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Improving the mechanical strength and photocatalytic activity of 3D-structured titania aerogels by ALD coating

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Aerogels are nanoporous, exceptionally lightweight materials with a large internal surface area, and they maintain the properties of their nanoscopic building blocks at the macroscale. These properties make aerogels attractive for catalytic applications. However, the production of aerogels typically lacks control over the structure at larger length scales. To address this limitation, we employed direct ink writing to 3D print a titanium dioxide nanoparticle-based aerogel. This extrusion-based additive manufacturing technique enabled hierarchical structuring of the material.

One challenge in working with aerogels is their high fragility. Although they can carry many times their own weight, aerogels are brittle and easily break under mechanical stresses. This issue is exacerbated by 3D printing, as the high shear forces during extrusion disrupt the aerogel microstructure. To address this, we employed atomic layer deposition (ALD) to improve the mechanical properties. This deposition technique enabled conformal coatings inside the nanopores of the aerogel, potentially overcoating cracks and breaking points. Nanoindentation measurements showed a recovery of hardness and an increase in elastic modulus after ALD coating of the 3D-printed aerogels.

The titania aerogels have been applied in photocatalytic water splitting, where periodic 3D microstructuring enhances gas permeability compared to a monolithic aerogel while maintaining the high light-harvesting efficiency of the nanoporous material. ALD coating improved the photocatalytic activity of the aerogels by enhancing nanoparticle interconnectivity. Calcination further enhanced photocatalytic activity by crystallizing the amorphous titania coating into anatase. The combined effects of ALD coating and calcination resulted in a 20-fold increase in hydrogen evolution from 16.5 ppm to 325 ppm.

Author: SCHMIDT, Malte Maximilian (Universität Hamburg)

Co-author: GRÖNE, Tjark Leon Raphael (Universität Hamburg)

Presenter: SCHMIDT, Malte Maximilian (Universität Hamburg)

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