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Strain rate sensitivity of germanium-selenium glasses

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Introduction : Classically, indentation studies for measuring hardness (Vickers, Rockwell, Meyer) assume an elasto-plastic material. In many cases this assumption does not introduce significant errors for room temperature test. However for chalcogenide glasses, the low glass-transition temperature (ie, 41° C for Se to 340° C for Ge40Se60) does not allow this assumption due to strain rate dependent viscoelastic effects. Both AFM images and displacement load curves exhibit a dependence on the strain rate.

Experimental setup : Constant Strain Rate (CSR) test

Glass Samples

- Selenium
- Ge05Se95
- Ge10Se90
- Ge15Se85
- Ge20Se80
- Ge25Se75

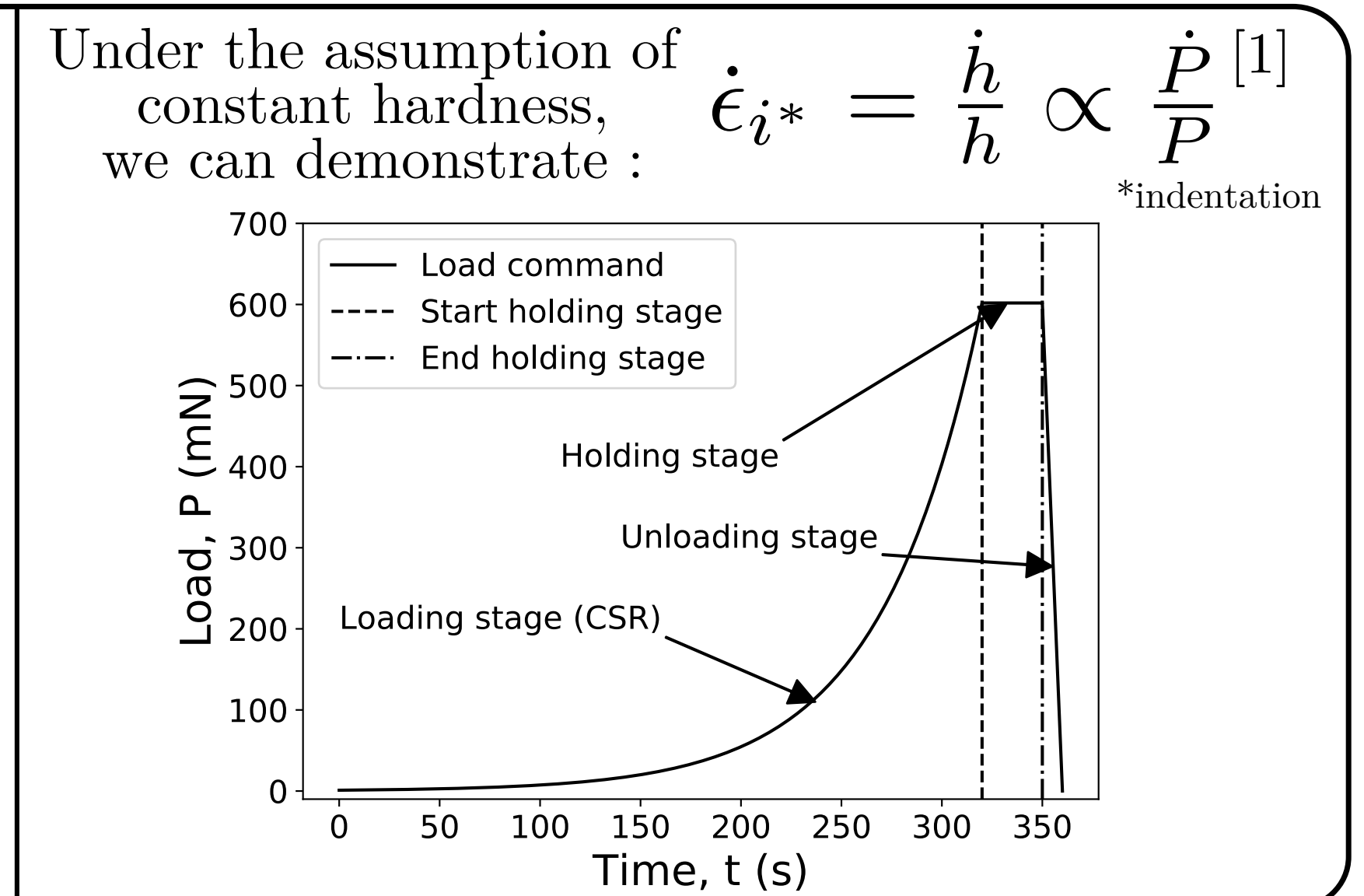
Strain rate
(Loading stage duration)

