

# 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.

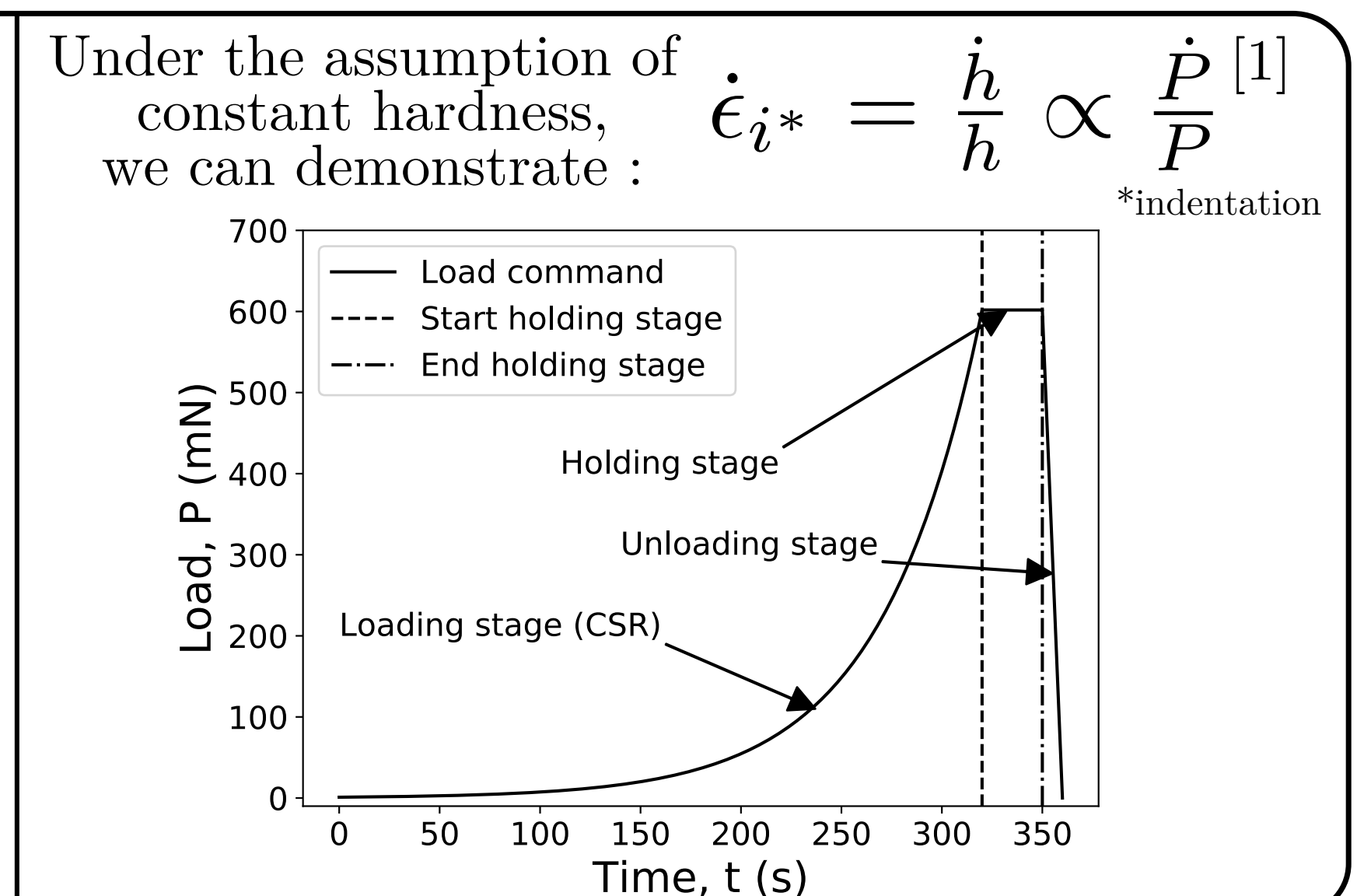
## Experimental setup : Constant Strain Rate (CSR) test

