Through a glass clearly – researchers shed new light on one of nature's mysteries

Waste disposal research.

Physics Web
July 11, 2006

Glass may seem to us to be one of nature's most transparent creations, but when it comes to its atomic structure it is a dark world of which little is known.

The reason why some liquids, when cooled rapidly, form glasses and others form crystals is one of the biggest mysteries still left to be solved in physics.

But now researchers at the University of Bath, together with colleagues in Bristol and Grenoble, have shone new light into the mysterious world of glass, paving the way for new and important materials to be developed.

Most liquids when cooled form a structure where the atoms are arranged in an ordered fashion. Scientists call these crystals – ice is one example.

Scientists define glasses as materials that, when cooled from liquids quickly, form structures that are disordered on an atomic scale. Glasses come in many forms, and the common substance that sits in our window frames is just one variety.

In an important breakthrough, a team led by Professor Philip Salmon, of the University of Bath's Department of Physics, last year found that there is a subtle and unexpected ordering never discovered before in the microscopic world of glass.

Professor Salmon found that glasses have atoms formed into tetrahedra – three-dimensional objects made by joining equilateral triangles with an atom at the centre and one at each corner. These tetrahedra arrange themselves into ring structures and ordering can extend over unexpectedly large distances of about one ten millionth of a millimetre. This structure was observed in two glasses made of different chemicals, Zinc Dichloride and Germanium Diselenide.

So little is known about glasses that this discovery was significant enough to be published in the prestigious journal Nature. It was co-authored by Dr Richard Martin.

Now Professor Salmon has taken his research further. Glasses are divided into two types: strong and fragile. The names are misleading as they refer to the properties of the material in liquid form rather than as a glass: strong materials maintain their viscosity (how 'thick' the liquid is) under high temperatures; fragile ones become much less viscous when heated.

By using the latest techniques in neutron diffraction, Professor Salmon has found the differences in atomic structure that separate glasses into the strong and fragile varieties.

His team has found that both types of glass form rings of joined tetrahedra. In strong glasses, starting from a single tetrahedron and looking outwards, large rings are first observed but the arrangement of the rings gradually becomes less ordered. In more fragile glasses, the rings don't have this initial open structure and the tetrahedra are more closely packed throughout. The more open the rings are at first, the stronger the glass.

Professor Salmon has shown that by applying pressure to strong glasses, this will collapse the initial ordered rings and make them disordered, turning the glass into a more fragile variety.

Professor Salmon believes that this breakthrough in understanding of glass structure will be of great interest to physicists interested in the nature of glass formation and to materials scientists who are developing glasses to make new lasers and store nuclear waste.

It could also be an important step in developing new materials. The two best known forms of crystalline carbon, diamond and graphite, have very different properties. Graphite is soft and is used, for example, in pencils whereas diamond, which is formed at high temperatures and pressures, is hard and is used as an industrial abrasive. Novel glasses with intriguing new properties could therefore be developed by making glasses under the same type of extreme conditions used to make diamonds.