Plastic deformation of Na-aluminosilicate glasses under micro and nano-indentation

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Résumé:

The transition « normal glass – anomalous glass » is followed on Na-aluminosilicate glass model system using micro- and nano-indentation investigation.

Mots clefs : Silicate glasses, Plasticity, Indentation

1 Introduction

Under micro-indentation, silica and silica-based glasses exhibit plastic response at the micrometer scale. Due to the small size, it is difficult to characterize the plastic deformation of amorphous material. Previously we have quantified the densification of silica after indentation with Raman spectroscopy [1], and derived a constitutive law for plastic deformation [2]. This phenomenon of densification (or compaction) is typical for anomalous glasses. It is in contrast to normal glasses such as window (or float) glass which densifies relatively little, but generates shear bands. Here we report on our efforts to study the impact of composition on the plastic response of glasses, and especially investigate the difference between normal and anomalous glasses under indentation. Na-aluminosilicate glasses have been chosen as system model. The degree of polymerization is varied through the Al/Na ratio.

2 Results

We used diffused composition gradients to evaluate individual Raman partial spectra as a basis for the investigation of structure. The glass compositions were controlled by µ-probe analysis, the moduli and hardness measured by Berkovich nano-indentation along all the series of diffused glass. Evolution of nano-indents' shape has been followed by Atomic Force Microscopy. We reveal the influence of glass polymerization on its elastic response under nano-indentation and the nano-indents' shape.
To study the impact of plastic deformation on the glass structure, we used 2 kg Vickers indents and mapped the Raman signal. The Raman maps have been obtained at the surface *x-y* surface (Figure 1) as well as inside the sample, as cross-sections. We used the evolution of the Si-O-Si(Al) vibrational mode in the 300-730 cm^{-1} region to evaluate the residual plastic strain.

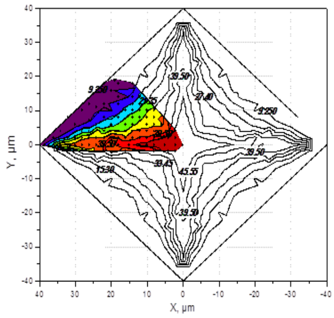

Figure 1. Raman mapping of fully polymerized Na-aluminosilicate glass

Based on these maps, we tentatively propose a family of constitutive laws spanning the transition between anomalous to normal glasses.

References

[1] A. Perriot, D. Vandembroucq, E. Barthel, V. Martinez, L. Grosvalet, Ch. Martinet, and B. Champagnon, Raman Microspectroscopic Characterization of Amorphous Silica Plastic Behavior, J. Am. Ceram. Soc. 89 (2006) 596-601
[2] G. Kermouche, E. Barthel, D. Vandembroucq and P. Dubujet, Mechanical modelling of indentation induced densification of silica, Acta Materialia 56 (2008) 3222-3228