Glass Samples	Selenium
	Ge05Se95
	Ge10Se90
	Ge15Se85
	Ge20Se80
	Ge25Se75

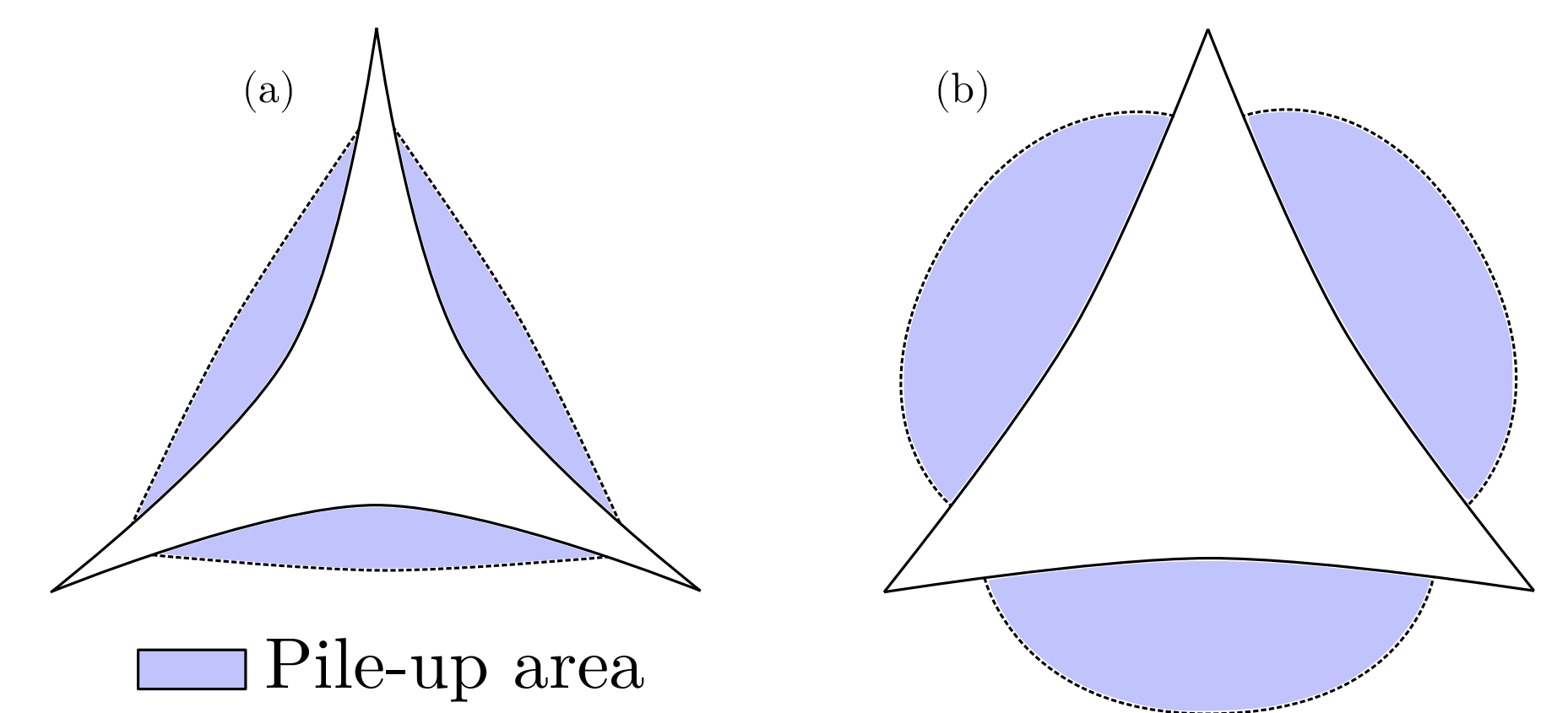
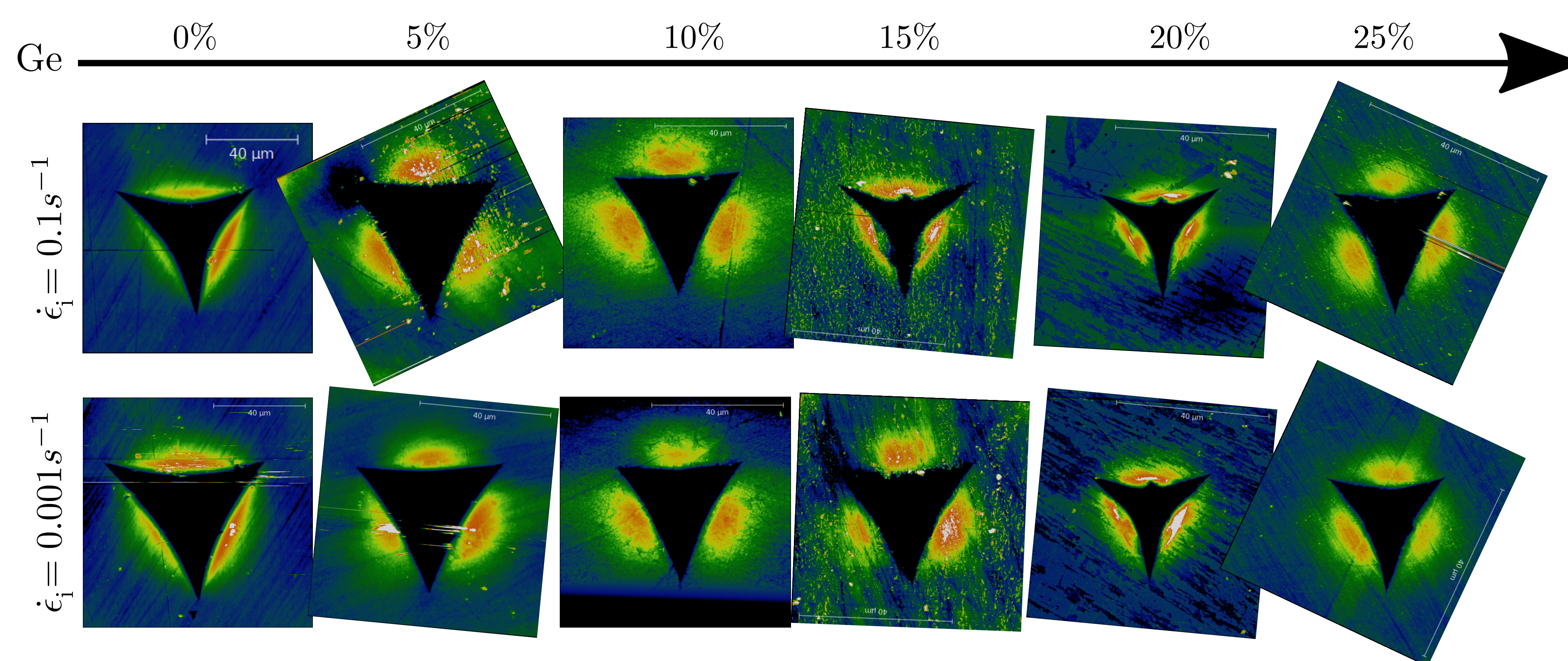
Strain rate (Loading stage duration)	1.0E-4 s <sup>-1</sup> (32000s)
	1.0E-3 s <sup>-1</sup> (3200s)
	2.5E-3 s <sup>-1</sup> (1280s)
	5.0E-3 s <sup>-1</sup> (640s)
	1.0E-2 s <sup>-1</sup> (320s)
	1.0E-1 s <sup>-1</sup> (32s)