- 1.0E-4 s⁻¹ (32000s)
- 1.0E-3 s⁻¹ (3200s)
- 2.5E-3 s⁻¹ (1280s)
- 5.0E-3 s⁻¹ (640s)
- 1.0E-2 s⁻¹ (320s)
- 1.0E-1 s⁻¹ (32s)

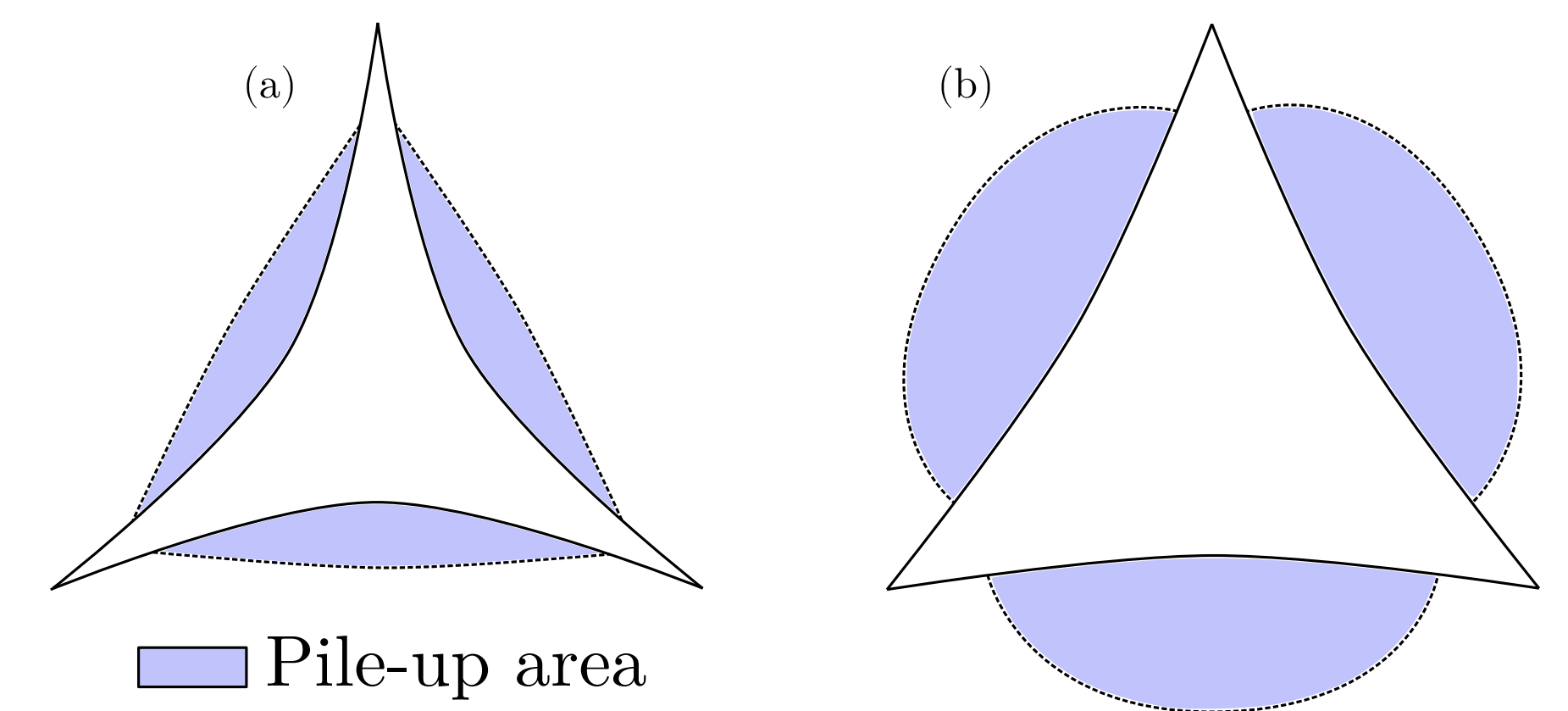
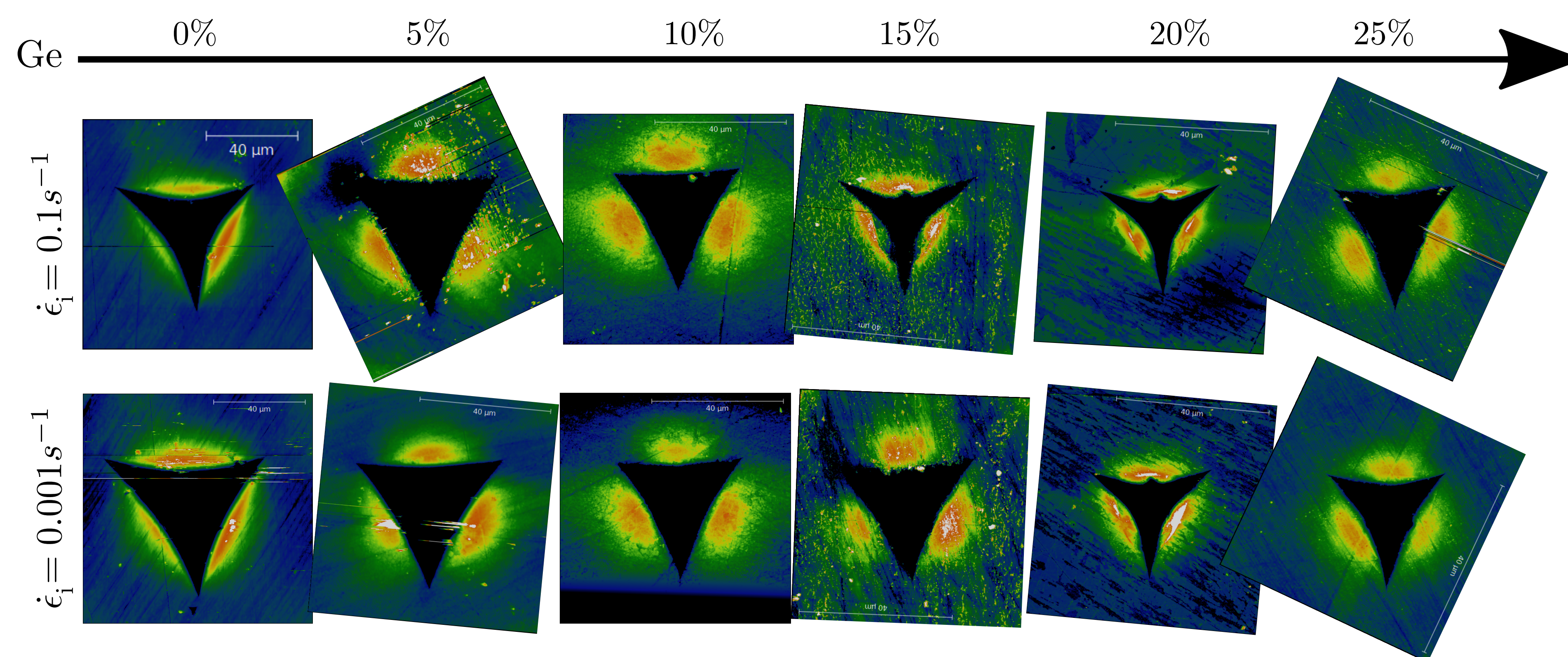
Settings

