Wetting, Imbibition and Switchable Elastocapillarity in Nanoporous Media

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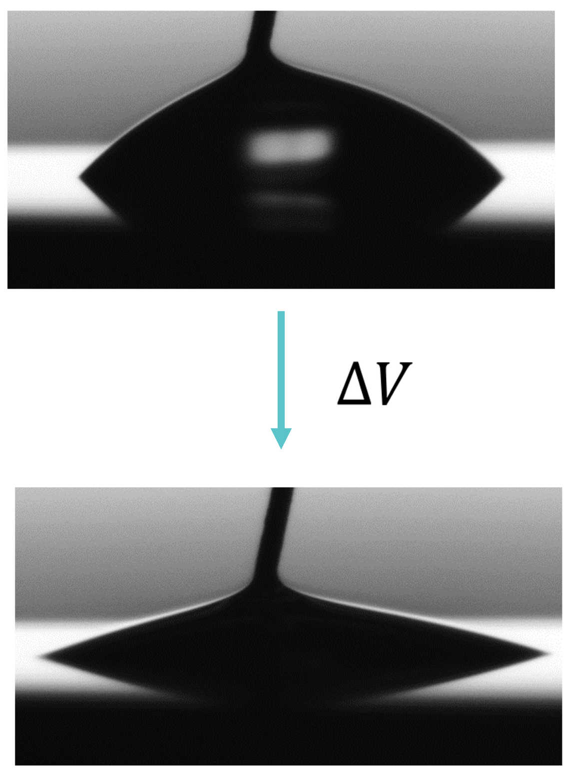
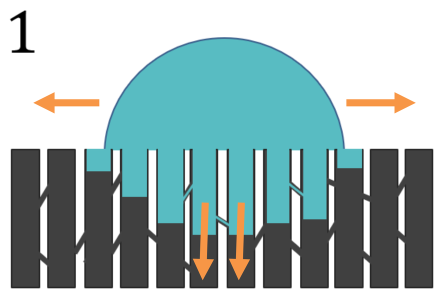
Electrowetting



Change in the wetting properties due to an electric field. Experimental images of NaCl solution on silicon.

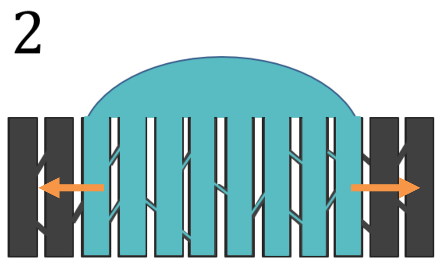
Spreading and radial imbibition at nanoporous silicon surfacs

