Strain rate sensitivity of germanium-selenium glasses

Gwenole Trenvouez, Cedric Bernard, Mariette Nivard, Vincent Kéryvin, Jean-Pierre Guin

Strain rate sensitivity of germanium-selenium glasses

Gwénolé Trenvouez[1], Cédric Bernard[2], Mariette Nivard[1], Vincent Keryvin[2] et Jean-Pierre Guin[1]

1. Institut de Physique de Rennes, département Mécanique et Verres - Université de Rennes 1 - Rennes - France
2. Institut de Recherche Dupuy de Lôme - Université de Bretagne Sud - Lorient - France

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

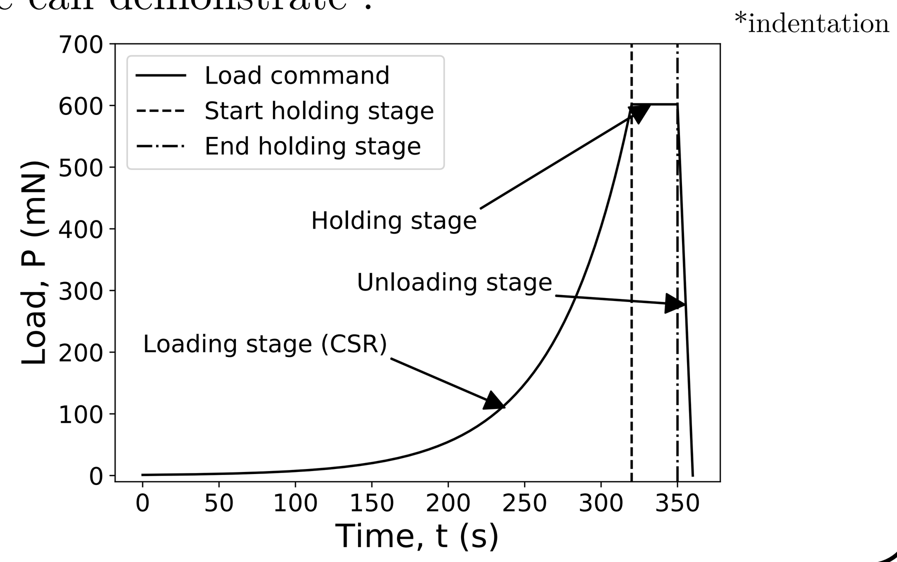
Strain rate (Loading stage duration)
1.0E-4 s^{-1} (32000s)
1.0E-3 s^{-1} (3200s)
2.5E-3 s^{-1} (1280s)
5.0E-3 s^{-1} (640s)
1.0E-2 s^{-1} (320s)
1.0E-1 s^{-1} (32s)

