

STRENGTH/HARDNESS

Although a number of early workers showed that permanent impressions remained when a hard solid was pressed against a glass surface, the work of Taylor in 1948 [41-42] showing such permanent Vickers indentations, was received with surprise. Douglas [43] proposed a model in which such permanent impressions could result from a lowering of the "viscosity" at the high stresses encountered in indentation: these approaching the activation energy for flow. Hagan [44-47] and others showed that the flow under a pointed indenter was different in the case of "normal"(SLS) glasses

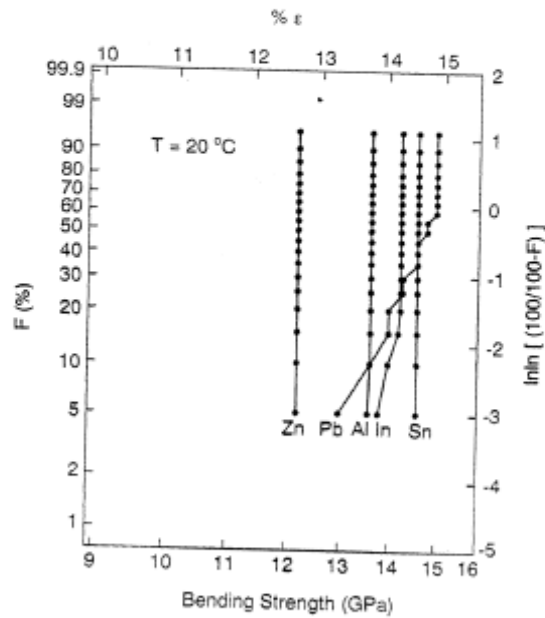


Figure 7. Room temperature bending strengths of silica fibers with a metal coating applied from the melt. This illustrates that the inert strength can be obtained at room temperature in the absence of water, that is, using hermetic coatings [36].

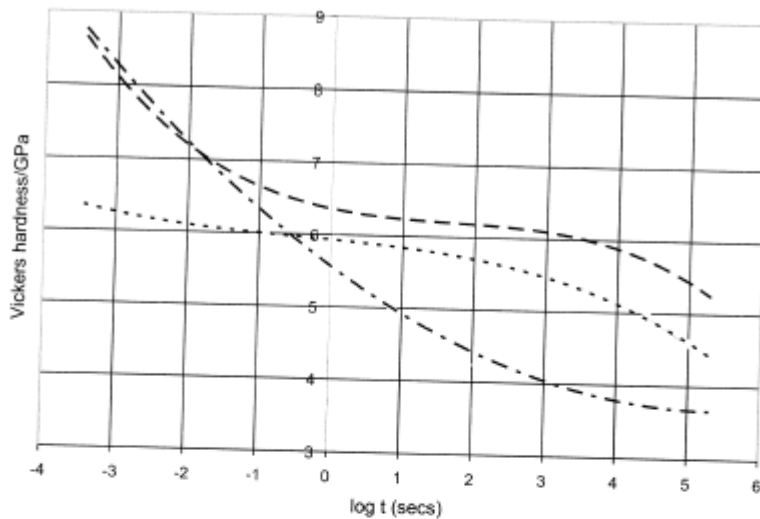


Figure 8. Schematic of Vickers hardness of soda lime silica glass as a function of time at room temperature: - - - - cleaved surface in air, - - - cleaved surface in oil, ···· natural surface in air. (from the original data in [50]).

where it appeared to be due to shear flow, and in "anomalous" glasses where compaction is apparently the primary mechanism of flow.

In 1964, Marsh[48] made measurements of the hardness of several glasses as a function of temperature, and of a soda lime silica glass as a function of loading rate. On the basis of the agreement he found between hardness and fracture parameters, he proposed that "flow" must be considered in any discussion of the so-called "brittle" fracture of glasses. Since that time, many attempts have been made to study the time (rate) dependence of the hardness of soda lime silica glasses [49]. The agreement was not particularly good since the data are very dependent on atmosphere and surface condition of the glass as well as the testing rate, Figure 8.

The temperature dependence of Vickers hardness was redone by Kurkjian et al [51], who found reasonable agreement with the results of Marsh. Some of these data are shown in Table 2. From this it can be seen that while the data are not sufficiently detailed, and although the hardness values are consistently higher than those of strength, there does appear to be a reasonable correlation between the hardness and strength under similar conditions. The ratio of Vickers hardness at 77K to that at room temperature [51] and the same ratio for tensile strength [52] are ~ 2 to 3 as noted earlier by Kurkjian et al [51]. It is especially surprising that there are not good data in the literature on the intrinsic strength and fatigue of standard soda lime silica glass as a function of time (e.g., fatigue) and temperature. This is another example of the need for fundamental data.

In addition to the rough correspondence of the data in this table, as shown earlier in Figures 3 and 4, there is qualitative agreement between strength and hardness as a function of composition. Thus, if the hardness is governed by flow under the indenter and fracture is governed by the (completely?) brittle behavior at a crack tip (or the continuous failure of bonds), presumably without any stress-moderating mechanisms acting, these correlations require an explanation. Such an attempt was made by Weidmann and Holloway [53] without complete success (see [54]). This correlation demands an explanation, or at least a rationalization, and to our knowledge, no one has attempted this since the work of Holloway and co-workers in 1974 and 1975.