Theory predicts aging process in DVDs, plexiglas, other polymer glasses

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Polymer glasses are versatile plastics widely used in applications ranging from aircraft windshields to DVDs. Researchers at the University of Illinois have developed a theory that predicts how these materials age. The theory also explains why motions at the molecular level can have macroscopic consequences.

"Glasses, including polymer glasses, are essentially frozen liquids," said Kenneth S. Schweizer, the G. Ronald and Margaret H. Morris Professor of Materials Science at the University of Illinois. "They appear solid, but because they are frozen liquids, the molecules continually undergo small motions that lead to a time dependence of properties."

Three years ago, Schweizer and graduate student Erica Saltzman developed a theory that described the transition upon cooling of a polymeric material from a liquid to an amorphous solid or glass. The theory explained how the viscosity of a polymer glass changes dramatically over a narrow temperature range. The researchers reported that work in the July 22, 2004, issue of the *Journal of Chemical Physics*.

Now, in the April 20 issue of *Physical Review Letters*, Schweizer and postdoctoral research associate Kang Chen present a theory to describe the aging process in polymer glasses. The new theory predicts not only how polymer molecules move, but also the material properties, at a wide variety of times and temperatures. Polymer glasses are plastics that possess unusual and technologically useful mechanical properties. Unlike most other types of solids, polymer glasses can possess high impact

resistance and, even though they are stiff, can often be significantly deformed without breaking. They are usually inexpensive to make, and easily melted and molded into many shapes.

And, they're always on the move.

Unlike window glass, which melts at roughly 1,200 degrees above room temperature, polymer glasses have melting points much closer to room temperature. So close, in fact, that many polymer glasses retain some liquid-like properties at room temperature, including motion at the molecular level.

"The movements are so small and so slow, we can't see them without the aid of sophisticated measuring tools," Schweizer said. "Nevertheless, this residual motion can significantly change the material's mechanical and thermal properties over time."

As the material gradually reconfigures and approaches equilibrium at room temperature, the movements become slower and slower. Under sufficiently cold conditions, this "relaxation" time can become astronomically large, even longer than the age of the universe for some materials.

"Among other possible effects, the aging process causes polymer glasses to become stiffer and often more brittle," said Schweizer, who also is a professor of chemistry, of chemical and biomolecular engineering, and a researcher at the university's Frederick Seitz Materials Research Laboratory.

Over time, the molecules crowd closer together, increasing the density and changing the mechanical properties of the material.

"Through our theory we developed a way to relate the physical

properties of a polymer glass to the time scale of molecular movement," Schweizer said. "This information is especially important in engineering applications where small changes in dimensions, stiffness or other properties can affect long-term performance or reliability."

Source: University of Illinois at Urbana-Champaign