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► To cite this version:

Gwenole Trenvoux, Cedric Bernard, Mariette Nivard, Vincent Kéryvin, Jean-Pierre Guin. Strain rate sensitivity of germanium-selenium glasses. PNCS-ESG 2018, Jul 2018, Saint Malo, France. hal-02127567

HAL Id: hal-02127567

<https://hal.science/hal-02127567>

Submitted on 13 May 2019

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Strain rate sensitivity of germanium-selenium glasses

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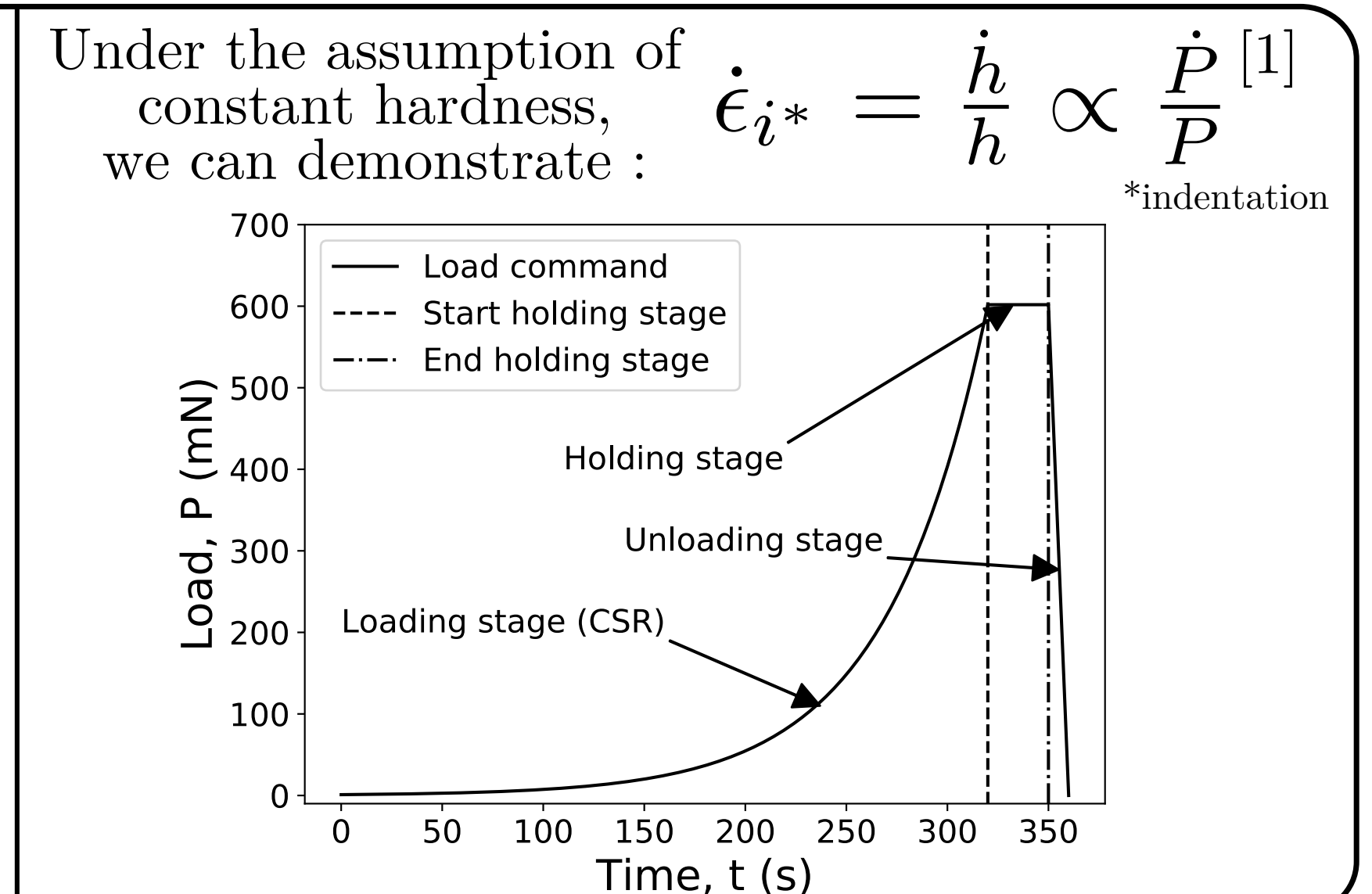
Introduction : Classically, indentation studies for measuring hardness (Vickers, Rockwell, Meyer) assume an elasto-plastic material. In many cases this assumption does not introduce significant errors for room temperature test. However for chalcogenide glasses, the low glass-transition temperature (ie, 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