1



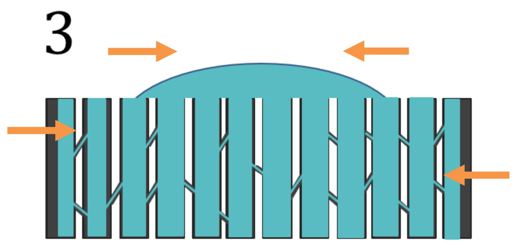
Spreading and vertical imbibition

2

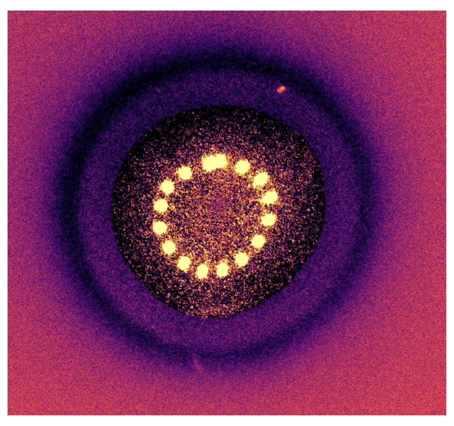


Contact line pinning and radial imbibition

3



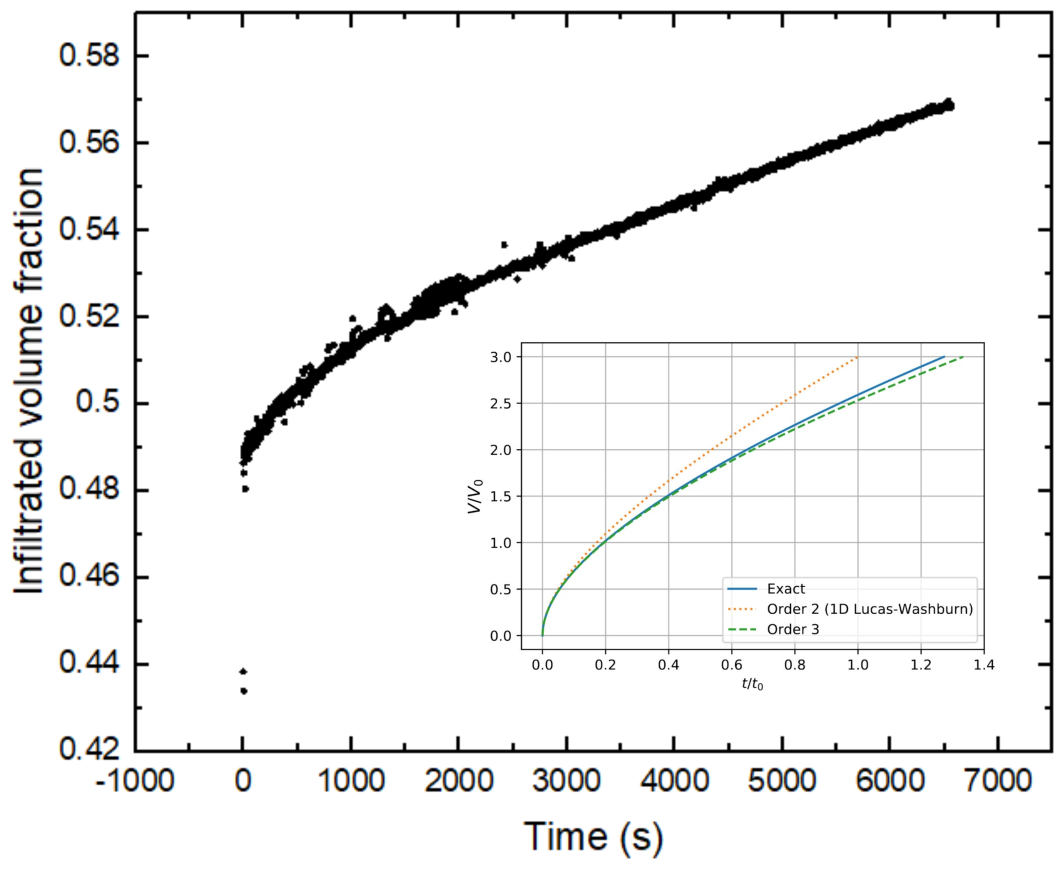
Receeding of the imbibition front and contact line



Experimental top view of water on a pSi substrate.

From Darcy's law, radial imbibition equation (1):

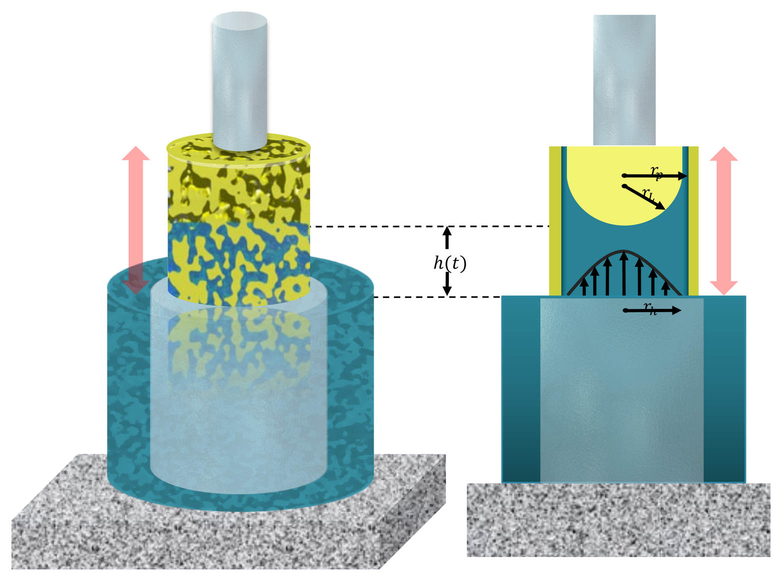
$$-\frac{2\kappa\Delta P}{\phi}t = r^2 \ln\left(\frac{r}{r_0}\right) + \frac{r_0^2 - r^2}{2}$$



