

Elasticity of Liquid Nitrogen in Nanoporous Vycor Glass

Klaus Schappert and Rolf Pelster

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- Elastic moduli in nanopores?



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- Factors influencing elasticity?

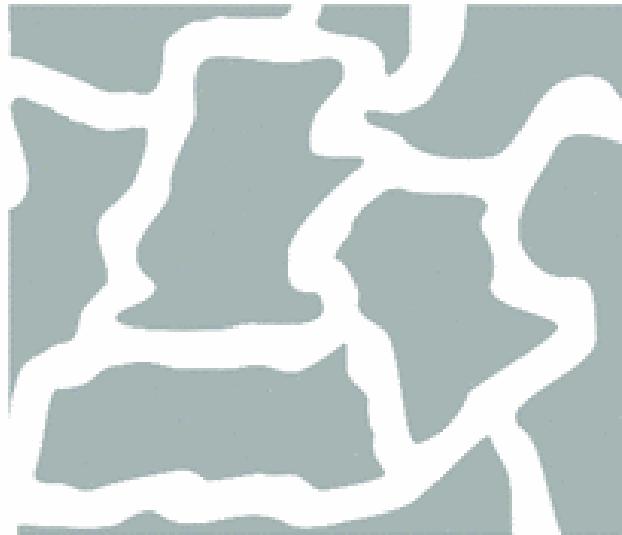
- Interaction between adsorbate and pore surface
- Laplace pressure
- pore size
- porosity

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- Laplace pressure
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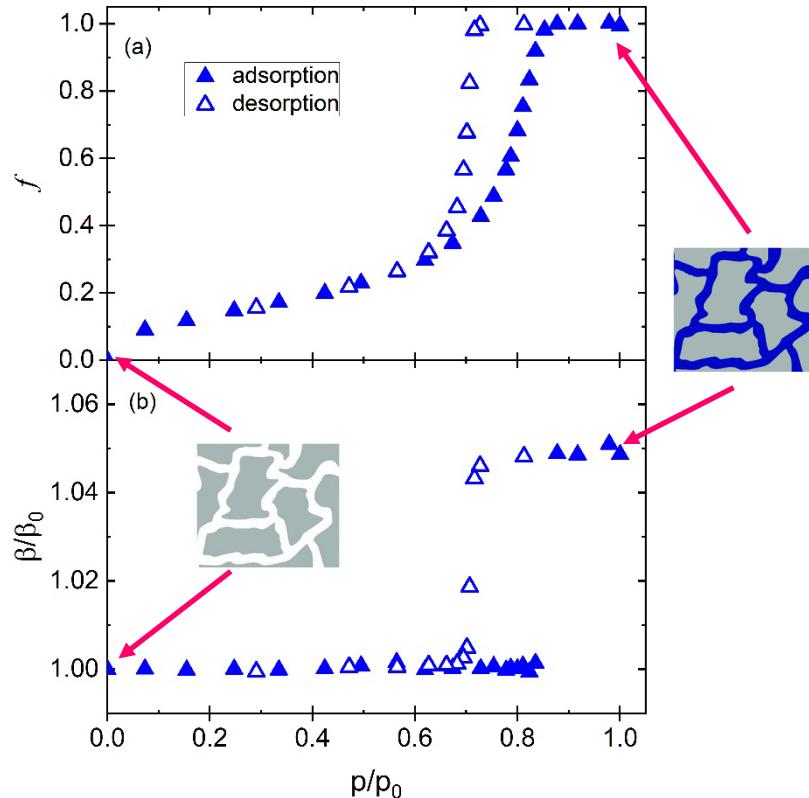
Nanoporous Vycor glass



K.S. and R.P., Phys. Rev. B 83, 184110 (2011)

- 3D network of interconnected pores
- average pore radius:
 $r_p = 3.8\text{-}4.0 \text{ nm}$
- porosity: $\phi = 0.25\text{-}0.28$

Effective longitudinal modulus β



□ Liquid argon (86 K) in porous Vycor glass

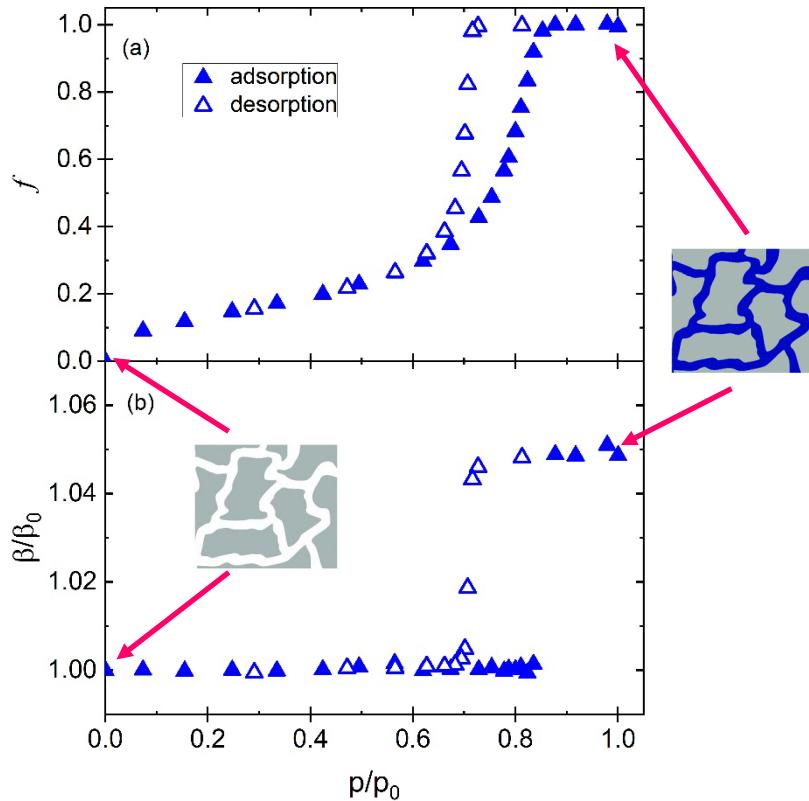
□ for $f < 1$:

