

Elastic deformation does not impact fluid sorption in stiff mesoporous materials

For almost a century we have been familiar with the deformations of porous solids upon adsorption. This phenomenon occurs in the drying of concrete and alters the permeation of some porous membranes for example. The reverse process – the impact of deformation on adsorption – has not been investigated as much. The Nanometric Thin Films team of the INSP, in collaboration with Etienne Rolley (LPENS), has shown that this reverse process is undetectable in stiff mesoporous materials, such as porous silicon.

In 2009, Annie Grosman and Camille Ortega, members of the Nanometric Thin Films at the time, observed that the sorption in a porous silicon layer still attached to its substrate was different from that of a free-standing layer. This effect was explained by the different strains in the two samples. Such a strain-adsorption coupling was consistent with many features of porous silicon but was not based on any direct evidence, and the existence of the coupling remained controversial.

A direct observation of this coupling is based on the precise measurement of the adsorbed amount in a single sample which is submitted either to a stress or a strain. We implemented an interferometric device which measures the adsorbed amount via the optical thickness of the silicon porous layer. During a sorption cycle, the layer is submitted either to a controlled strain (by bending the underlying substrate in the case of a supported layer), or a controlled stress (by stretching with a piezo ceramic drive in the case of a membrane). In the elastic limit, we found that the effect on adsorption of strain or stress is always below the experimental resolution.

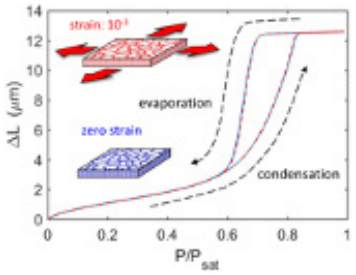

Figure 1
Optical thickness as a function of hexane vapor pressure, here for a porous layer 20 µm thick and with a 70 % porosity.
Blue curve: without strain / red curve: strain of 0,8 10-3. We do not measure any significant effect of the strain.

With a global thermodynamic approach, we have shown that this result is consistent with the measured deformations induced by sorption in porous silicon. In a general way, for stiff mesoporous materials such as porous silicon, but also, zeolite, silica or porous alumina, the deformations induced by capillary forces during sorption are easy enough to measure, however a controlled strain is expected to have always a very small impact on adsorption, beyond the resolution of current techniques.

Reference

"Stress or strain does not impact sorption in stiff mesoporous materials"
Marine Bossert, Annie Grosman, Isabelle Trimaille, Camille Noûs and Etienne Rolley
Langmuir, 36, 11054-11060 (2020)

https://pubs.acs.org/doi/abs/10.1021/acs.langmuir.0c01939

Contact

marine.bossert(at)insp.jussieu.fr