- 25±0.5°C
- 33±1% RH
- Berkovich tip

Building load control

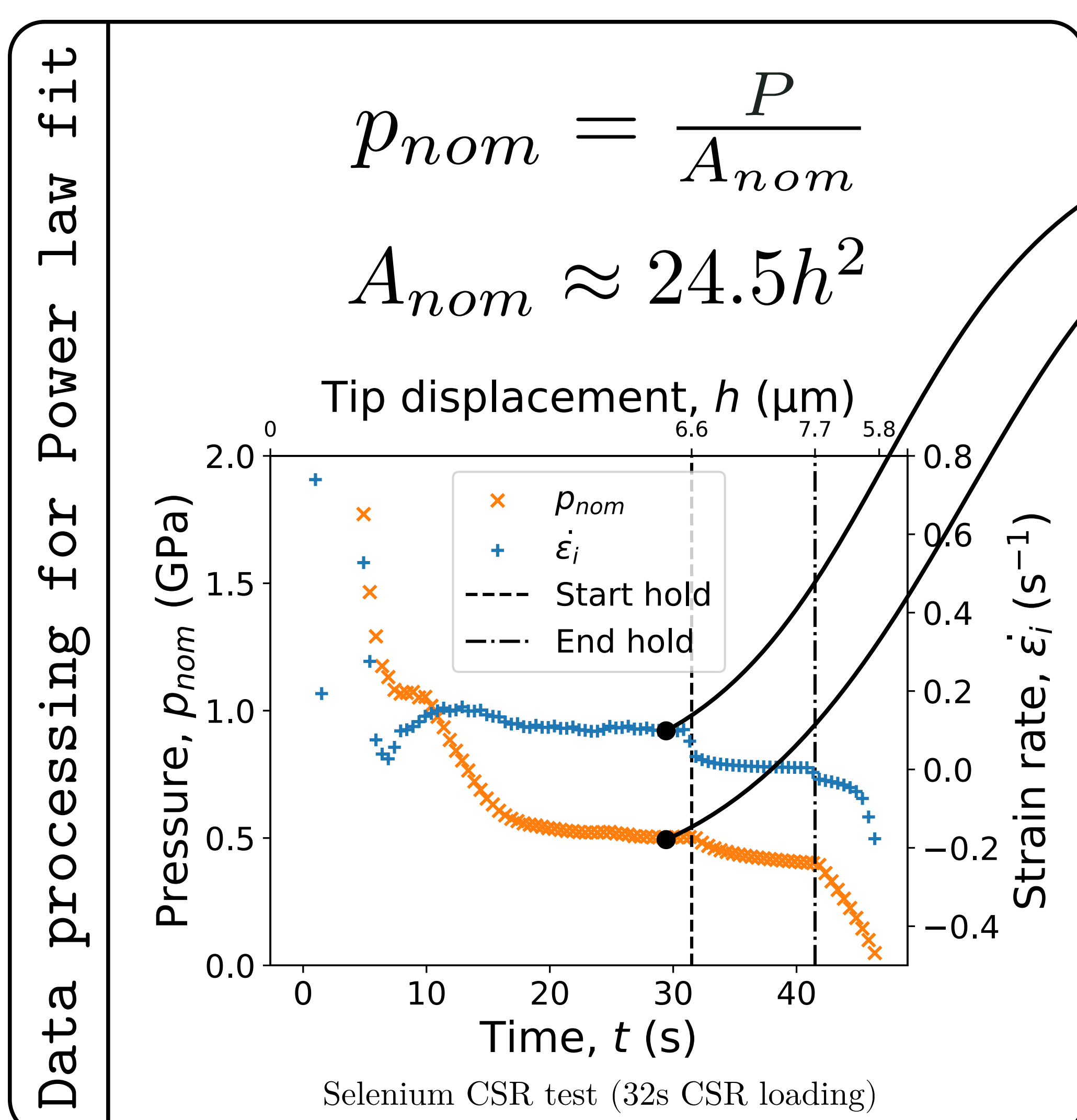


Topography approach by atomic force microscopy :



Near rigidity percolation threshold ($r = 2.4$, 20% of Ge) indent topography is strongly dependent of indentation strain rate :
(a) shape for high strain rate, (b) shape for low strain rate.

Creep behaviour and power law fitting :