- modulus unchanged
 $\beta \approx \beta_0$

□ for $f \approx 1$:

- increased modulus
 $\beta > \beta_0$

Effective modulus $\beta \leftrightarrow$ intrinsic modulus $\beta_{Ar,ads}$



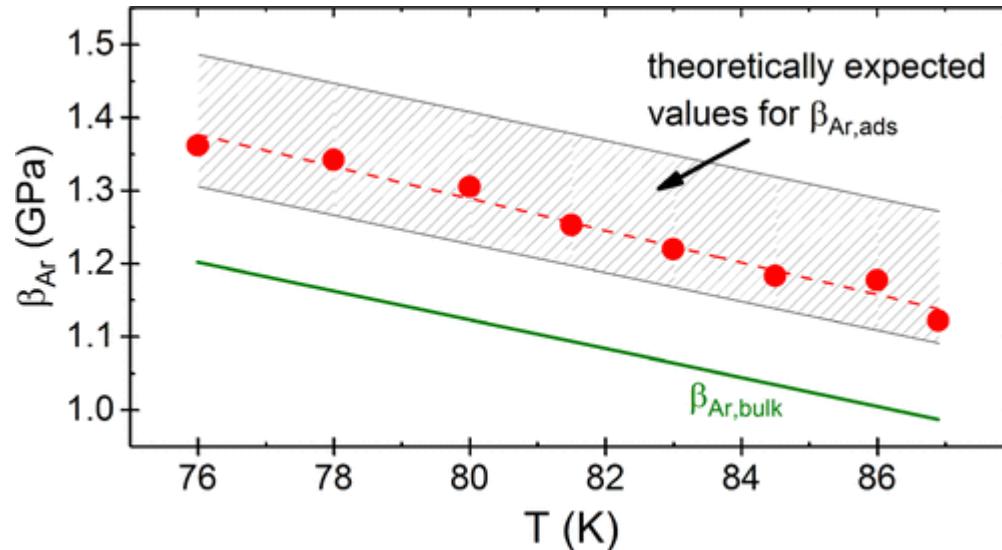
for $f \approx 1$ (filled pores):

$\beta_{Ar,ads}$?

effective medium equation

$$\Delta\beta = (\beta - \beta_0) = C \beta_{Ar,ads}$$

$\beta_{Ar,ads}$ in Vycor



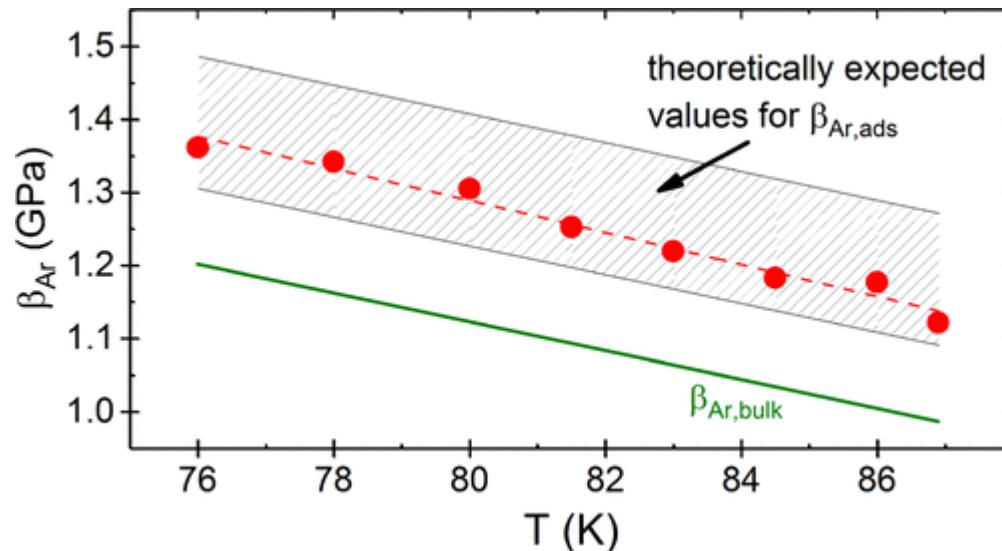
K. Schappert and R. Pelster, J. Phys. Chem. C 122,
5537–5544 (2018)

$\beta_{Ar,ads}$ in Vycor

Enhancement as a result
of adsorption stress:

$$\beta_{ads} = \beta_{bulk}(p_0) + \alpha \Delta p_S^{sat}$$

with Δp_S^{sat} from:
G. Y. Gor, Langmuir 30,
13564–13569 (2014)