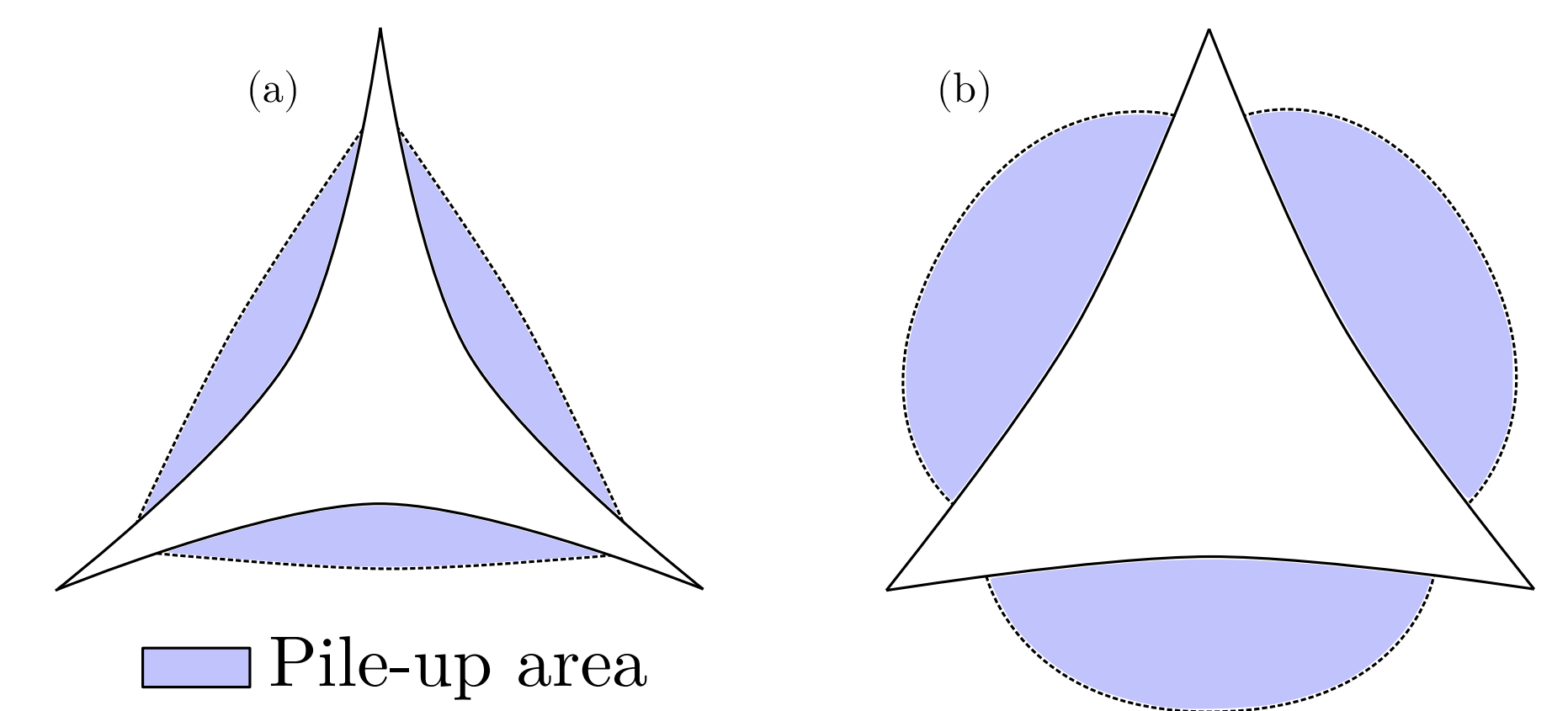
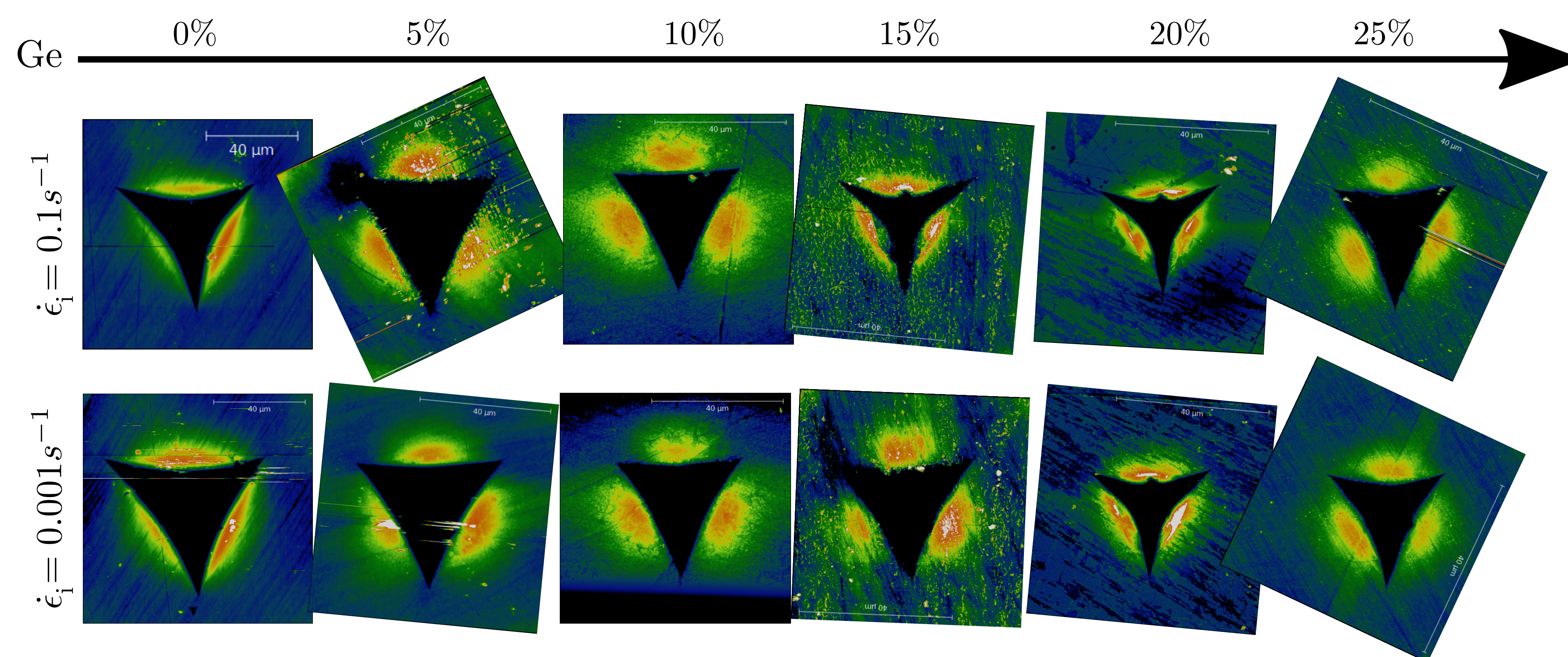
Glass Samples	Strain rate (Loading stage duration)
Selenium	1.0E-4 s ⁻¹ (32000s)
Ge05Se95	1.0E-3 s ⁻¹ (3200s)
Ge10Se90	2.5E-3 s ⁻¹ (1280s)
Ge15Se85	5.0E-3 s ⁻¹ (640s)
Ge20Se80	1.0E-2 s ⁻¹ (320s)
Ge25Se75	1.0E-1 s ⁻¹ (32s)