Settings
25±0.5°C
33±1% RH
Berkovich tip

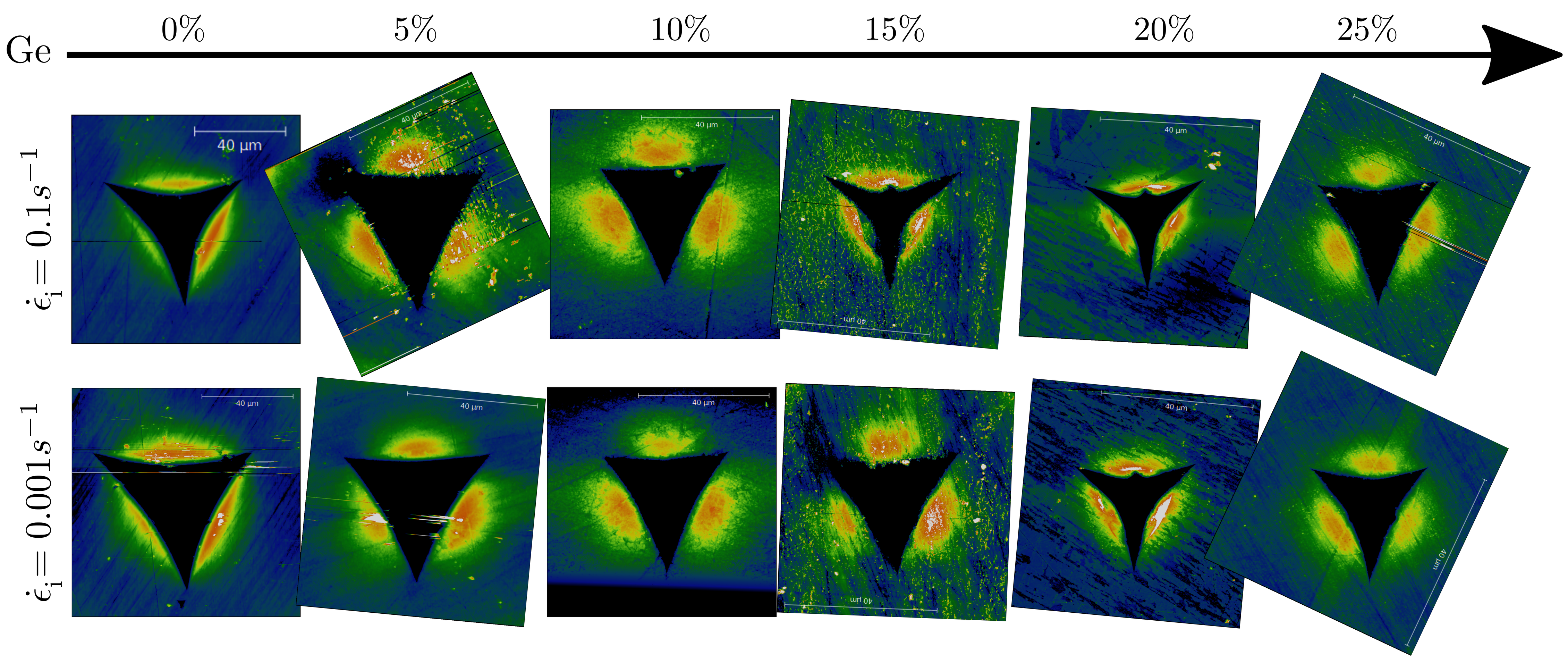
Building load control

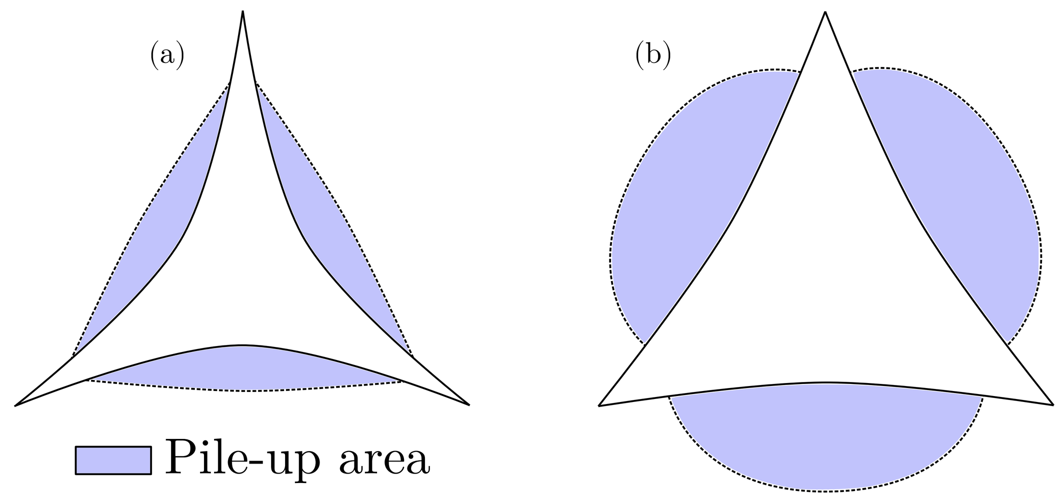
Under the assumption of constant hardness, we can demonstrate : $\dot{\epsilon}_{i^*} = \frac{\dot{h}}{h} \propto \frac{\dot{P}}{P}$ [1]

