Are Leached Porous Glasses Fractal?

The concept of fractal geometry has proven useful for the description of ramified objects such as branched polymers and colloidal aggregates. The concept has also been used to interpret a variety of experimental observations on solid materials such as epoxy resins[1] and porous glasses,[2] as well as globular structures, such as protein molecules.[3] It is our opinion that these later applications are suspect. In this Comment, we study the structure of a porous Vycor glass and demonstrate that the fractal interpretation of energy transfer by Even *et al.*[2] is inconsistent with the observed structure of this material.

Even *et al.* performed their picosecond spectroscopy experiment on a leached borosilicate glass (Vycor 7930). They concluded that, on the dimensional scale of approximately 90 Å, this structure consists of a percolationlike network of channels with a fractal dimension $D=1.74$.

We studied the structure of Vycor 7930 using small-angle neutron scattering, and small-angle x-ray scattering. If a fractal network exists in this material, this feature would be reflected in the dependence of the scattered intensity, I, on momentum transfer, K. In particular, we expect[4] power-law decay ($I \sim K^{-D}$) where $D=1.74$. By contrast, the data in Fig. 1 show a peak near $K=0.03$ Å^{-1} (corresponding to length scales of about $2\pi/0.03=200$ Å), and the slope of -4 at large K is the signature of scattering from a smooth surface.[4] We conclude that the structure is nonfractal over dimensional scales from 5 to 500 Å.

A reasonable interpretation for the observed peak in the structure factor is that it is the remnant of a spinodal decomposition process. Vycor glass is prepared by leaching of a phase-separated borosilicate glass.[5] The early stages of spinodal decomposition lead to phase separation via the growth of an unstable Fourier component in the density-fluctuation spectrum. For glass, it is reasonable that this early-stage structure is trapped because of the divergence of the viscosity at the glass transition temperature. The leaching process removes the more soluble phase so that the leach pattern follows the concentration distribution left by the spinodal process.

Transmission electron micrographs of Vycor 7930 confirm the nonfractal structure (inset). The smooth particlelike structures range in size from 150 to 250 Å. The presence of fractal porosity on large length scales is not apparent in transmission electron micrographs obtained to date.

Although our work concentrated on a particular material, we believe that fractal concepts should be used with caution when applied to any solid object. Even for an exceedingly porous material such as a silica aerogel, fractal structures exist[6] only over a limited length scale between 10 and 100 Å. Dense structures, such as epoxy resins and globular proteins, are not geometric fractals.

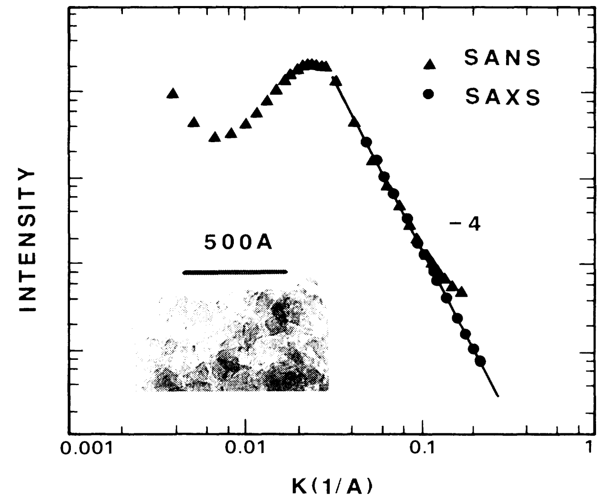

FIG. 1. Scattering curves for Vycor 7930. The deviation of the small-angle neutron-scattering data from Porod's law near $K=0.2$ Å^{-1} is due to the existence of an uncorrected, incoherent background. The scattering curves were corrected only for the empty-beam background intensity. The inset is a transmission electron micrograph of the sample.

Anomalous dynamic exponents for these materials are not related to fractal mass distributions. If fractal dynamics exist in these systems, one must either identify a subset of atoms whose spatial arrangement is self-similar[3] or seek an alternative explanation for the unusual dynamics.

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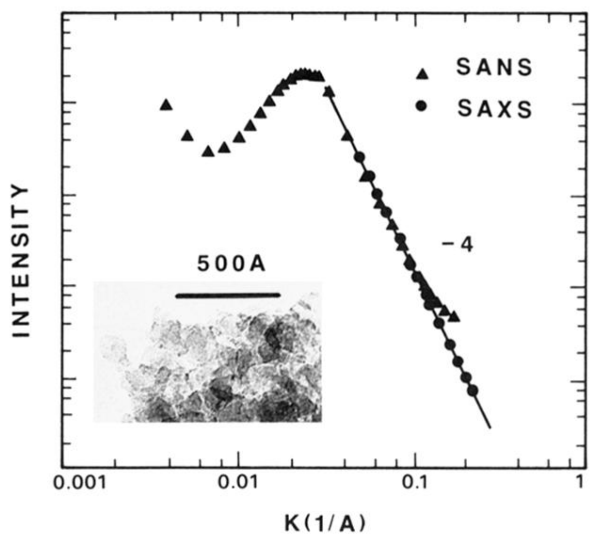

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