Strengthening of Glass by High-Pressure Ar Impregnation

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THE gas solubilities that have been determined[1-3] for some types of glass suggest that compressional stresses that resist breakage will result from fixed gases impregnated near the surface of glass.

Rods of three glasses, soda-lime silica, borosilicate, and 96% silica,* were cleaned and exposed to H_2, N_2, and Ar under pressures of 1 to 3 kbars at 240° to 800°C. All the gas impregnation conditions were at temperature below the strain points of the glasses so that the compressional forces parallel to the surface would not be lost. The Ar distribution was determined with the electron probe.

Measurements were made on rods ¼ in. in diameter in four-point loading tests at a loading rate of 300 g/s. Measurements were also made on untreated rods and on rods subjected to the same thermal history at atmospheric pressure. To reduce data scatter, all tests were conducted on rods uniformly abraded with 100-mesh SiC.

The strength of the 96% silica increased significantly when it was impregnated with Ar. Figure 1 shows the increase in strength with increasing pressure (and hence concentration) of Ar. Each point represents the average of measurements on 6 or 7 rods. The time of treatment at each pressure varied somewhat, making the plot only an approximate relation between pressure of impregnation and strength. (The treatment at 3500 psi and 650°C lasted 15 h, that at 1 kbar and 650°C 40 h, and that at 2 kbars and 650° to 700°C 7 h.) Nevertheless, the glasses impregnated at 2 kbars (average strength 20.8×10^3 psi) were definitely strengthened compared to the reference glasses (average strength 17.6×10^3 psi) at the 1% significance level (Fisher's *t* test).

Electron probe measurements (Fig. 2) showed that Ar penetrated to a depth of 60 μm, with a concentration of 1 mol% near the surface. Relatively high pressurization temperatures could be used with the 96% silica without exceeding its strain point of 810°C. Thus Ar impregnation could be accomplished without relaxation of the induced compressional stress.

The strengths of the three glasses were not improved by N_2 and H_2 impregnation. Argon impregnation of the borosilicate and soda-lime silica glasses did not raise the strengths, probably because of the limitations imposed by a relatively low strain point, which required temperatures that were too low for appreciable penetration of the gas into the glass.

Acknowledgments

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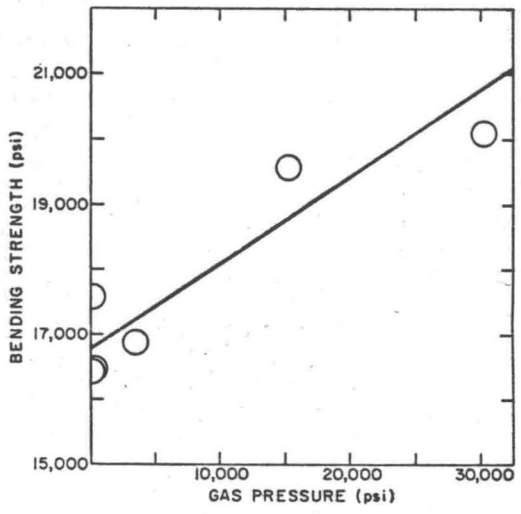

Fig. 1. Bending strength of SiO_2 glass rods vs pressure in Ar treatment at 650°C.

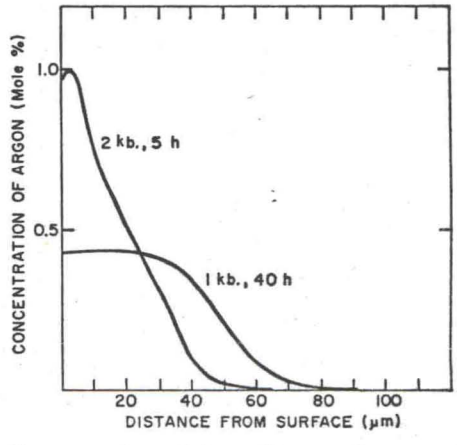

Fig. 2. Concentration of Ar vs distance from surface after high-pressure Ar treatments at 650°C.

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*Code 7900, Corning Glass Works, Corning, N. Y.

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