Structural adaptation in Na+/K+ ion exchanged glasses leading to a relaxation of the compressive stress

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Abstract

A major limitation in many technological applications of glassy materials is their brittle fracture behavior [1]. However, exchanging smaller ions such as Na+ in the glass structure with larger ions such as K+ leads to chemical strengthening, as it allows for developing high surface compressive stress, which in turn drastically improves the modulus of rupture of the treated glass [2]. The magnitude of this surface compressive stress depends on the extent of stress and structural relaxation occurring during the ion exchange [2,3]. Therefore, the optimization of the ion-exchange process requires a fundamental understanding of the nature of this relaxation process [3].
In the present work, we investigated how the relaxation of the compressive stress developed in Na+/K+ ion-exchanged binary Na-silicate and ternary Na,Mg-, Na,Ba- and Na,Ca- silicate glasses affects the glass structure. For this purpose, two experimental methods were used: μ-XANES (X-ray Absorption Near Edge Structure measurements) and nuclear magnetic resonance (NMR) spectroscopy. The μ-XANES allowed the study of the environment of Ca2+, K+, Na+ and Mg2+, while NMR probed the environment of 23Na and 29Si.

In the Na+/K+ ion exchanged glasses, the K+-foreign cations are introduced in the cages of the Na+-host cations. Due to stress relaxation, the size of the K-O coordination shell in ion-exchanged glasses increases. This increase is achieved by two structural adaptation mechanisms: a contraction of the Na-O, Ca-O and Mg-O coordination shell and both a shortening of the Si-NBO distances and an opening of the Q4 Si-O-Si angles.

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