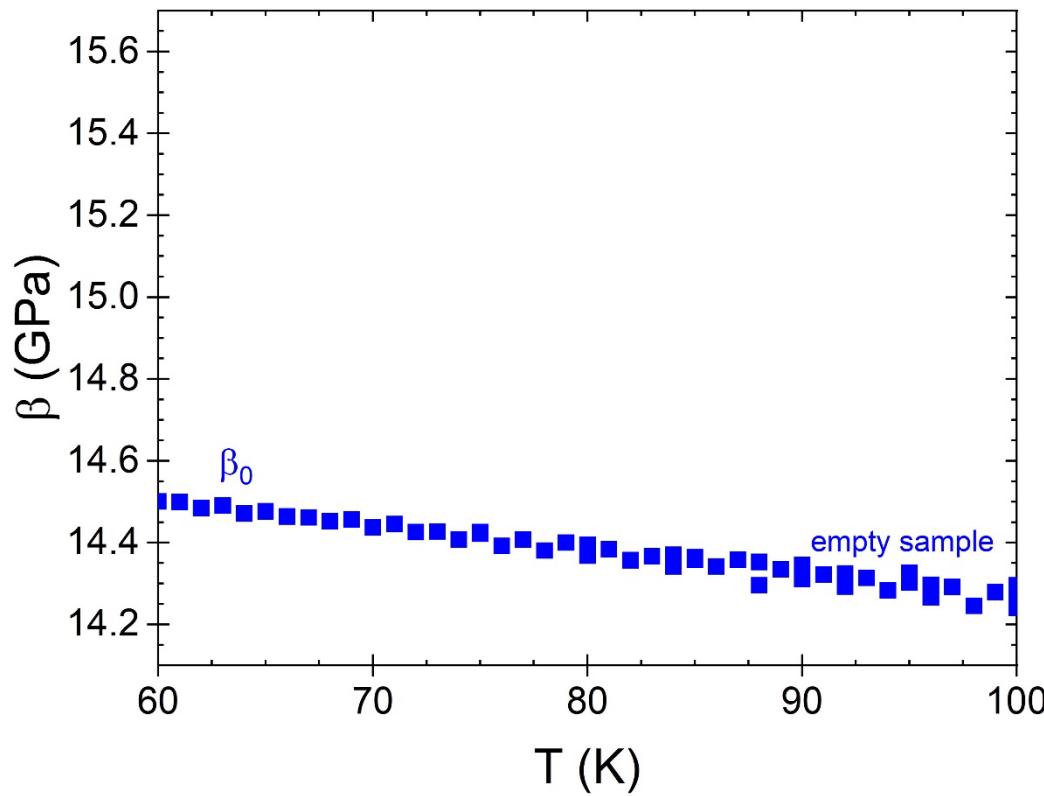


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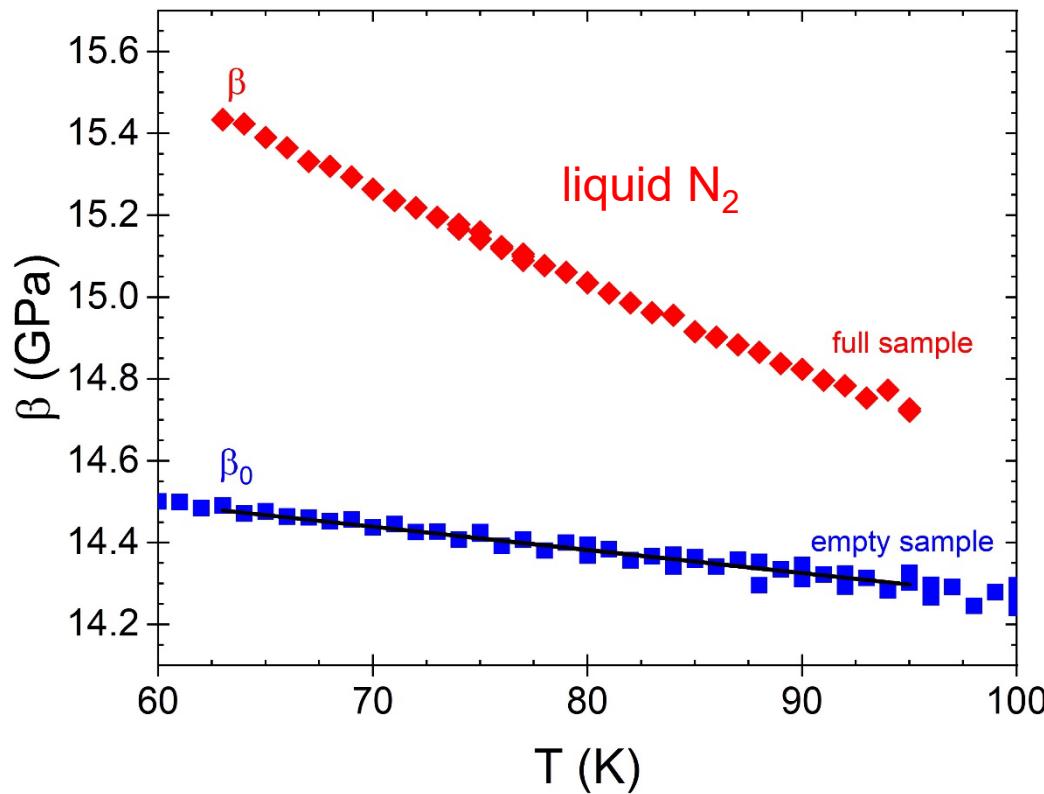


Influence of nanoconfinement on $\beta_{N2,ads}$?