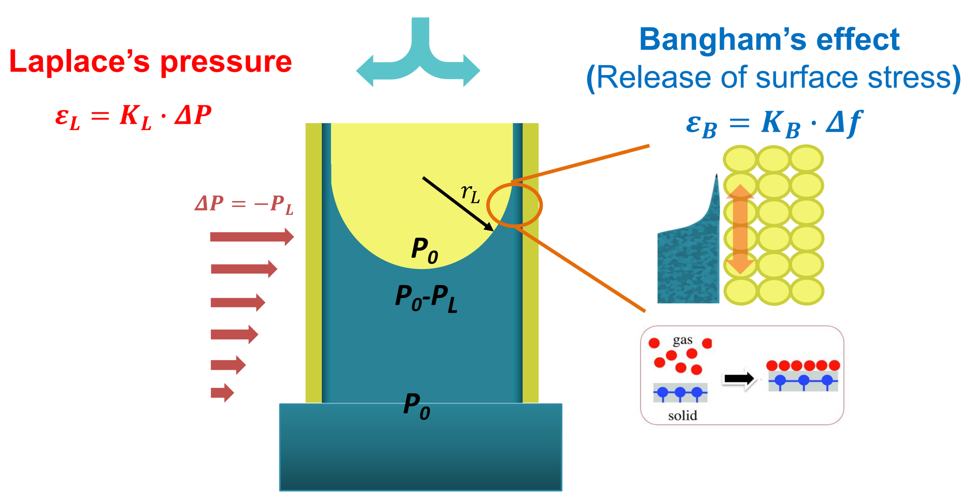
Experimental curve (squalane) and theoretical behavior according to model.

Imbibition-induced deformation of nanoporous media

Dilatometry experiment upon imbibition



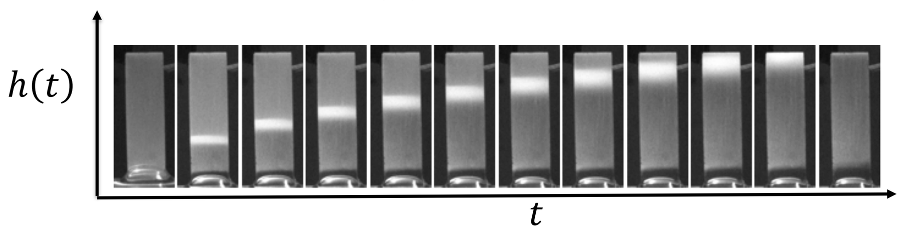
Interplay of strain (ε) inducing phenomena

