DEFORMATION PROCESSES IN SILICA AND DIFFERENT SODA-LIME GLASSES UNDER CONICAL INDENTATIONS

S. Van der Zwaag*

Technical University of Delft
Department of Metallurgy
Rotterdamseweg 137
Delft, The Netherlands.

J. T. Hagan*

B. P. Research Center
Chertsey Road
Sunbury on Thames
Middlesex, UK

We report a summary of studies on the effect of composition and indenter angle on the deformation processes in silica and some soda-lime-silica glasses under conical indentations. The gradual changes in subsurface deformation behavior for different compositions and indenter angles were examined. The indentations were sectioned to reveal the subsurface deformation features in the deformed zone. Details of experiments and results will be presented elsewhere.

The initial deformation in pure silica glass, due to low shear and hydrostatic stresses, is almost completely recoverable. The deformation is in the form of compaction of the silica network. At high shear stress levels, permanent densification and "freezing in" of the elastic deformation features occur as shown in Fig. 1a, which illustrates 136° cone indentations in fused

* This work was performed at the Cavendish Labs, U. of Cambridge, U.K.
silica. The broad semi-circular density contours, EE, also occur for 90° cone indentations.

For 90° cone indentations in a soda-lime-silica glass (71 SiO2, 14Na2O, 7CaO) some features of the elastic behavior, EE, are retained, but a new set of deformation (spiral) flow lines, FF, develop at the bottom of the deformed zone as illustrated in Fig. 2. There is a central undeformed region devoid of any flow lines. The central undeformed zone disappears at an indenter angle of 136° (see Fig. 3) and reappears at an indenter angle of 150°, Fig. 4.

Fig. 1. Optical micrograph of conical indentations on fused silica
(a) indentation at 50N (cone angle 136°) (b) same indent as in (a).
(c) indentation at 75N (cone angle 150°)
For intermediate glass compositions, the circular and spiral flow lines are initially broad and degenerate into fault-like features (similar to those of soda-lime-silica glass) as the oxide content is increased.

The present studies show that deformations associated with conical indentations in silicates are characterized by some features, frozen in by the elastically induced deformation, which result from radial displacement of material from the indenter face; this radial displacement gives rise to the spiral flow lines in high oxide content glasses.

Fig. 2. Optical micrographs of conical indentations on soda-lime-silica glass (cone angle 90°, 71 SiO₂, 14Na₂O, 7CaO) (a) 25N, (b) 50N, (c) 75N.
Fig. 3. Optical micrographs of conical indentations on soda-lime-silica glass (cone angle 136°, same glass as Fig. 2) (a) 25N, (b) 50N, (c) 100N.
Fig. 4. Optical micrographs of conical indentations on soda-lime-silica glass (cone angle 150°, same glass as Figs. 2 and 3) (a) 50N, (b) 150N, (c) 200N.