PLASTIC FLOW AND STRUCTURAL HETEROGENEITIES IN SILICATE GLASSES - A HIGH THROUGHPUT INVESTIGATION

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Most silicate glasses have similar values of elastic moduli, hardness and fracture toughness, yet some are considerably more sensitive to crack initiation through indentation than others [1]. This observation challenges our understanding of the structure of silicate glasses, their plastic deformation and damage mechanisms. In fact, the impact of plastic deformation on the structure of silicate glasses has proved difficult to study because 1) of their amorphous nature and 2) in these materials, plasticity develops only locally (at the scale of a few microns). We will show that in fact, Raman spectroscopy stands out as one of the very rare techniques which can identify structural modifications connected to plastic deformation in silicate glasses: in particular, combining different micromechanics experiments with Raman spectroscopy, we can differentiate the structure of amorphous silica densified along different loading paths, a finding which is confirmed by molecular dynamics simulations [2]. To study the impact of glass composition, we need to consider more complex compositions such as soda lime silicates (window glass) but the interpretation of the evolutions of the Raman spectra with plastic deformation becomes significantly more involved. To solve this problem, we propose a new strategy based on a high throughput methodology: using controlled interdiffusion at interfaces between ternary glasses, we create composition gradients extending over hundreds of microns. Mapping cross sections of these gradients, we can effectively scan an extensive composition library and measure: 1) the elementary composition (with an electron microprobe) 2) the Raman spectra 3) the hardness (with nanoindentation). The full collection of ca 120 Raman spectra is analyzed using hyperspectral analysis techniques (more precisely non negative matrix factorization with sparsity constraint) to obtain a reduced basis of partial Raman spectra. We find a good correlation with composition and can ascribe each partial spectrum to a local environment, from which we derive a relation between yield stress and local structure. We will show how this approach can be generalized to plastic strain gradients and open up for a better understanding of the relation between structure, plastic deformation and crack initiation in silicate glasses.

[1] Barthel, E.; Keryvin, V.; Rosales-Sosa, G. & Kermouche, G., Acta Materialia 194 (2020) 473-481
[2] Martinet, C.; Heili, M.; Martinez, V.; Kermouche, G.; Molnar, G.; Shcheblanov, N.; Barthel, E. & Tanguy, A. Journal of Non-Crystalline Solids 533 (2020) 119898