25±0.5°C
33±1% RH
Berkovich tip

Building
load control

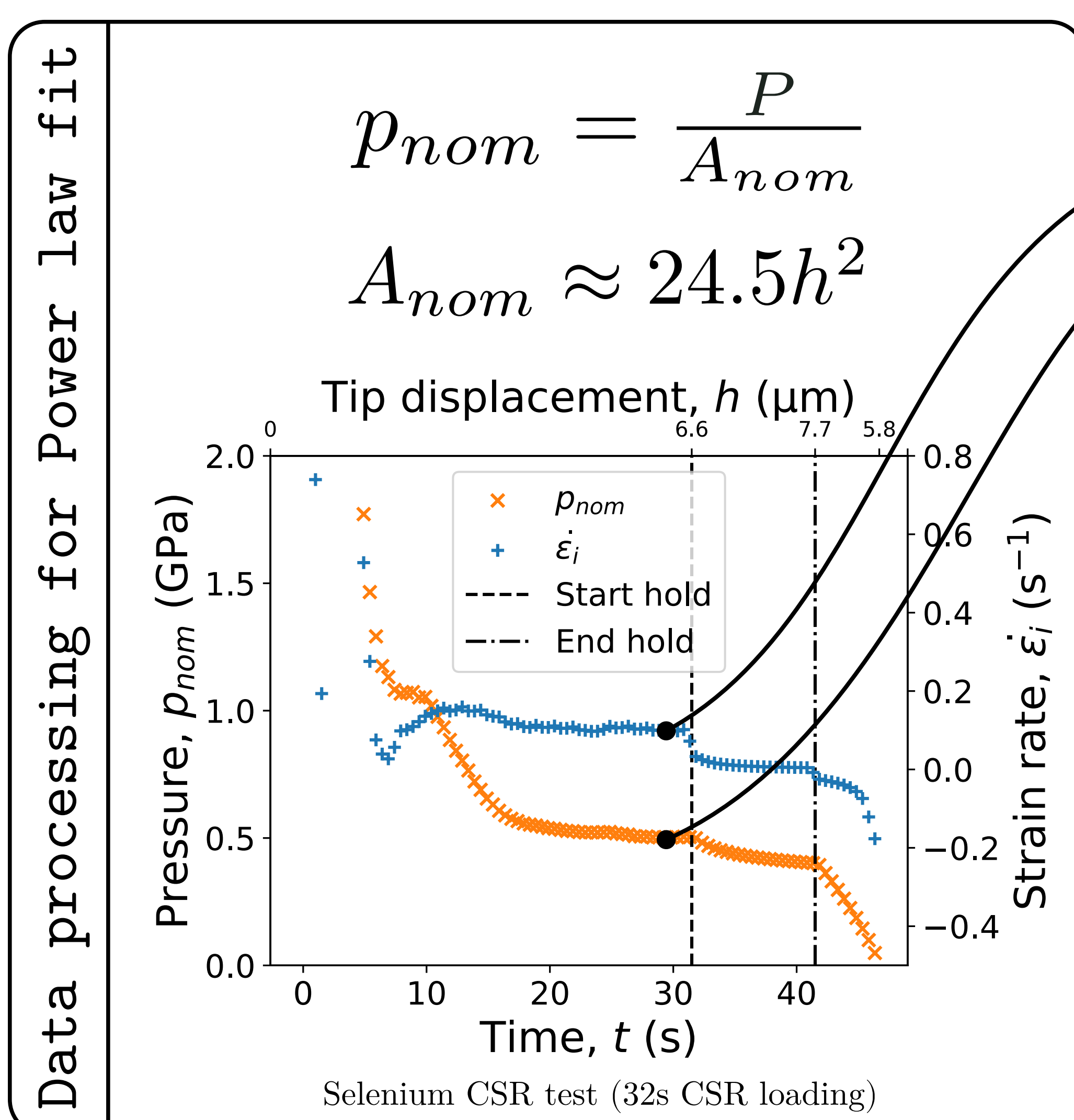


Topography approach by atomic force microscopy :



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
 $\dot{\epsilon}_i = 0.1 \text{ s}^{-1}$
 $p_{nom} = 0.5 \text{ GPa}$