*indentation



Topography approach by atomic force microscopy :





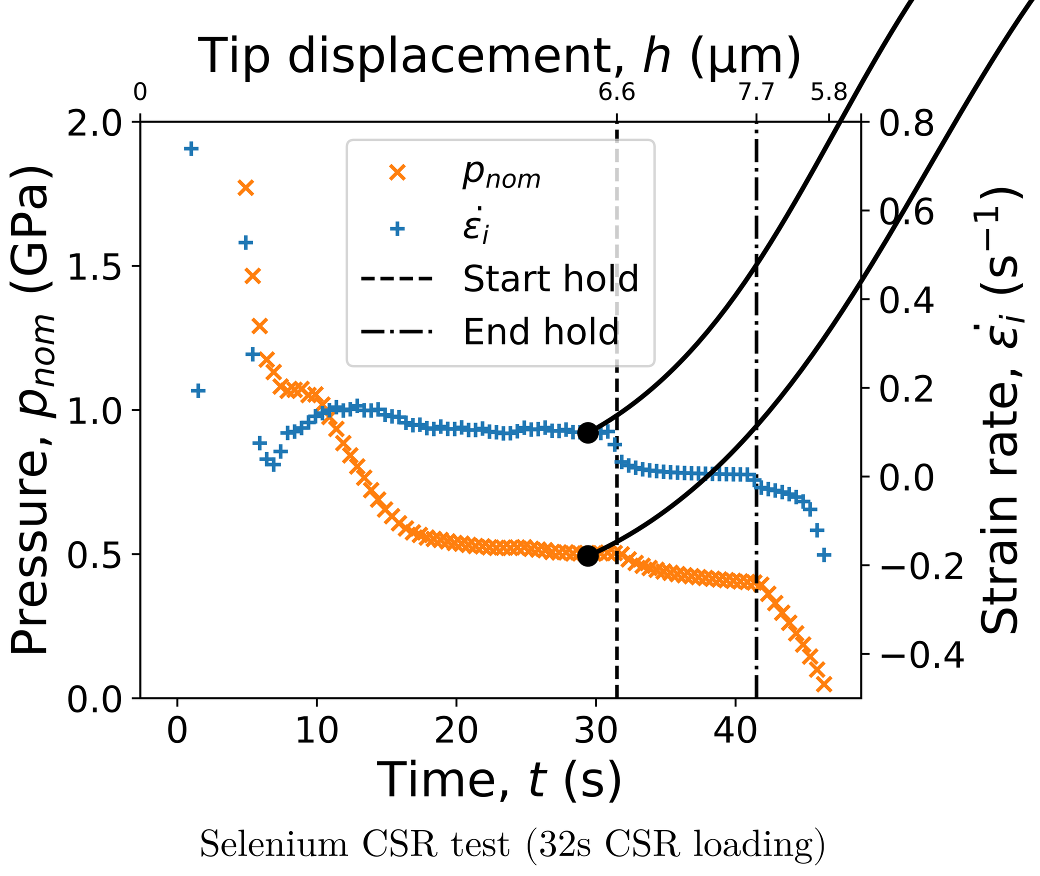
Near rigidity percolation threshold (r = 2.4, 20% of Ge) indent topography is strongly dependent of indentation strain rate : (a) shape for high strain rate, (b) shape for low strain rate.

