Electrically induced viscous flow in oxide glasses at room temperature: electrical-nanoindentation tests vs e-beam effect

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Abstract

Over the past decade, several studies have demonstrated the possibility of inducing strong creep/relaxation phenomena in amorphous silica at room temperature during mechanical testing under TEM/SEM electron beam irradiation. Depending on the e-beam parameters, the viscous flow can be so pronounced that silica exhibits ductile behavior, described as superplastic by the authors, allowing it to be shaped at room temperature. These intriguing observations raise several questions. What electrical magnitude drives the mechanical processes? Does the phenomenon also occur in other oxide glasses? Is this solely an effect of electron irradiation, or can it be replicated with a DC current? The present work aims to address these questions by performing electrical-nanoindentation tests on amorphous thin films, deposited on silicon substrates, of a dense Al2O3 model material and a nanoporous SiOCH material used in microelectronic applications. The tests involve biasing the substrate and measuring the current flowing through the tip during mechanical loading. Significant viscous flow was observed in both materials, indicating that this is indeed a purely electrically-assisted phenomenon and appears to be generic to oxide glasses. Furthermore, electrical-nanoindentation tests have also shed light on the relevant electrical magnitude, which was previously challenging to determine in e-beam irradiation experiments that involve multiple less well controlled parameters: acceleration voltage, probe current, magnification, irradiation time, irradiated volume, etc. Finally, micropillar relaxation tests of amorphous silica under e-beam irradiation were conducted to quantify the mechanical response of the oxide glass in relation to the electrical quantity of interest.

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