Diffusion and phase separation in silicate melts: physics problems inspired by glass industry

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Silicate glass is among the oldest man-made materials, and was already fabricated in ancient Egypt. Glass is still used today for a variety of technological applications, from energy-efficient buildings to display cover glass or solar photovoltaic panels, requiring a good understanding of its properties. In the liquid state, silicate melts are liquids of high viscosity, due to the strongly polymerized silica network, interrupted in places by network modifiers cations such as sodium or calcium. This specific network structure is associated to several distinct timescales and results in intriguing transport phenomena, such as uphill molecular diffusion, or a large viscosity ratio between immiscible phases.

In this talk, I will discuss several transport phenomena such as coupled diffusion between species and phase separation in silicate melts. Such basic physics problems are studied at the joint unit CNRS/Saint-Gobain Surface of glass and Interfaces, and are inspired by questions from the glass melting and transformation industry. Chemical diffusion controls the dissolution of glass raw materials in industrial installations, but also the corrosion of furnace refractories. It is also involved in interdiffusion phenomena between glass substrate and thin films. I will discuss the coupled exchanges between the different species of silicate melts, which we studied both in bulk glasses and in thin films.

For the study of phase separation we have used in situ 3D imaging thanks to synchrotron micro- and nanotomography at the ESRF. Coarsening of a bicontinuous microstructure is controlled by hydrodynamic transport, with a dynamic asymmetry induced by the strong viscosity ratio between phases. Topology changes such as fragmentation or coalescence are characterized thanks to in situ imaging. In the case of phase-separated silicate thin films, specific coarsening mechanisms are observed, leading to nanotextured surfaces.

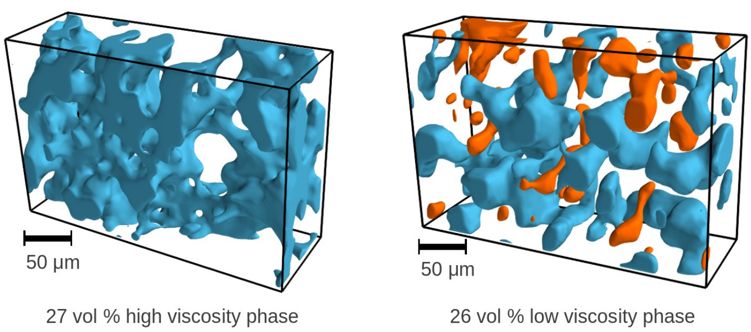

Figure 1: Microstructure of minority phase in phase-separated glasses, observed by in situ microtomography. Note the different morphology when the minority phase is the more viscous or fluid one. Different coarsening mechanisms are at play for the two phases.