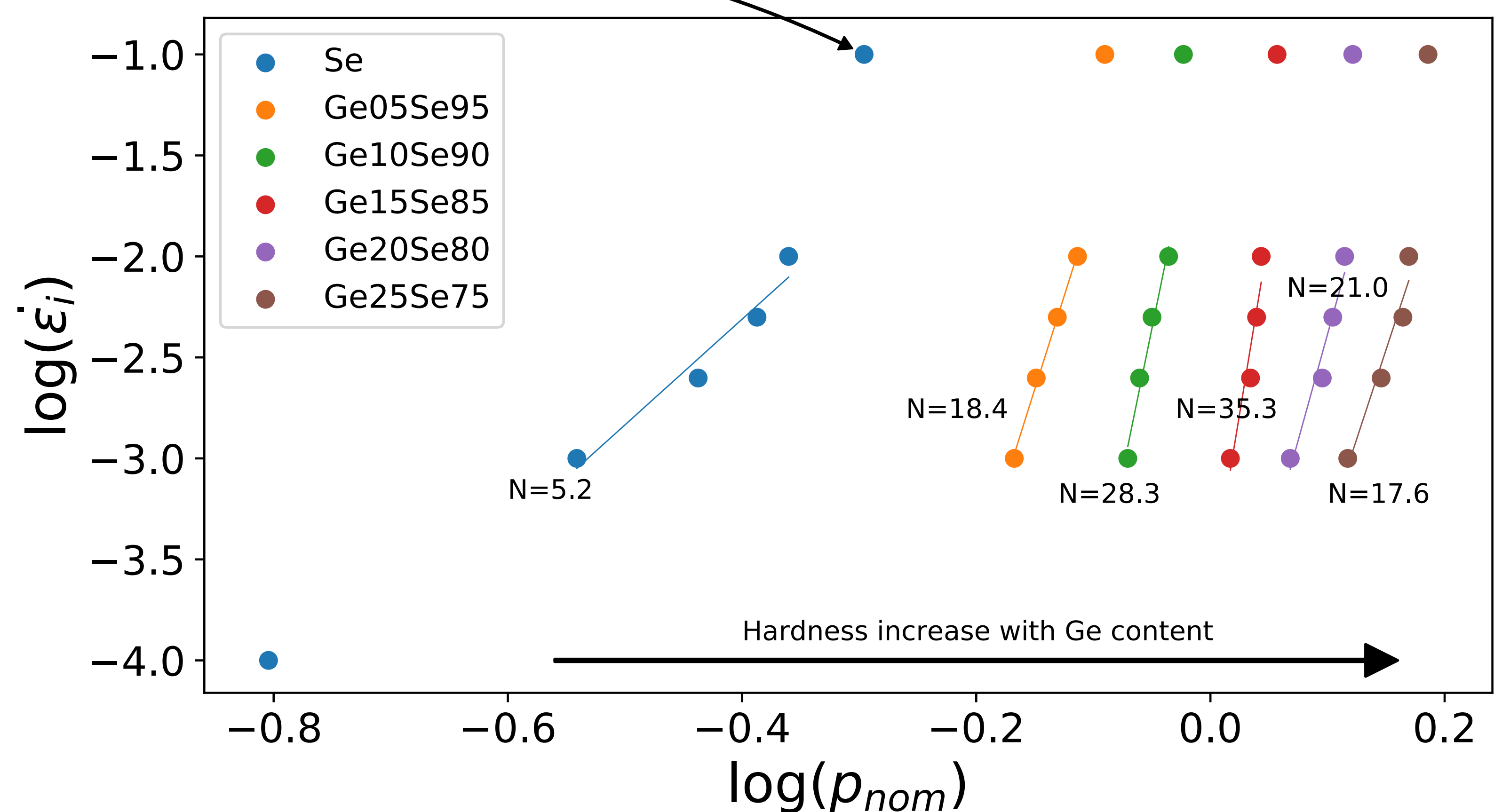
Classical power law for uniaxial test

$$\dot{\epsilon} = \alpha \sigma^n$$

Power law for indentation test

$$\dot{\epsilon}_{i*} = \beta p_{nom}^N$$

*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.