EDITORIAL

Glasses and Amorphous Materials

Gases, liquids, and solids—these are the simplest ways to classify substances. Elementary texts imply that this is an easy characterization because we all "know" what each part of this characterization means. Many materials, however, do not easily conform to simple definition. If liquids take the shape of the vessel in which they are contained without filling the vessel, then our definition of a liquid must be a time-dependent one, because we may have to wait a long time if the material is very viscous. In this week's *Science* we explore some of the world of glasses, the wonderful area in which materials have the properties of liquids in terms of their lack of long-range structure and the properties of solids in terms of stability. These materials are not at equilibrium; the slow structural relaxation times are responsible for their special properties. Plastic at higher temperatures, they can be shaped; more rigid at lower temperatures, they can play important structural roles. The transition between the two regimes plays a critical role in understanding the important properties of these materials.

Angell provides an overview of the formation of glasses from liquids and biopolymers. Glasses can be formed by many routes, the most common of which is the cooling of a viscous liquid. Different types of amorphous structures can form depending on how the glass is prepared; water is an example of a material exhibiting "polyamorphism" (see cover). The ability of a material to form a glass can range from "strong" to "fragile," depending on the bonding and interactions between the components. Angell explores the concept of complex amorphous systems that lose degrees of freedom through weak first-order transitions and applies this idea to the problem of the differences between native and denatured hydrated proteins.

Stillinger describes his view of supercooled liquids and glass formation in terms of a general potential energy topographic map. As a liquid cools, its motion explores a huge number of energy minima that vary in depth. This approach allows a number of key phenomena exhibited by glasses to be understood, such as their non-Arrhenius viscosity and relaxation times. Stillinger also considers whether there can be an "ideal glass state."

Frick and Richter discuss the microscopic basis for macroscopic changes in the properties of polymers as deduced from neutron diffraction studies of the glass transition. They examine local motions, vibrations, and relaxation processes. The microscopic disorder of the glassy solid remains largely unchanged as the polymer is transformed to the melt or liquid state.

Hodge discusses physical aging in polymer glasses. The changes in physical properties as the glass undergoes structural relaxation toward its equilibrium amorphous state are important for materials used commercially. Understanding these issues better is a major challenge not only to the theorists but also to those who design, manufacture, and use these materials.

Greer discusses the relatively new field of metallic glasses. It is now possible to make solid metallic materials with a wide range of compositions and novel magnetic and mechanical properties. Metallic glasses are often formed by supercooling the melt, but alloy compositions now exist that form glasses at relatively slow cooling rates. Studies of these alloys show that metallic glasses can be true amorphous phases, rather than a collection of disordered nanocrystals.

Understanding glasses brings together many of the important aspects of physical science. Statistical mechanics and spectroscopy are critical to this task, as are of course synthesis and analysis. Because polymeric plastic materials are so crucial to our lives and our economy, we need to understand them better. But glasses themselves are not a field of science, and our understanding of them grows out of basic, fundamental studies, many of which have developed for other reasons. The loss of proposed facilities for neutron diffraction in the United States (*Science*, 17 February 1995, page 952) is a sad consequence of an inability or lack of commitment to support the basic capabilities required in the long run for further progress. We do not want to lose sight of the ends we are trying to reach or the beginnings from which they must develop, and we must work to ensure that our research goals can be met. The scientific community must make this clear to the public, which benefits from our work, and to government agencies, which help support it.

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