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WATER CONTENT, FICTIVE TEMPERATURE, AND DENSITY RELATIONSHIPS FOR FUSED SILICA

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The interactions of various gases, including water vapor, with glass have been widely studied.[1] The interaction of water vapor with fused silica serves as a practical and illustrative model system. Brückner[2] reported a decrease in the density of fused silica with increased water content where the "water" existed in the glass as hydroxyl units. However, Douglas and Isard[3] reported a rise of similar magnitude in the density of fused silica with increased fictive temperature. Therefore, in order to have well characterized fused silica, it is desirable to have a knowledge of the simultaneous effects of both "water" content and fictive temperature on the glass density (being indicative of the glass structure).

The sample material studied was a standard commercial fused silica.* A hole 1/8 inch in diameter was drilled in a 3/4 inch diameter rod. Disks were sliced from the rod, ground, and then polished to a final thickness of about 0.005 inch. The finished disks were suspended from a fused silica support bar by platinum hooks. The support bar assembly

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* Amersil CFQ Rod, Standard Quality (T-08); Amersil, Inc., San Francisco, California.

The authors are, respectively, graduate student research assistant, lieutenant, U. S. Army, and professor of ceramic engineering.

was placed in a fused silica envelope approximately 1-3/4 inches in diameter and 27 inches long. The top of the envelope (the specimen end) was located in the hot zone of a Kanthal-wound tube furnace. The bottom of the envelope (the cold finger) contained water and was immersed in a controlled temperature oil bath. After evacuating the envelope, the temperature in the cold finger was brought to a desired temperature which established a given vapor pressure in the system. Runs were made with specimen temperatures of 1000, 1100, and 1200°C and water vapor pressures from 0 atm (evacuated envelope) to 1 atm (cold finger temperature of 100°C). The time for the runs ranged from a few hours at 1200°C to a few weeks at 1000°C in order to obtain equilibrium densities. The runs were ended with air quenches in order to "freeze in" the equilibrium glass structures.

The density was measured in a graded density column.* The hydroxyl content was determined from the 2.7μ absorption peak in the IR spectra of the specimen following the method used by Hetherington and Jack.[4]

Figure 1 shows the resulting dependency of density on both water (or OH) content and fictive temperature. Figure 1(a) indicates the best fit isotherms for the density-hydroxyl content variation. Figure 1(b) shows the density-fictive temperature constant composition curves corresponding to the isotherms of Fig. 1(a).

Figure 1(a) is in general agreement with the results of Brückner[2] showing a drop in density with increased hydroxyl content. Brückner's values tended to be slightly higher than the 1200°C isotherm as might

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* ASTM: D1505-63T: "Density of Plastics by the Density-Gradient Technique"

be expected from the 1300°C annealing step he used prior to measuring the density and water content of his specimens.

Figure 1(b) is in general agreement with the results of Douglas and Isard[3] with a rise in density with increasing fictive temperature. Their data agree rather closely with the 0.0 weight percent OH curve.

A series of studies of the permeation, diffusion, and solution of various gases in fused silica is currently underway. The data of Fig. 1 will allow a more complete characterization of the fused silica used in these studies.

ACKNOWLEDGMENTS

The fused silica disks were fabricated by Jack Borde. Dane Anderberg was responsible for the fabrication of the glass experimental apparatus.

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FIGURE CAPTIONS

Fig. 1. The density of fused silica as a function of (a) water content at different fictive temperatures, and (b) fictive temperature at different water contents.

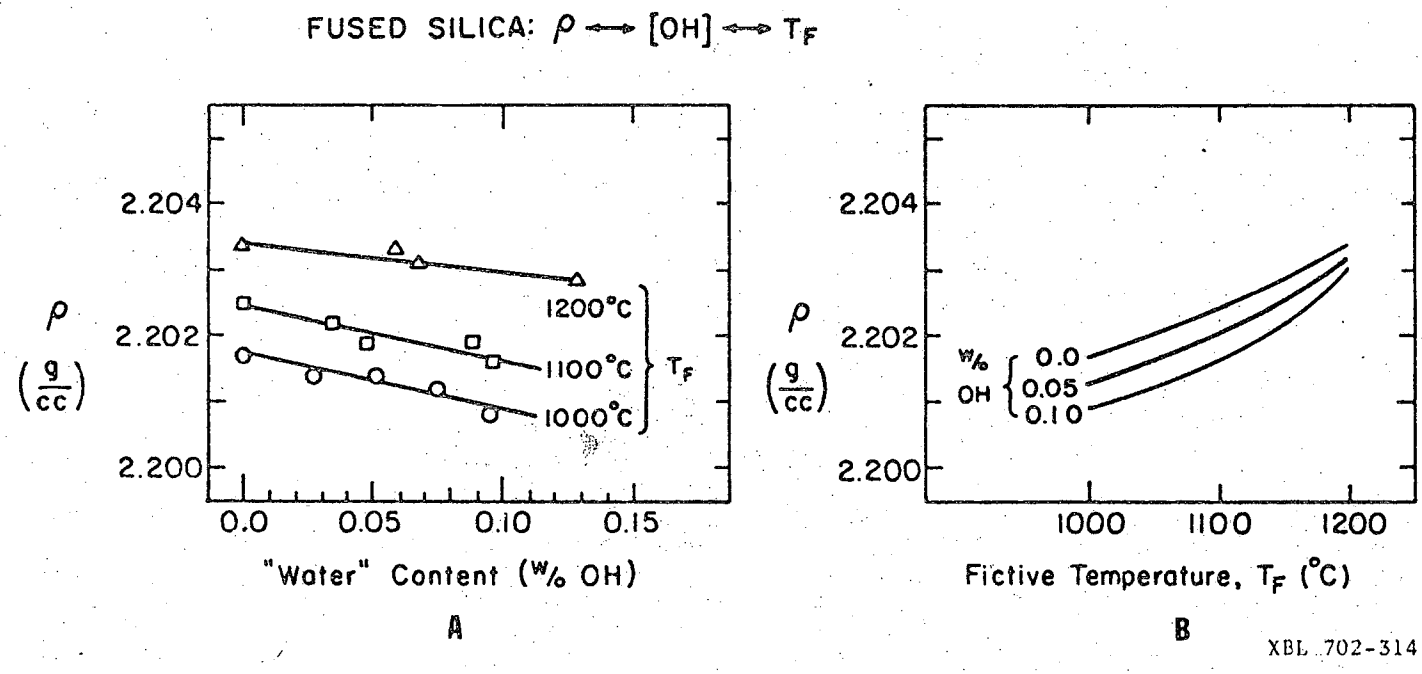
FUSED SILICA: ρ ⟷ [OH] ⟷ T_F
ρ (g/cc)
2.204
2.202
2.200
1200°C
1100°C
1000°C
T_F
0.0
0.05
0.10
0.15
"Water" Content (w/o OH)
A
ρ (g/cc)
2.204
2.202
2.200
w/o OH
0.0
0.05
0.10
1000
1100
1200
Fictive Temperature, T_F (°C)
B
XBL 702-314

Fig. 1

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