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## Ultrasound measures surface stress in nanopores

BY [LUCY SMITH](#) on [JANUARY 11, 2017](#)

**Ultrasound is a versatile technique to study the elastic behaviour of materials. In a recent [Letter in \*Journal of Physics: Condensed Matter\*](#) Klaus Schappert and Rolf Pelster have shown that changes of the longitudinal modulus during sorption of a substance in a nanoporous matrix reveal the adsorption-induced changes of surface stress. Below the authors of the study explain more about their research.**

Surface and interfacial energies are key parameters for many adsorption phenomena, e.g. for the sorption-induced deformation of porous materials. Adsorbates in nanoporous solids exert a normal pressure on the pore walls, which leads to a deformation of the porous matrix. This effect is due to a change of the material's surface stress, i.e. it is linked to the free energy per unit area necessary to deform the pore walls.

For non-porous solids changes of surface stress are easily determined from the bending of a film or cantilever. For porous materials such a method is inappropriate and this raises the question of how a change of surface stress in consequence of adsorption can be measured experimentally. Now, we have developed an indirect method using ultrasonic waves, which supplies values that correspond to theoretical predictions.

For our model system of argon in nanoporous glass a reduction of the vapour pressure  $p$  below the saturation vapour pressure  $p_0$  results in a decrease of the adsorbed argon's longitudinal modulus (cp. Fig. 1). The continuous decrease of  $\beta_{Ar,ads}$  can be explained by the simultaneous decrease of the deforming normal pressure  $\Delta p_s$  acting on the pore surface. One term contributing to  $\Delta p_s$  is the negative Laplace pressure due to the

curved liquid-vapour interfaces at the pore ends (cp. Fig. 1). Lowering the vapour pressure leads to an increase of the curvature and thus to a decrease of the normal pressure  $\Delta p_s$ . But also the adsorbate is exposed to this pressure. Therefore, the longitudinal modulus of the adsorbate differs always slightly from the modulus of the bulk substance, in particular at the saturation vapour pressure  $p_0$ , where  $\Delta p_s$  takes its maximum value.

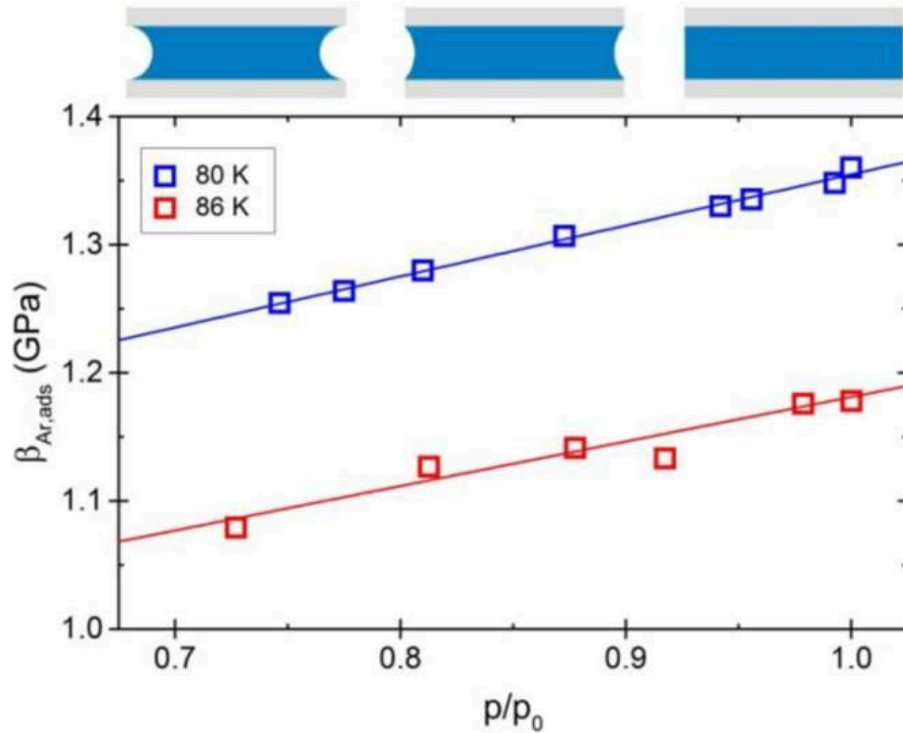


Fig. 1: Longitudinal modulus of adsorbed liquid argon,  $\beta_{Ar,ads}$ , at 86 K and 80 K as a function of the reduced pressure  $p/p_0$  (for full pores). A reduction of the vapour pressure  $p$  increases the curvature of the menisci at the pore ends (cp. schematic sketch).

Now we have discovered that the measured change of elasticity reveals the normal pressure at saturation,  $\Delta p_s(p=p_0) = \Delta p_s^{sat}$ . As we show in Fig. 2 there is a linear relation between the longitudinal modulus of the adsorbate  $\beta_{Ar,ads}$  and the deforming normal pressure  $\Delta p_s$ . When the normal pressure vanishes, i.e.  $\Delta p_s = 0$ , we can expect the elastic behaviour of bulk argon. Consequently, a linear extrapolation of the longitudinal modulus of the adsorbed argon to the value for the longitudinal modulus of bulk argon yields the normal pressure at saturation,  $\Delta p_s^{sat}$ . This also gives access to the change of surface stress,  $(\Delta f)_{sat}$ , since  $\Delta p_s^{sat} = -(\Delta f)_{sat}/r$  holds, where  $r \approx 4$  nm denotes the pore radius.

