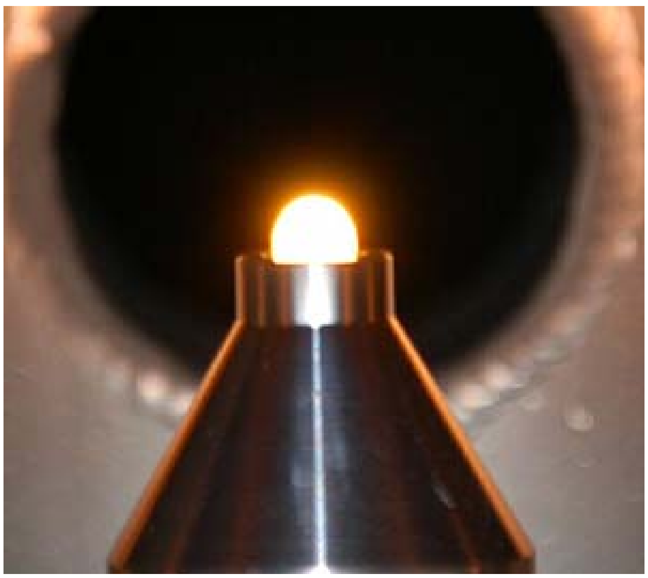
Aerodynamic levitator allows samples to 'float on air'

January 8 2013, by Agatha Bardoel



A metal oxide drop levitated in a flow of high-purity argon gas. The sample is being heated from above with a laser beam that can heat it more than 2500 degrees centigrade. The sample is held in a special "levitation nozzle" installed in the NOMAD beam line.

To you and to me, glass is a window pane, a mirror, something to hold the claret. To scientists, however, glass is a liquid that has lost its mobility, yet keeps its memory of being a liquid.

Both liquids and glasses are disordered materials in which the atoms don't establish long-range patterns. Using neutron scattering to probe that disordered system at the atomic level researchers can learn how to make new and potentially better glasses for applications such as lasers and fiber optics, as well as gain a better understanding of geological materials.

To study liquids and glasses, a collaborating team from Materials Development Inc. in Arlington Heights, Illinois; Stony Brook University in New York; Argonne National Laboratory (ANL); and the Neutron Sciences Directorate at Oak Ridge National Laboratory (ORNL) has developed a container-less sample environment, in which a drop of pure liquid literally "floats" on a jet of flowing gas.

This aerodynamic levitator sample environment has been installed on the Nanoscale-Ordered Materials Diffractometer (NOMAD) at the Spallation Neutron Source at ORNL. There, the research team is using it to study small drops of liquids such as calcium, magnesium, and aluminum silicates.

"We study liquids as they transform to glass," says Richard Weber, the principal investigator and the owner of Materials Development Inc. "That is important because many materials are processed as liquids at some stage in their life, such as silicon wafers that start as sand and then are converted into silicon by melting and processing. "We look at the liquid state, measure its structure, and see how it actually transforms into glass."

Research team (left to right): Lou Santodonato, Rick Weber, John Carruth, Jörg Neuefeind, Chris Benmore, Lawrie Skinner, Sonia Tumber, Danni Jin. Not pictured: Cory Fletcher, Bruce Hill, John Parise. Photo by Renee' Manning.

"Glass is a liquid that has lost all its mobility, but at the atomic level, unlike a crystal, it is still a disordered system," explains NOMAD's lead instrument scientist Jörg Neuefeind. "It has kept the memory of being a liquid, but it's not moving anymore. Window glass and fiber-optic glass are typical glasses. There are also metallic glasses, which look and behave like a metal but still are disordered."

"There is some structure, but no long-range periodic arrangements, such as we find in a crystal," Neuefeind continues. "In rock salt sodium chloride, the atoms are ordered over distances up to the macroscopic. In a glass, while there are building blocks that are held together by the atomic forces, this order disappears over much shorter length scales—over 10 to 100 angstroms (billionths of a meter)—these are very short distances. This lack of long-range order makes these materials interesting both fundamentally and for applications."

Neuefeind says NOMAD is specifically designed to look at the structure of such materials. "The principle is simple: You have a very powerful beam of neutrons that hits the sample, the sample scatters the neutrons, and you detect where the distribution of neutrons scatter from the sample. "It is a combination of a very powerful neutron beam with large detector coverage, which means that you can recover most of the neutrons that are scattered. "That tells you where the atoms are and what configurations they take."

The levitator has two components. There is a 400 watt carbon dioxide laser that is used to heat the sample as it floats on the gas flow. The laser is focused on the sample inside NOMAD, using various mirrors and lenses to control the size and shape of the beam.

The second component is the levitation system, a special nozzle designed to produce a smooth gas flow that can trap a drop of liquid about the size of lentil–about an eighth of an inch in diameter—above the gas.

"This is done so that it is not in contact with anything," Weber explains. "We want the sample to be very pure, not to be contaminated by or to interact with a surface that can cause it to crystallize. We heat it from above. Then we use various instruments to measure its temperature and configurations."

Weber has been working with these sample environments for several years. Materials Development Inc. optimized the method for the neutron beam line, working with Neuefeind and the sample environment team at ORNL to install it in NOMAD.

"It is designed specifically to work with a neutron beam line and is installed in the beam line so we can analyze the structure as it's in the process of transforming to glass," Weber says. "It is a perfect way to analyze what changes in the structure of the liquid as we heat it up and cool it down. This is sometimes called supercooling, when the liquid cools below its normal melting point."

"We take a sample at room temperature and heat it above its melting point, which can reach 2000 to 2500 degrees centigrade in about a minute. Then, as it cools," Weber says, "we take measurements with the neutrons. That gives insight into how to improve the quality of glasses. If you are turning a liquid to a glass, you learn what makes the glass, what is the backbone of the glass that holds it together, where you might be able to modify it, to get particular properties, such as strength or optical performance. It is important fundamentally. It's got applications, as well. It bridges those two areas. So it is very useful."

More information: Skinner, L.B. et al., Structure of Molten CaSiO3: Neutron Diffraction Isotope Substitution with Aerodynamic Levitation and Molecular Dynamics Study, *J. Phys. Chem. B* 116(3), 13439–13447 (2012); DOI: 10.1021/jp3066019.

Provided by Oak Ridge National Laboratory