Creep behaviour and power law fitting :

Data processing for Power law fit

$$p_{nom} = \frac{P}{A_{nom}}$$

$$A_{nom} \approx 24.5h^2$$



Selenium CSR test (32s CSR loading)

Data set for an established creep

$\dot{\epsilon}_i = 0.1s^{-1}$

$p_{nom} = 0.5$GPa

Classical power law for uniaxial test

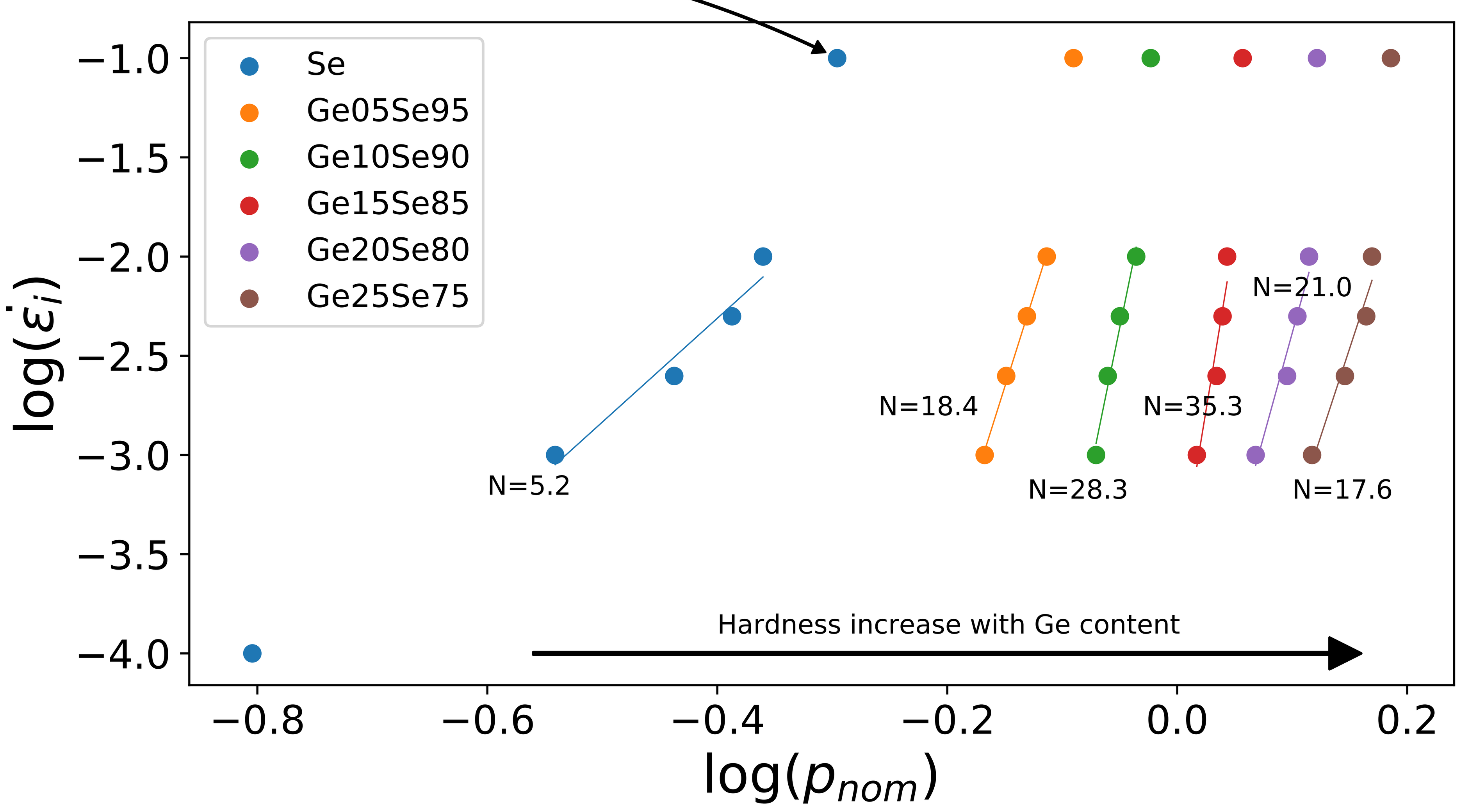
$$\dot{\epsilon} = \alpha\sigma^n$$

Power law for indentation test

$$\dot{\epsilon}_{i^*} = \beta p_{nom}^N \text{ [2]}$$

*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.