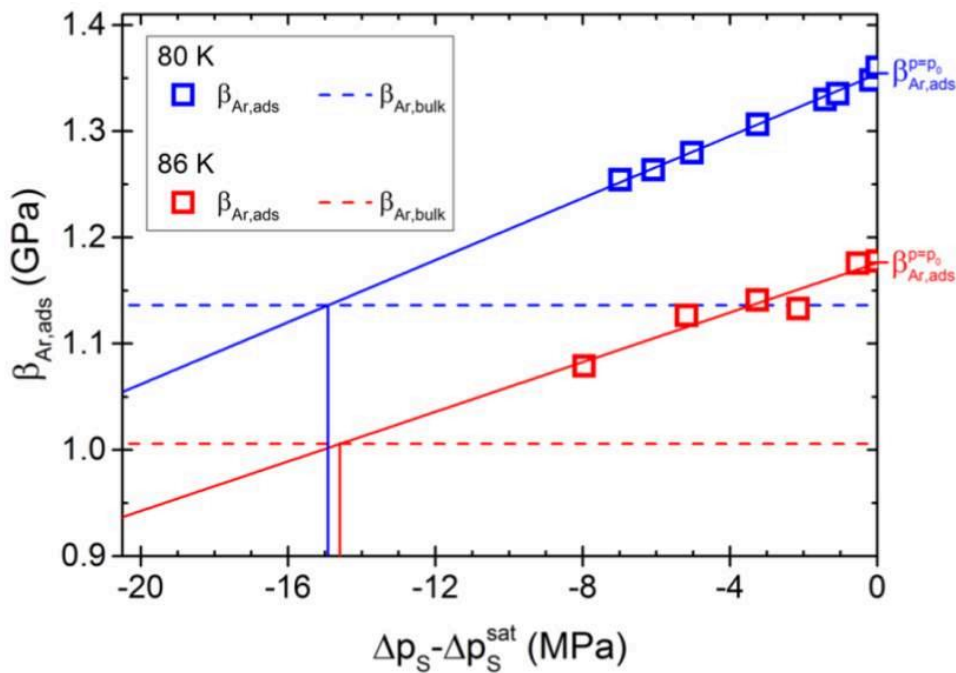


Fig. 2: Dependence of the longitudinal modulus of adsorbed liquid argon,  $\beta_{Ar,ads}$ , on the pressure  $\Delta p_s - \Delta p_s^{sat}$  at 86 K and 80 K. The points of intersection of the linear extrapolation with the horizontal lines (showing the bulk values of the longitudinal modulus at the respective temperatures) reveal the normal pressure at saturation,  $\Delta p_s^{sat} \approx 15$  MPa.

Thus, for nanoporous materials our experimental method offers the possibility to study adsorption-induced changes of surface stress from changes in the adsorbate's elasticity. The application of our method on other porous systems, in particular on those that are considered as storage materials (e.g. for methane or  $\text{CO}_2$ ) or for other technical applications, will help to gain a better understanding of the behaviour of such systems.

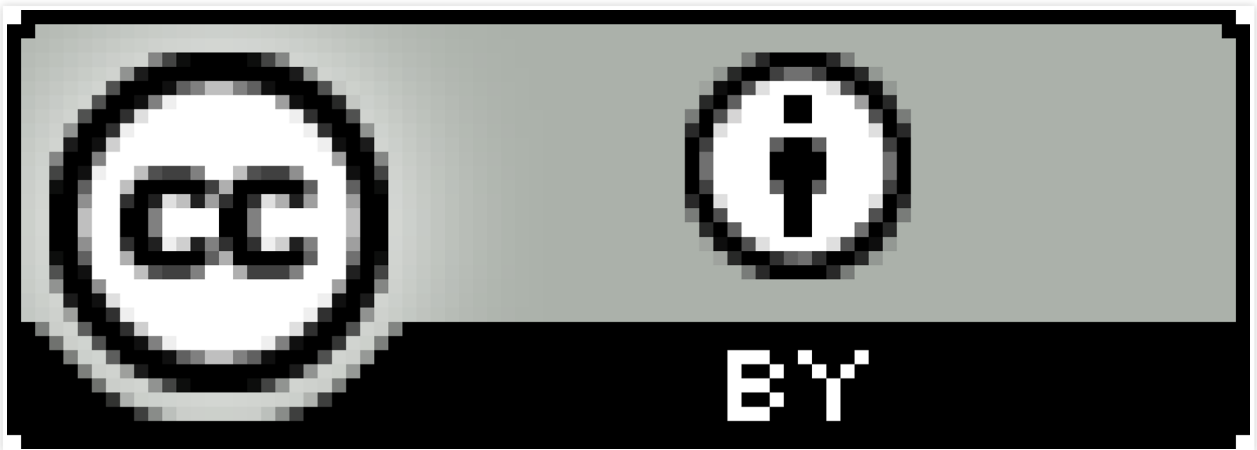
### About the authors



**Klaus Schappert** is postdoctoral researcher in the Physics Department at the Universität des Saarlandes in Saarbrücken, Germany. He studies effects of adsorption in nanoporous materials and his current research focuses on influences of nanoconfinement on the elastic behaviour of adsorbed substances, on their phase behaviour, and on sorption-induced deformation.



**Rolf Pelster** is Professor for Experimental Physics and Didactics of Physics at the Universität des Saarlandes in Saarbrücken, Germany. His group specialises in the study of heterogeneous materials applying different techniques including dielectric spectroscopy, infrared spectroscopy, and ultrasonic measurements. More information can be found at <http://www.uni-saarland.de/lehrstuhl/pelster.html>.



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Images taken from [Klaus Schappert and Rolf Pelster, J. Phys.: Condens. Matter 29, 06LT01 \(2017\)](#),

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