Thermophysical Properties of High Temperature Liquid Metals and Alloys

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Objective

The objective of this research is to extend, for the first time, the laser polarimetry technique for measuring the normal spectral emissivity to the microsecond time regime. This will enable accurate determination of true temperature of liquid specimens at high temperatures in rapid pulse heating experiments. In addition to the measurement of other experimental quantities, the proposed project will yield data on selected thermophysical properties with unsurpassed accuracy that can be used in support of microgravity materials science research. The properties to be measured include enthalpy, specific heat capacity, heat of fusion, and electrical resistivity above the melting point of selected refractory metals and alloys.

Relevance to Microgravity

Thermophysical property values for liquid metals and alloys are needed in modeling solidification, casting design, crystal growth, and in welding designs. A number of these processes (and related experiments) are currently being practiced in the reduced gravity environment of space. The present research supports these efforts by aiming to provide thermophysical measurements methodology and thermophysical data of unsurpassed accuracy on standard materials, pure elements and alloys of importance to NASA's microgravity mission.

Accomplishments

Five years ago, NIST and CRI began a NASA-sponsored joint effort to integrate the laser polarimeter and the millisecond pulse-heating system to conduct research with the objective of validating and establishing the accuracy of the laser polarimetry method and obtaining accurate emissivity data on selected metals. An initial three-year NRA program resulted in the validation of the laser polarimetric technique and the determination of the spectral emissivity and thermophysical properties on a number of materials at temperatures up to and including the melting point.[1-3] Two years ago, we began the current NRA program aimed at extending the operating range of this system for the measurement of spectral emissivities and true temperature into the liquid state by integration of a microsecond pulse-heating and pyrometry system with an ultra-high speed laser polarimeter system. These studies have advanced tremendously in the last two years, leading to the complete development and preliminary validation of a new ultra high speed laser polarimeter system for the measurement of normal spectral emissivity of liquid materials with microsecond

time resolution, allowing determination of true temperature and thermophysical properties in the liquid state during microsecond pulse-heating.

The previous (existing) microsecond pulse heating system was modified to accommodate a new chamber, new electrical and electronic systems to control the pulse heating, and provisions to accommodate the ultra high speed polarimeter system. A single wavelength pyrometer was used to measure the radiance temperature of the specimen at an effective wavelength of 652 nm, which is close to the laser polarimeter's operating wavelength of 677 nm. In addition, the voltage drop across a known specimen length (with the aid of voltage probes) and the current through the specimen are also recorded precisely. Preliminary studies were conducted in the past year leading to the first precise results of the normal spectral emissivity, true temperature, enthalpy, heat capacity, and electrical resistivity of liquid niobium at temperatures up to 500 K above the melting point. Preliminary results for liquid niobium in the 2800-3300 K temperature range for the emissivity, enthalpy, resistivity and heat capacity are:

Normal emissivity (at 677 nm):	$\varepsilon(T)$	=	$0.348 + 0.000015T$
Electrical resistivity ($\mu\Omega$-cm):	$\rho(T)$	=	$93.512 + 0.002285T$
Specific Enthalpy (J/mol):	$H(T)$	=	$-8766.67 + 42.674T$

$C_p = 42.67$ J/mol.K, $2800K < T < 3300K$, $\Delta H_f = 30 \pm 0.5$ kJ/mol

Future Research Plans

This past year has resulted in the installation and successful testing of an ultra high speed laser polarimeter system and integration with the NIST microsecond pulse heating and pyrometry facility. The preliminary results obtained on niobium show the system to be very promising. Further detailed measurements on niobium are being conducted, and we expect to submit one or two archival publications on this work in the next few months. In the next year, we hope to extend the measurements to other materials including refractory metals, such as molybdenum, tungsten, and industrially important alloys, such as Inconel 718 and 90Ti-6Al-4V from their melting point to about 1000 K above their melting point.

References

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2. A. Cezairliyan, S. Krishnan, J.L. McClure, and D. Basak, *Int. J. Thermophys*. (1998 - in press).
3. S. Krishnan and D. Basak, *Int. J. Thermophysics* (1998 - submitted).