydrophobic drugs from e.g. an implant surface.

Mesoporous transition metal oxides are sustainable alternatives to the Ir-, and Ru-based electrocatalysts that today are used for water splitting and recombination in electrolyzers and fuel cells. By tailoring the roughness of nanoporous NiO, the oxygen evolution reaction requires less over-potential compared to commercially available Ir/C-catalysts. By altering the composition, the product selectivity in the oxygen reduction reaction can be tuned. This enables noble-metal-free local production of O_2, H_2O_2, and OH^-.