25±0.5°C  
33±1% RH  
Berkovich tip

Building  
load control

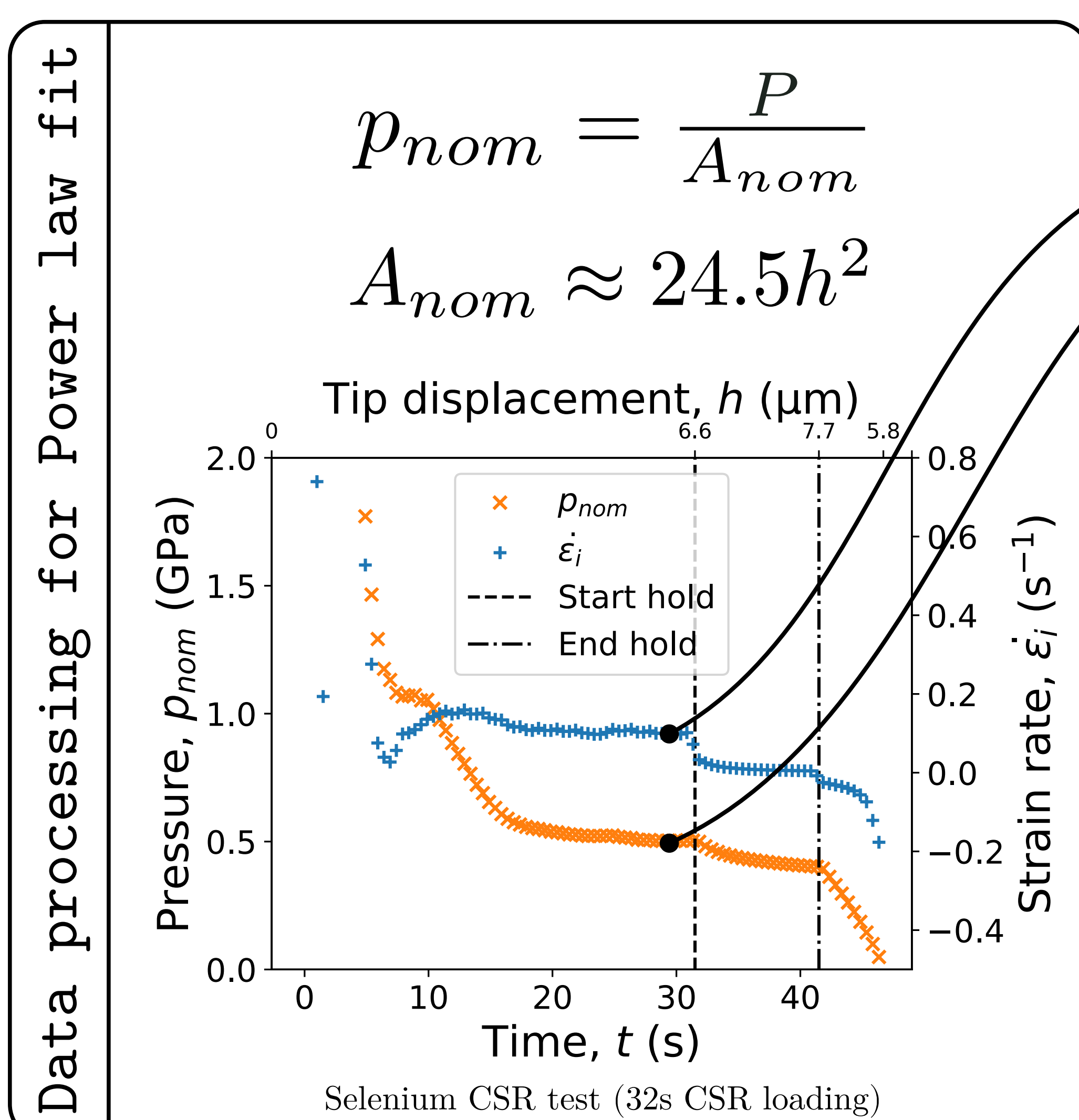


## Topography approach by atomic force microscopy :



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