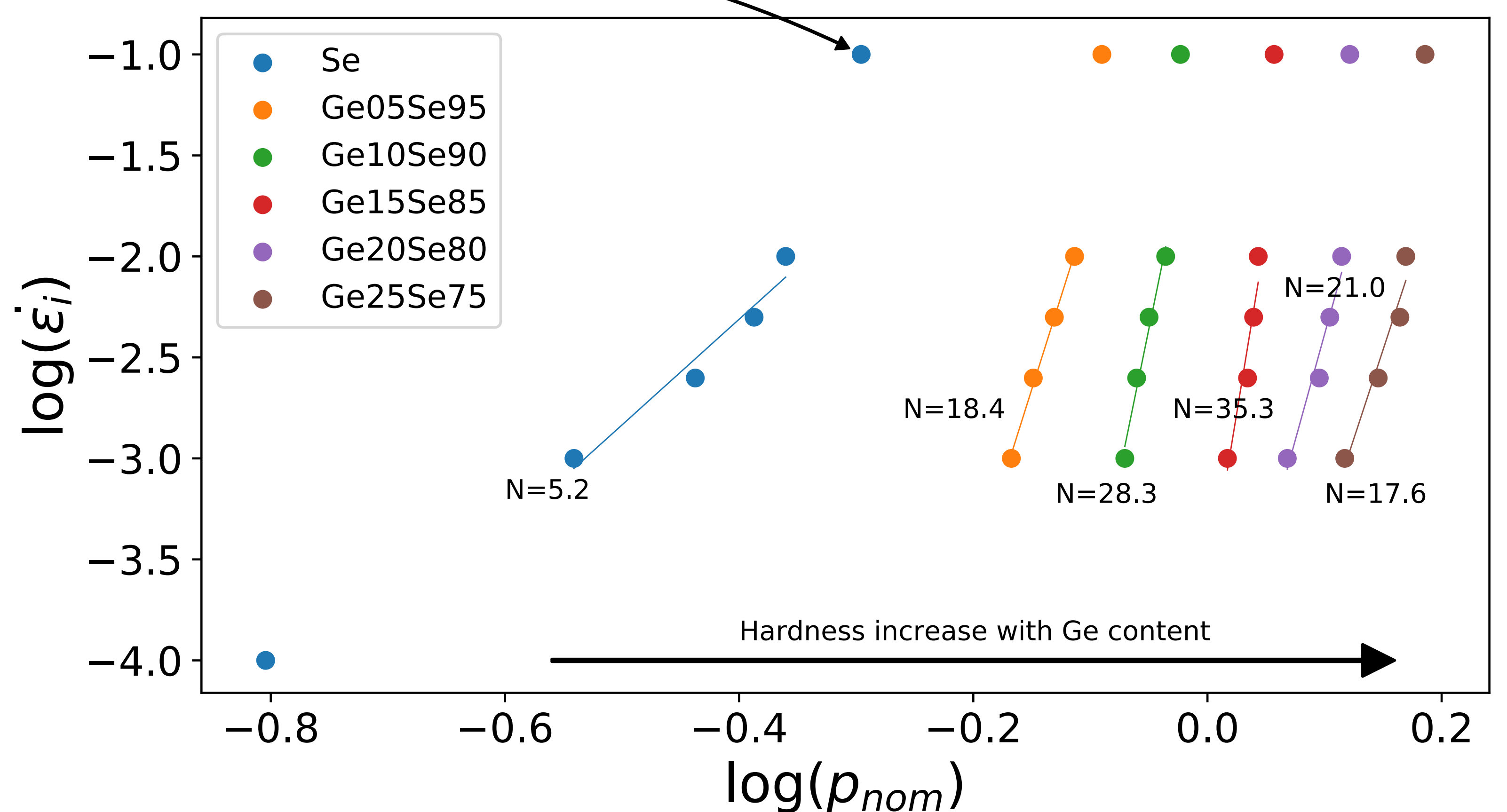


Data set for an established creep
 $\dot{\epsilon}_i = 0.1s^{-1}$
 $p_{nom} = 0.5GPa$

Classical power law for uniaxial test
 $\dot{\epsilon} = \alpha\sigma^n$

Power law for indentation test
 $\dot{\epsilon}_{i*} = \beta p_{nom}^N$ [2]

*indentation
Valid only for establish creep behaviour :
For a constant strain rate,
nominal pressure is constant



Conclusion : 1. Creep exponent (N) and residual imprint are linked to glass composition/structure and strain rate. 2. Near percolation threshold : i) viscous phenomena expressed strongly at low strain rate, ii) Elastic recovery is locked by visco-plastic effects.

References : [1] B. N. Lucas and W. C. Oliver. Indentation power-law creep of high-purity indium. Metallurgical and Materials Transactions A,30(3) :601–610, March 1999. [2] Caijun Su and al. Measurement of power-law creep parameters by instrumented indentation methods. Journal of the Mechanics and Physics of Solids, 61(2) :517–536, February 2013.