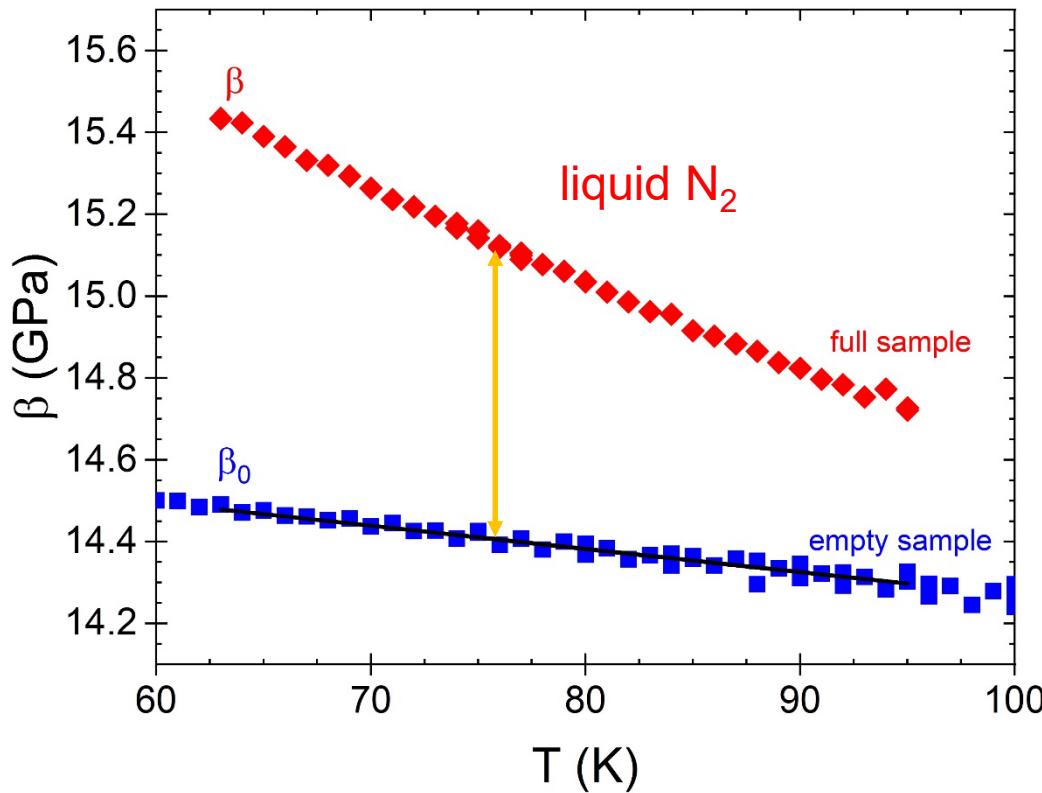
Longitudinal modulus of empty nanoporous glass



