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Water in Hierarchically Porous Silicon: An In-Situ X-ray Imaging Study

Nature excellently designs highly efficient, multi-functional (hybride-)materials such as hierarchically capillary systems in respiratory systems or plants. These systems are characterized by large internal surfaces, good mechanical stability and an optimized mass transport. Inspired by natural materials we are aiming to mimic such systems with artificially produced hierarchically porous silicon [1]. Water infiltrates porous media just by capillary forces, dragging the liquid against gravity into the matrix. For porous materials with a monomodal pore-size distributions the imbibition is well described by the Lucas-Washburn law [2], while a bi- or multimodal pore-sized system deviates from it due to different capillary pressures occurring from the drastic variations in pore radii. In opaque materials, like silicon, the tracking of the pathways water takes while rising up in the porous matrix is challenging, therefore we performed in-situ Zernike phase-contrast X-ray imaging at DESY. Findings from the X-ray imaging study are essential for the interpretation of laboratory experiments and designing more advanced (hybride-)material systems for capillarity-driven pumps, sensors or actuators [3].

[1] S. Gries et al., Wafer-Scale Fabrication of Hierarchically Porous Silicon and Silica by Active Nanoparticle-Assisted Chemical Etching and Pseudomorphic Thermal Oxidation. Small 2023, 19, 2206842. https://doi.org/10.1002/smll.202206842

[2] J. Sanchez & L. Dammann et al., Deformation dynamics of nanopores upon water imbibition, Proc. Natl. Acad. Sci. U.S.A. 2024, 121 (38) e2318386121, https://doi.org/10.1073/pnas.2318386121

[3] M. Brinker et al., Wafer-Scale Electroactive Nanoporous Silicon: Large and Fully Reversible Electrochemo-Mechanical Actuation in Aqueous Electrolytes. Adv. Mater. 2022, 34, 2105923, https://doi.org/10.1002/adma.202105923

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