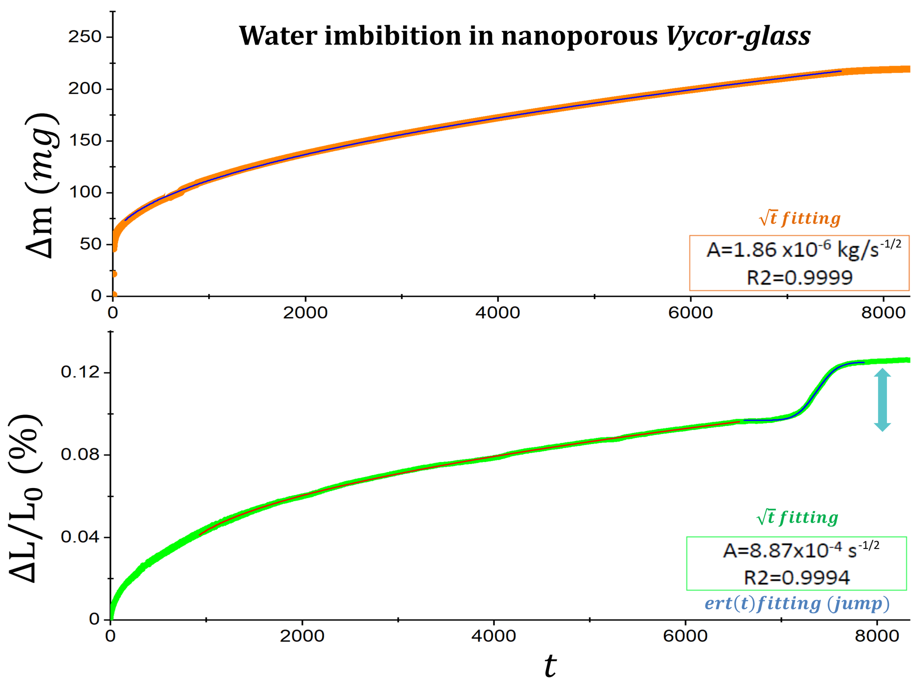


Experimental results

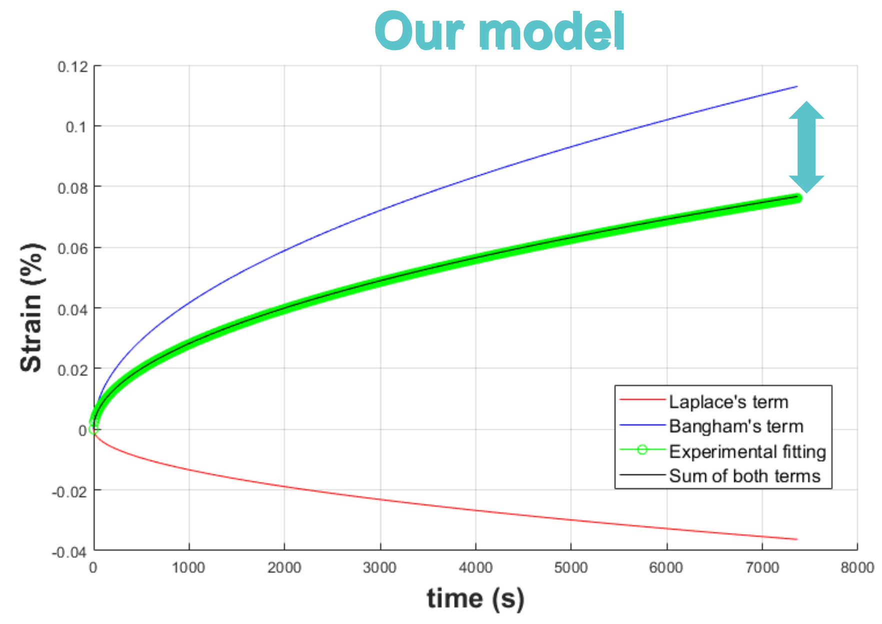
Capillary rise $h(t)$ follows the Lucas-Washburn law:

$$h(t) \propto \sqrt{t}$$





Our model



The **released surface stress** $\delta f(t)$ must be proportional to the "*amount of wetted surface*"

$$[\varepsilon(t)]_B = \frac{2}{3K}\frac{\nu - 1}{1 - 2\nu}\frac{\delta f(t)}{(1-\phi)r} \qquad \delta f(t) \propto S(t)_{wetted} = C \times A \times \alpha \times h(t)$$

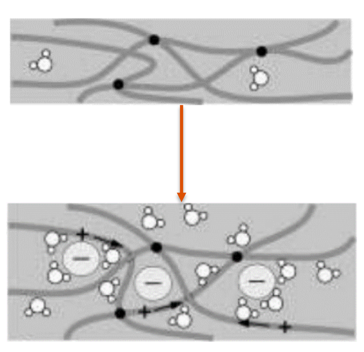
At a given time t, only the proportional part of the body $h(t)$ is under the **Laplace pressure** influence

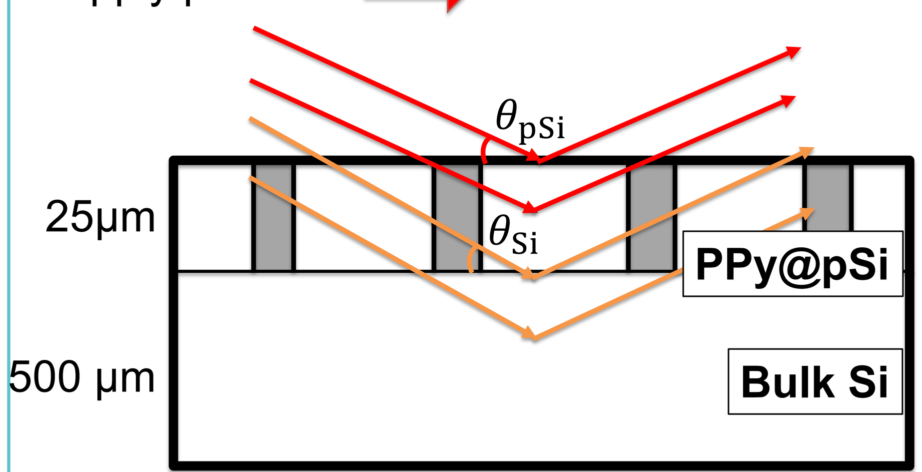
$$[\varepsilon(t)]_L = -\frac{\gamma}{r\, M_{PL}} \times \frac{h(t)}{L}$$

$$\varepsilon(t) = [\varepsilon(t)]_L + [\varepsilon(t)]_B = \left[\left(-\frac{\gamma}{r\, M_{PL}} \times \frac{1}{L}\right) + \left(C\frac{4}{3K}\frac{\nu - 1}{1-2\nu}\frac{A}{[(1-\phi)r]^2}\right)\right] \times h(t)$$