Longitudinal modulus of empty and filled sample

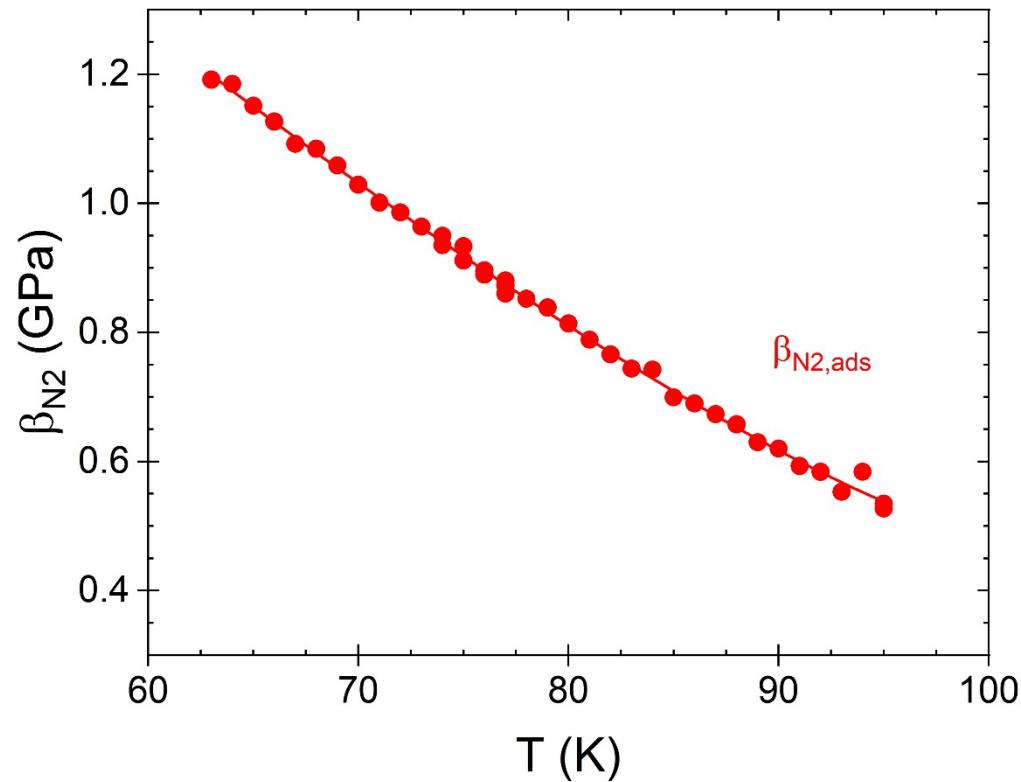


Effective medium analysis for $f = 1$

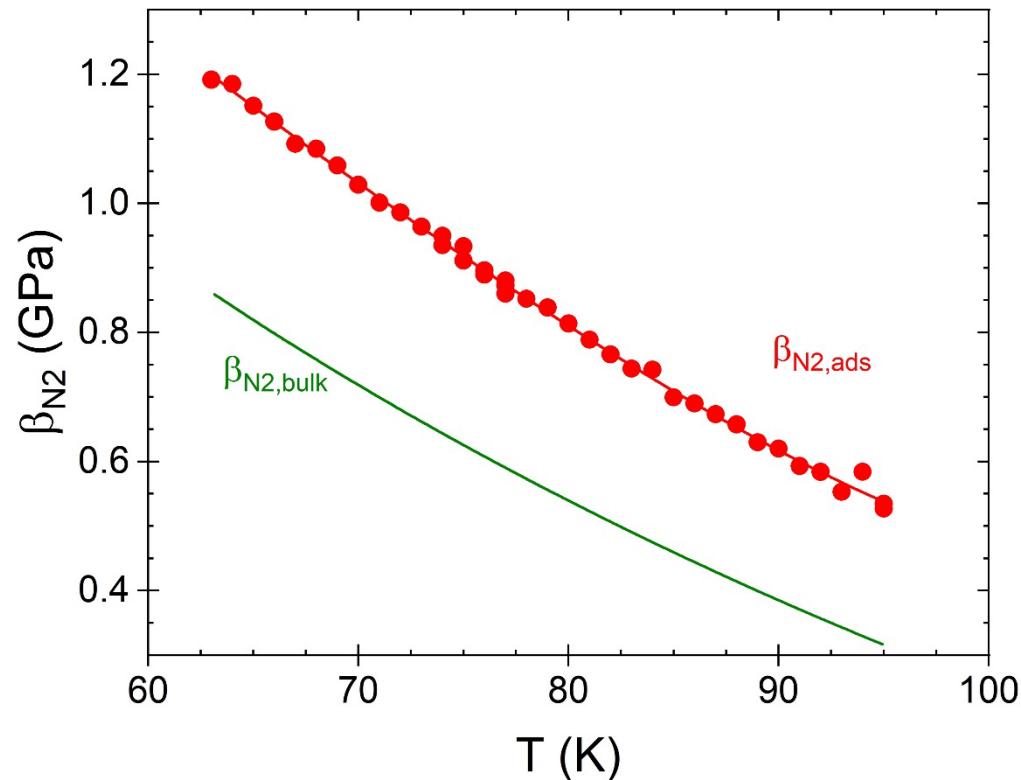


$$\begin{aligned}\Delta\beta &= (\beta - \beta_0) \\ &= C \beta_{N2,ads}\end{aligned}$$

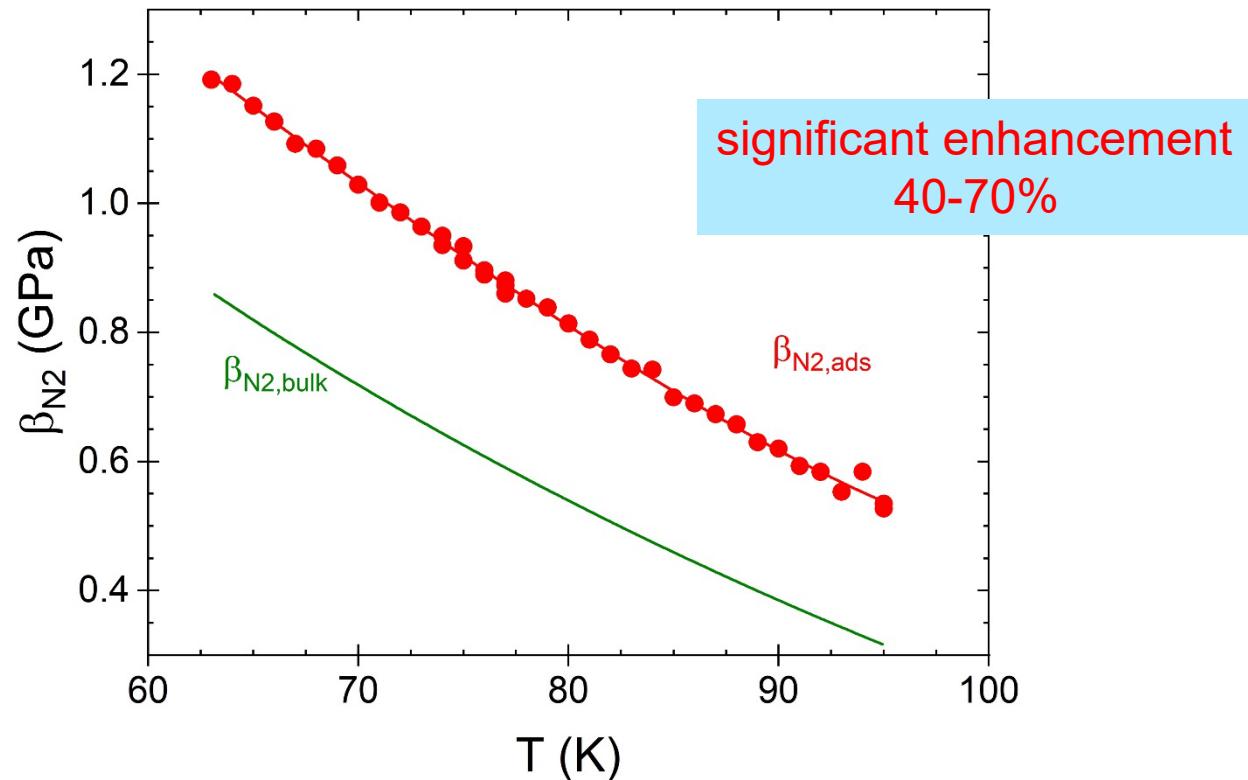
Longitudinal modulus of nanoconfined nitrogen



