Electric field-induced softening (EFIS) of alkali silicate glasses

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Abstract

We report on a new phenomenon in alkali silicate glasses, termed electric field induced softening (EFIS), whereby electric fields produce abrupt softening and viscous flow at furnace temperatures well below the glass transition temperature. The experiments are carried out with cylindrical specimens sandwiched between two metal electrodes, under a compressive stress. The strain, the specimen temperature (obtained with a pyrometer), and the optical emission spectrum are measured simultaneously as a function of time. The softening is accompanied by an abrupt increase in electrical conductivity as well as photoemission. The effect is more pronounced (that is, it occurs at a lower temperature) with AC field of _˜1 kHz than with DC electric field. Unusual events at the metal-glass interface, resembling dielectric breakdown are observed, which, however, are less localized in AC than in DC experiments. These observations suggest the following sequence of events: polarization of the sample from ion displacement under the application of electric field as in electro-thermal poling, formation of an alkali ion depletion layer, development of large internal electric fields across this layer, electrolysis and charge injection followed by dielectric breakdown, and very high localized heating near the anode, ultimately leading to thermal runaway and softening throughout the sample. The results suggest that AC electric field assisted softening may be better suited to practical applications of this phenomenon. The magnitude of EFIS is significantly larger in single alkali than in relatively lower conductivity mixed-alkali glass of same mole fraction of silica, raising the possibility that EFIS can be induced in highly conductive classes even at ambient furnace temperature.

Keywords: Glass softening, Electrical properties, Thermally stimulated current, Alkali migration, Dielectric breakdown, Thermal runaway

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