In-situ X-ray diffraction study of electrosorption-induced actuation in porous silicon

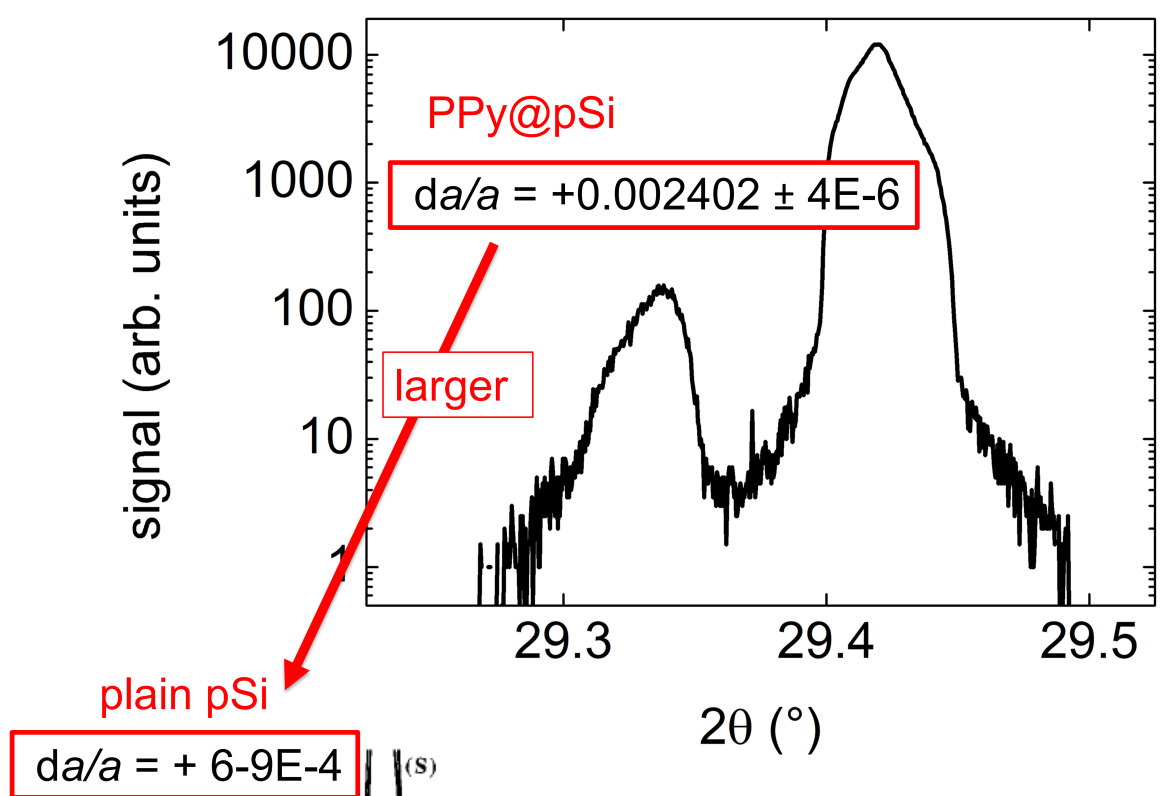
- polypyrrole (PPy) actuation:
  expansion by intake of ions
  contraction by release of ions
- Infiltrate pores of pSi with PPy,
  infiltrate with electrolyte,
  apply potential → **actuator**

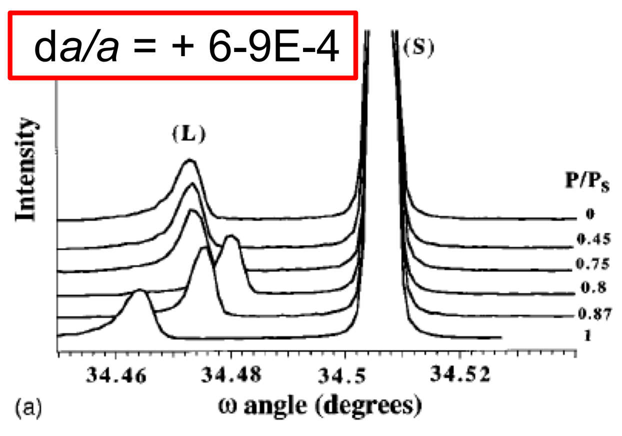




- θ-2θ - measurement: Bragg diffraction on both pSi and bulk Si.
- Lattice mismatch of pSi:

$$\frac{\partial a}{a} = \frac{\theta_{pSi} - \theta_{Si}}{\tan(\theta_{Si})} = \frac{\partial\theta}{\tan(\theta_{Si})}$$