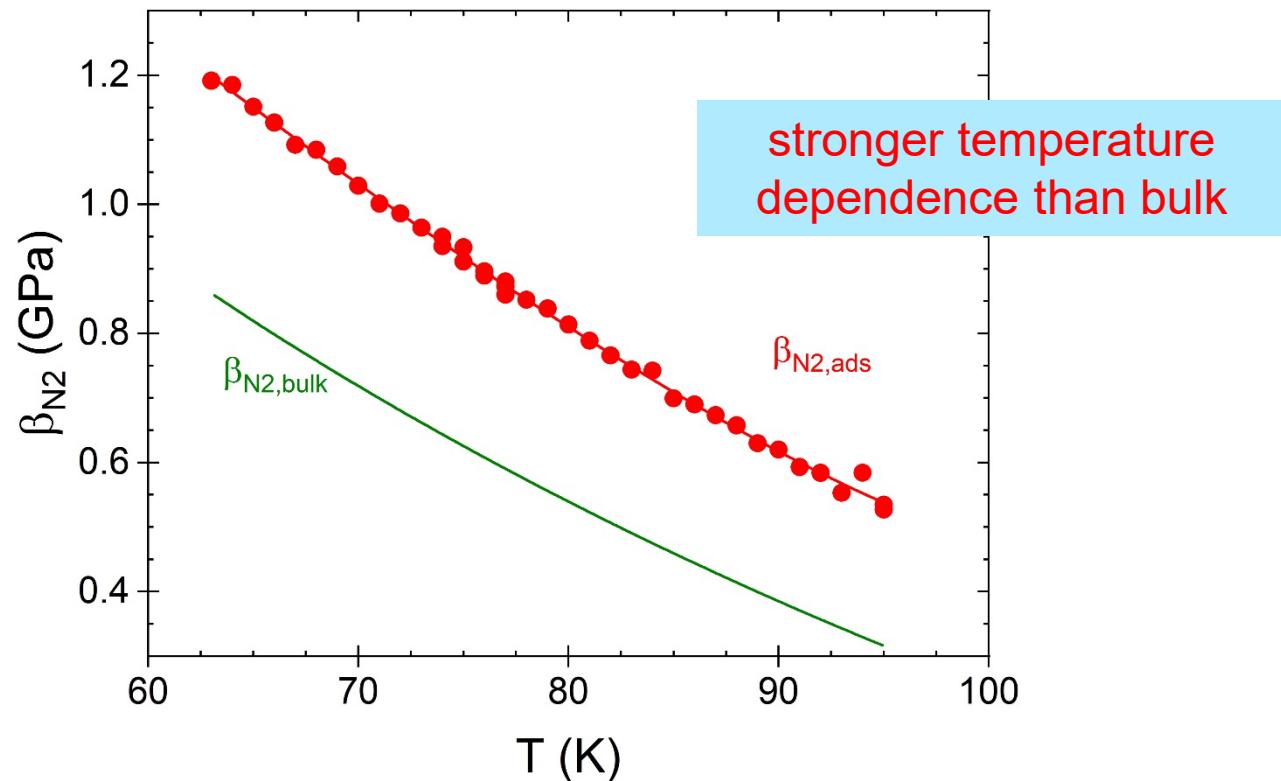
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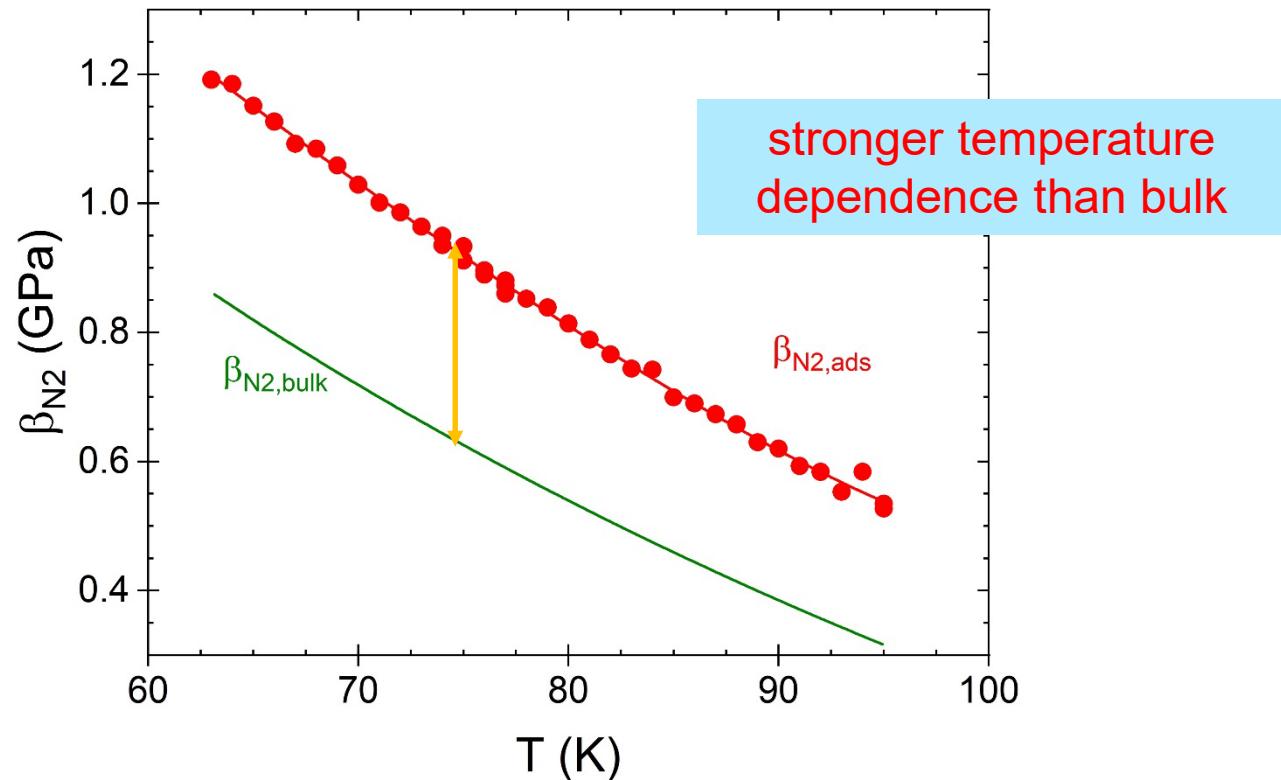
Longitudinal modulus of nanoconfined nitrogen



