Electrostatic levitation Technique for Thermophysical Property Measurements of Molten Materials on Earth and in Space

K. Ohsaka and W. K. Rhim
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109 USA

ABSTRACT

Thermophysical properties of high temperature molten materials have not been determined accurately because of the experimental problems associated with taking measurements at high temperatures. However, the demands for accurate thermophysical propert y values have been strong in recent years for applications in both scientific and engineering. For instance, the structures of liquids are less understood in comparison to those of solids and gases. The theoretical studies of simple liquids will significantly advance if certain thermophysical properties of molten metals are accurately determined since the metals form the simplest liquid structures. The electronics industry constantly demands high quality semiconductor materials for high density integrated circuit devices. in order to simulate the crystal growth for optimization of the growth process, the accurate thermophysical properties of molten semiconductors are essential input parameters.

Among the problems associated with taking measurements at high temperatures is the sample contamination due to reaction with the container material. This is a common problem for any property measurements. This contamination can be totally avoided if the material is processed in a container-te.ss manner. Sever-al techniques have been developed to achieve this objective on earth through levitation of a material in air. The common obstacle to these techniques is gravity which puts a limitation on materials which can be levitated. Low density materials are generally easy to levitate and process. To overcome this limitation, it is natural to seek a microgravity environment to perform the measurements. A short duration of the microgravity environment can be realized on earth by free fall of the sample. For a long duration, a satellite orbiting around the earth is an ideal place. Since access to the space environment is very limited and expensive, it is important to make the best effort to perform earth-based measurements first. The space-based measurements should be reserved only for measurements which cannot be performed on earth.

At JPL, we have developed a high temperature electrostatic levitation system for the ground based applications 1, 2]. The system is operated in a high vacuum level (~10^{-8} torr) and can heat up a sample to 2000 K. A typical sample. diameter is 2-3 mm. Advantages of the electrostatic levitation technique over other levitation techniques, especially the electromagnetic levitation is decoupling of levitation and heating elements and a wide selection of samples to be levitated. The sample can be levitated at any temperature between room and maximum temperatures. Both conductive ant] non-conductive (including semi-conductive) materials can be levitated. For any thermophysical proper-[y measurements, diagnostic devices must be incorporated with the levitation technique, The devices must be based on non-invasive techniques to take advantage of the Invitation technique.. We have developed the diagnostic techniques such as a high speed pyrometer, sample image acquisition and oscillating sample image acquisition. These techniques allow us to measure the thermophysical properties which include the density (specific volume)[3, 4], total hemispherical emissivity[5, 6], specific heat[5, 6], surface tension[7, 8], and viscosity 7, 8].

An objective of our measurements is to find the limitation of the ground-based measurements in order to determine the necessity of similar measurements in space. We have identified the property measurements which may be significantly improved if they are performed in a microgravity environment because the measured property values are sensitive to the levitation force which is very strong for the ground-based levitation. For example, we employed an oscillation damping technique to determine the viscosity and found that the damping constant was affected by the levitation parameters[7]. The next logical step will be to test whether a short duration of the microgravity environment realized on earth is enough for these measurements.

We are also working on enhancing the present capabilities of the system. We will install devices which will allow us to raise the upper limit of the temperature, to measure the spectral emissivity of the sample, and to manipulate the sample rotation. These enhanced capabilities will allow us to improve the accuracy of the measurements. We envision adding the capabilities which will allow us to measure the thermal and electrical conductivities and to determine the liquid structures in the near future.

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