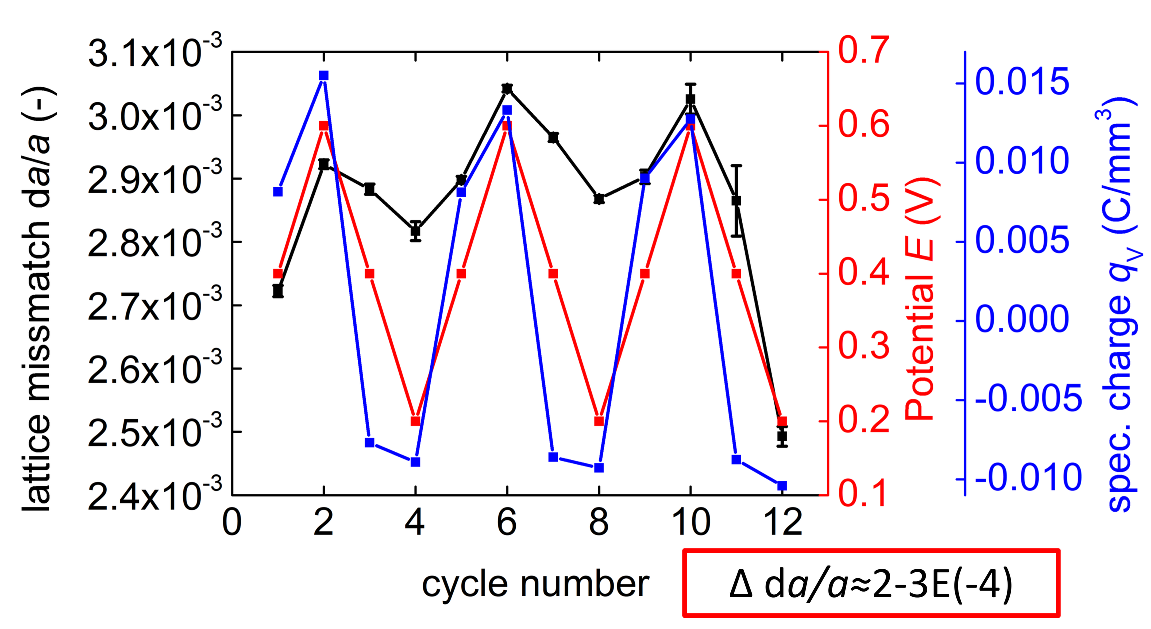




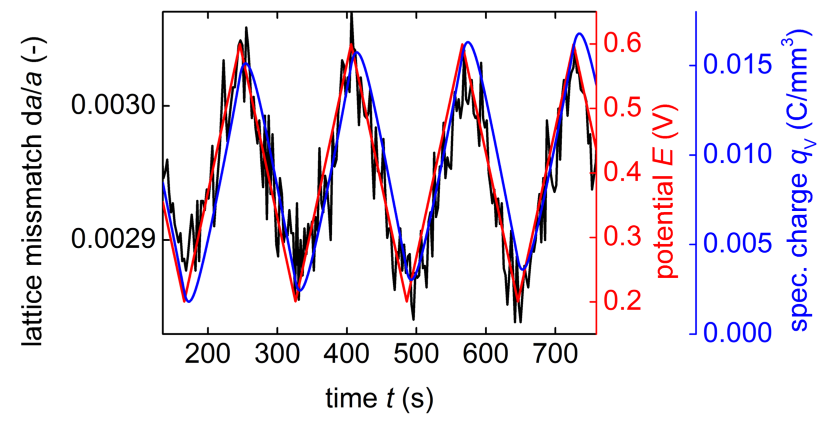
Dolino, G., Bellet, D. and Faivre, C. (1996). Adsorption strains in porous silicon. *Phys. Rev. B*, *54*(24), 17919.

- θ- 2θ measurement shows clear splitting of pSi- and Si peak
- PPy filling alone strains pSi a lot

voltage control of lattice mismatch:



- lattice **expands** when voltage is **increased**
- lattice **contracts** when voltage is **decreased**



linear dependency of electroactuation!

SPP 2171

SFB 986 M³

ΧΦΜ