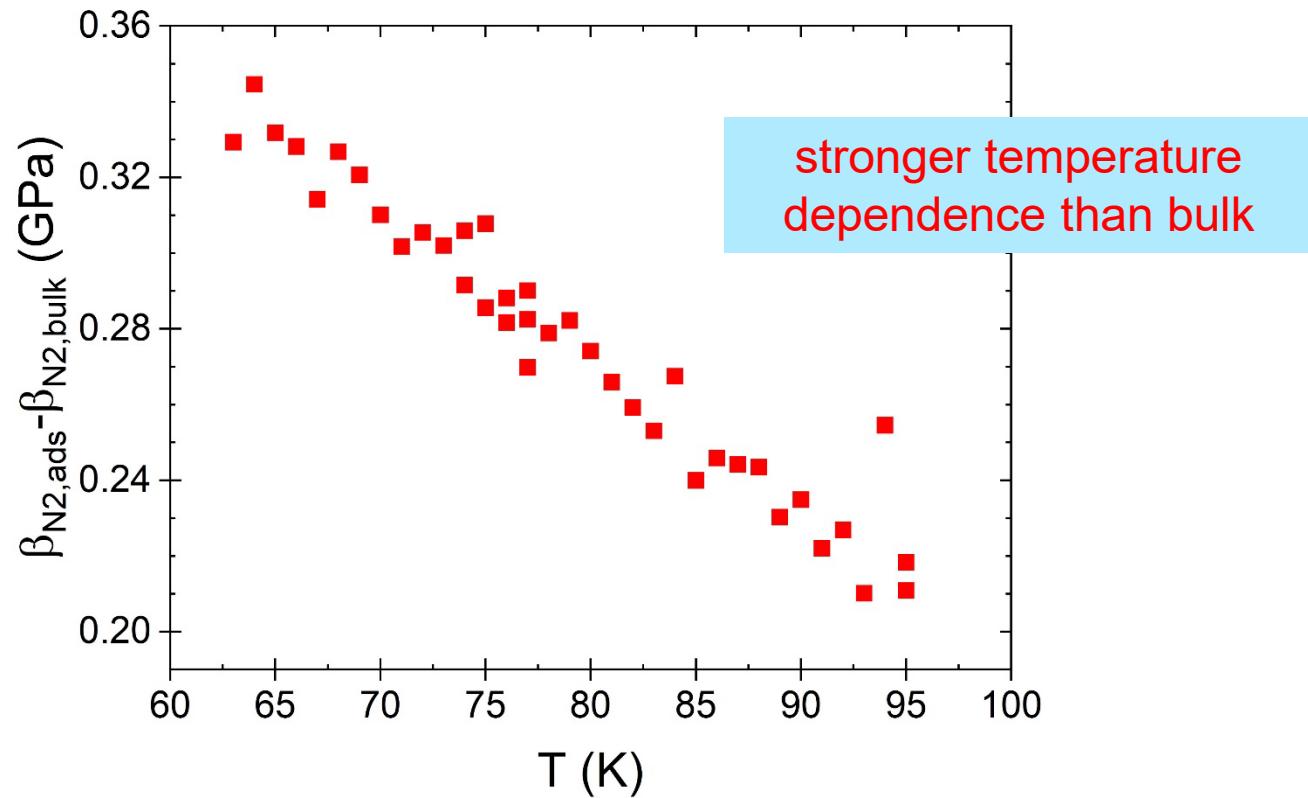
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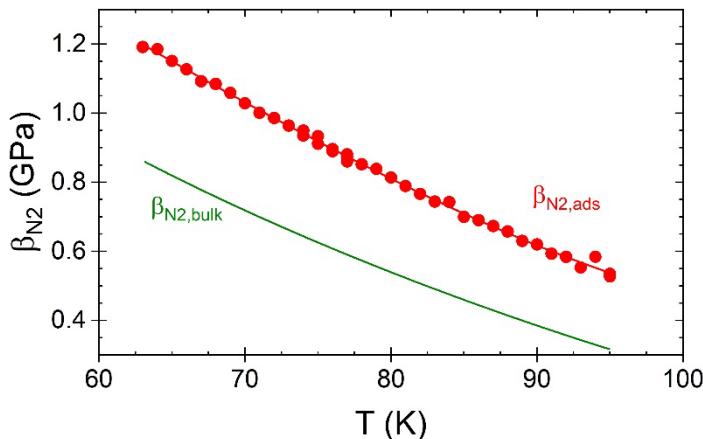


