Macroscopic and structural effects of electron irradiation on model glasses

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Abstract

Glass is often exposed to radiation when used in cosmic and nuclear industry; influence of fast electrons on glass properties is of especial interest as all types of irradiation generates secondary electrons. The presented study observed the effect of 50 keV electron beam on model glasses, namely to vitreous silica and two binary alkali-silicate glasses (15K2O.85SiO2 and 15Li2O.85SiO2), with aim to better understand, evaluate and correlate the observed changes in volume and structure.
Glasses were irradiated with 50 keV electron beams with various doses up to a few decades of kC/m2. Atomic Force Microscopy was utilised to monitor volume changes induced by electron bombarding. Volume responses to low-dose electron bombardment were alike for all glasses; the compaction was recorded. However, higher doses showed volume expansion of alkali-silicate glasses while vitreous silica revealed only further compaction. Irradiated spots were observed by confocal Raman spectroscopy to find out structural changes generated by radiation. Irradiation caused a shift and narrowing of Si-O-Si vibration band for silica glass, what means the volume compaction in vitreous silica is given by both the decrease of the average Si-O-Si bond angle and the narrowing of the Si-O-Si angle distribution. It is also shown, compaction at lower doses is strongly correlated with the increase of the D2 peak, situated at 602 cm-1, that is responsible for the increase of the three-membered rings.
Expansion of alkali-silicate glasses is related to migration of alkali ions out of the irradiated volume. Volume relaxation of irradiated glasses was observed by annealing. It resulted in the levelling of the pits created by irradiation, but only for doses below the incubation dose. Annealing of high-dose (above incubation dose) irradiated glass did not lead to full volume recovering as the alkali ions had migrated out of the irradiated volume. Relaxation was accompanied with a decrease of D2 peak and the reversion of the Si-O-Si vibrations band.

Keywords: Vitreous silica, silicate glass, electron irradiation, glass structure

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