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LETTERS

The Structure of Glasses

A series of thought-provoking articles appeared in the special issue "Frontiers in materials science" (31 Mar., p. 1918) dealing with glass theory. Another article relating structures to modulus, *the* yardstick of structural order (even within amorphous disorder), might have further enriched the survey.

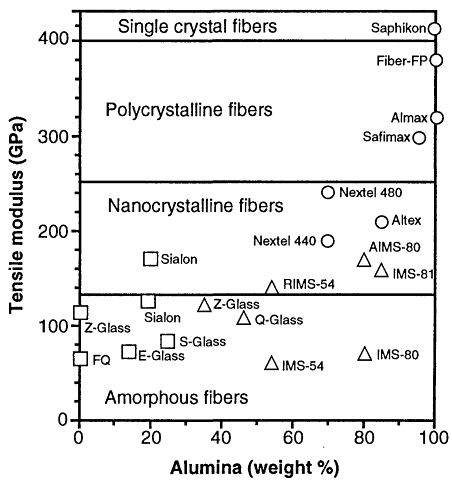

Fig. 1. Oxide fibers: Modulus versus composition and process. Amorphous and nanocrystalline fibers are glasses; polycrystalline and single crystal fibers are ceramics. (○) Sol-gel or slurry-spun fibers (all others are melt spun fibers). (□) "Strong" silicates (FQ is fused quartz, E- and S-glass are commercial fibers, and Z-glass is a zinc oxide–modified silicate). (△) "Fragile" and "inviscid" aluminates (Z-glass is a zinc oxide–modified aluminate, IMS is an inviscid melt spun fiber with a given percent alumina, RIMS is a redrawn inviscid melt spun fiber, and AIMS is a specially annealed inviscid melt spun fiber).

By way of example, one can compare (Fig. 1) the modulus of alumina-based fibers (*1*), as fibers are not only convenient specimens for structural analysis, but also potential commercial products. Thus, glasses are x-ray amorphous, yield glassy fracture, and have a structure in which the molecules are more or less randomly arranged in three dimensions. Depending on the degree of structural order, the glassy modulus ranges from 69 to 125 gigapascals (GPa), but does not correlate with composition: the structural order (modulus) of a rapidly quenched inviscid melt spun glass fiber (54% alumina) is lower than that of E-glass (15% alumina) and the same as that of fused quartz (0% alumina). As internal order (modulus) increases through compositional or process changes, or both, nanocrystalline materials with glassy fracture are obtained (125 to 250 GPa), then polycrystalline materials with brittle fracture (190 to 400 GPa), and finally single crystal materials (410 GPa). Some implications (for example, melt spun fibers with sol-gel fiber properties) may trigger new glass research (*1*) and yield new commercial bulk glasses and glass fibers (*2*).

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2. ——— and S. D. Brown, *Composites Sci. Tech.* **51**, 243 (1994).

Economic Growth and Environmental Policy

There is much to agree with in the Policy Forum "Economic growth, carrying capacity, and the environment" by Kenneth Arrow *et al.* (28 Apr., p. 520). They argue that findings regarding downturns for certain pollutants

> imply neither that economic growth is sufficient to induce environmental improvement in general, nor that . . . the Earth's resource base is capable of supporting indefinite economic growth.

In the same vein, they conclude that economic liberalization and other policies that promote gross national product growth are not substitutes for environmental policy.

These views are not, however, expressed in the empirical papers the authors cite. These papers do not claim that the Earth's resources are limitless, and they do not assert that economic growth is a substitute for environmental policy. From the outset, researchers in this area have studied a broad mix of environmental problems, some of which appear to decline at early levels of development, some only at intermediate levels, and some not even at the highest levels. Indeed, as analysis of the authors' attributions reveals, most of the concerns they raise can be found in the very literature they are examining.

Rather than continuing to refine the rhetoric of "sustainability," we should con-