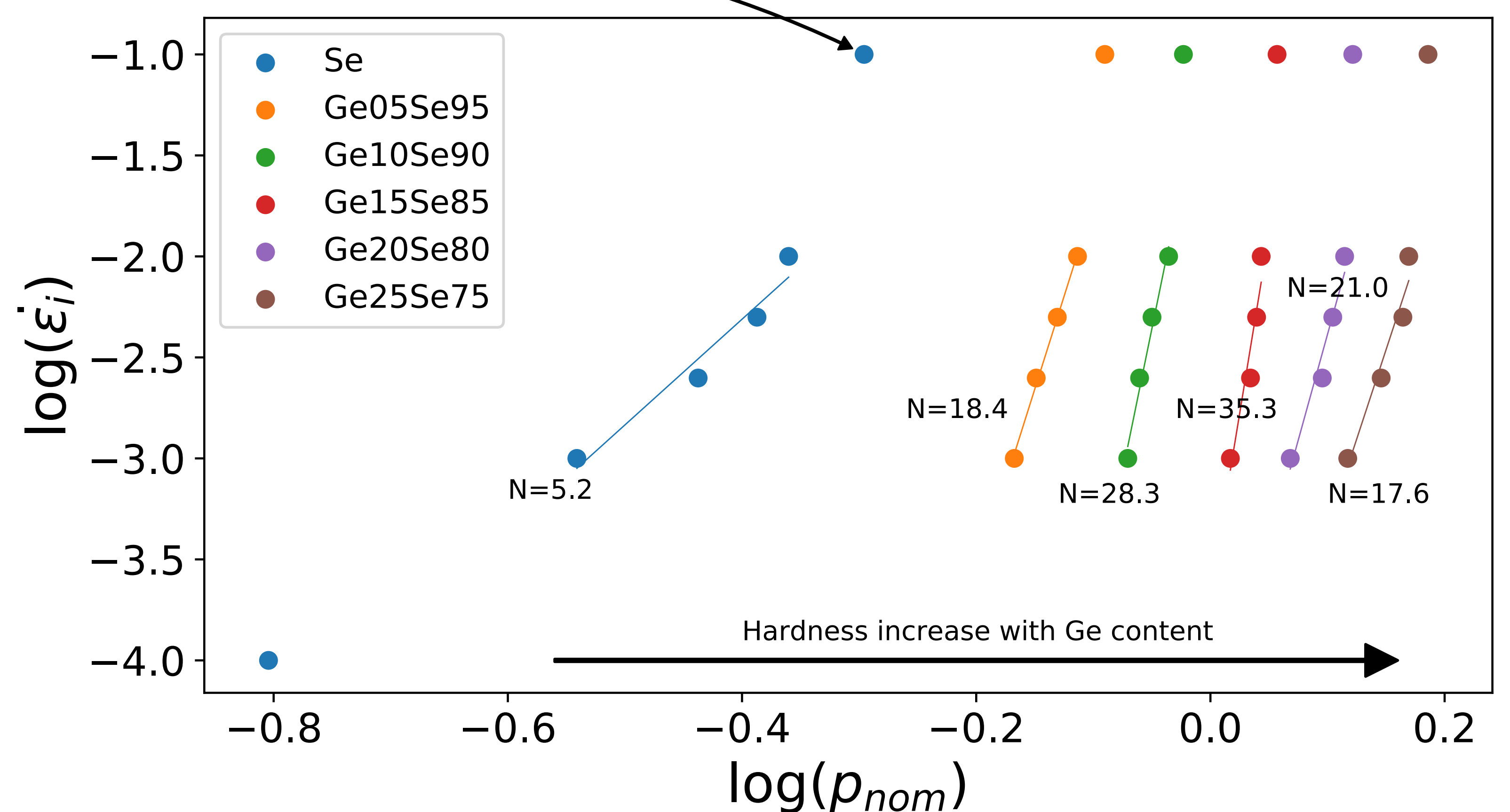
Classical power law for uniaxial test

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

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.