Longitudinal modulus of nanoconfined nitrogen

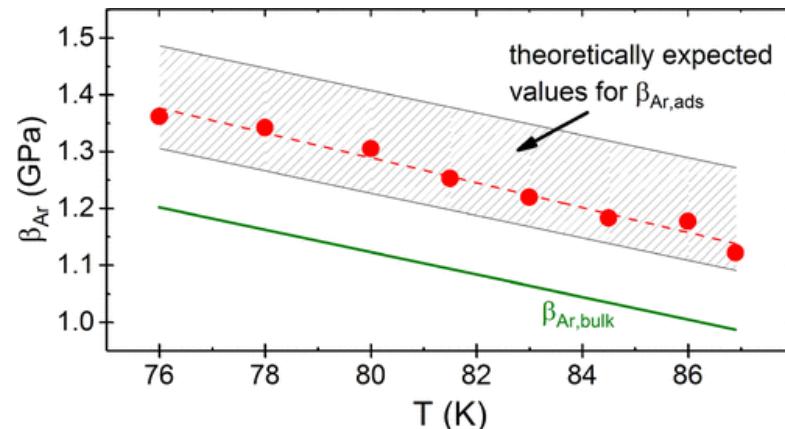


Longitudinal modulus of nanoconfined adsorbates

NITROGEN
significant enhancement
40-70%



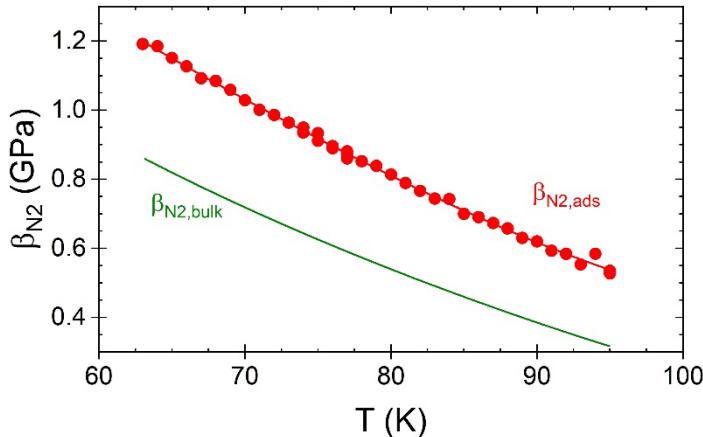
ARGON
enhancement
 $\approx 15\%$



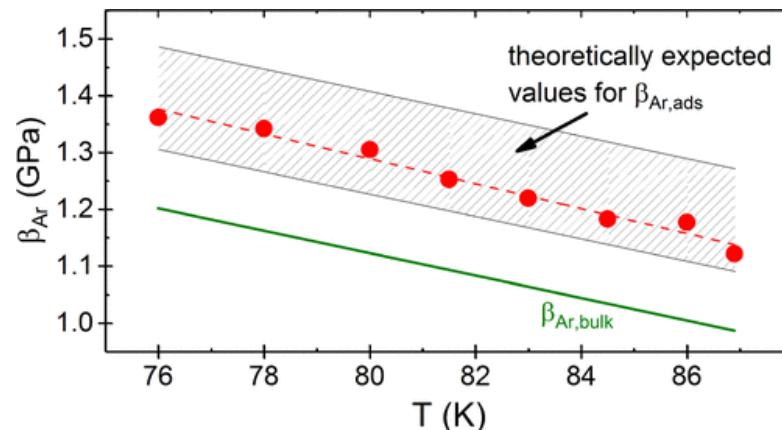
$$\beta_{ads} = \frac{\beta - \beta_0}{C}$$

Longitudinal modulus of nanoconfined adsorbates

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significant enhancement
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ARGON
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Summary

- Experimental observation:
 - Significant enhancement of modulus:

$$\beta_{N2,ads} > \beta_{N2,bulk}$$

- Stronger temperature dependence:

$$\frac{d\beta_{N2,ads}}{dT} > \frac{d\beta_{N2,bulk}}{dT}$$

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interaction influences strength of enhancement

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 - Comparison with argon:
interaction influences strength of enhancement
- Simulations or DFT calculations required of
 $\Delta p_S^{sat}(T)$ and $\beta_{N2,ads}(T)$



Thank you very much
for your attention!