Project ID: **65435**

Project Title: **Millimeter-Wave Measurements of High Level and Low Activity Glass Melts**

Lead Principal Investigator:

Dr. Paul P. Woskov
Plasma Science and Fusion Center
Massachusetts Institute of Technology
167 Albany Street
Room NW16-110
Cambridge, Massachusetts 02139
Telephone: 617-253-8648
e-mail: ppw@psfc.mit.edu

Co Principal Investigators:

Dr. S.K. Sundaram
Senior Research Scientist
Pacific Northwest National Laboratory
P. O. Box 999
Richland Washington 99352
Telephone: 509-373-6665
e-mail: sk.sundaram@pnl.gov

Dr. T. Bond Calloway, Jr.
Principal Research Engineer
Immobilization Process Development
Savannah River Technology Center
Aiken South Carolina 29808
Telephone: 803-725-4999
e-mail: bond.calloway@srs.gov

PROGRESS REPORT

RESEARCH OBJECTIVE

New real-time sensors for characterizing glass melts in high level waste (HLW) and low activity waste (LAW) melters will be developed. Millimeter-wave technology will be applied to the simultaneous measurement of temperature, conductivity, and viscosity for the first time. This new sensor technology will make possible better process control to improve reliability and efficiency of waste glass melters. Also, it will provide new data for bridging the gap between theoretical glass melt models and their relationship to melter performance. Robust waveguide interfacing with the melter will make possible reliable *in situ* monitoring of molten glass properties at the surface and throughout the glass volume. Laboratory studies will be undertaken over a wide range of waste glass chemistries to enable an understanding of the relationship between the melt chemistry and the millimeter-wave measurable characteristics. A basic goal is to characterize glass melts *in situ* so that data will represent the actual melt's behavior. The work is closely coupled to the needs of the Defense Waste Processing Facility (DWPF), West Valley Demonstration Project (WVDP), and vitrification efforts at Hanford, Oak Ridge, and Idaho sites. This research is a collaboration between the Massachusetts Institute of Technology (MIT) Plasma Science and Fusion Center (PSFC), the Pacific Northwest National Laboratory (PNNL), and the Savannah River Technology Center (SRTC).

RESEARCH PROGRESS AND IMPLICATIONS

As of the first year progress has been made in parallel on the various research objectives. The development of the new millimeter-wave sensor capability has been initiated on a laboratory furnace. Glass data has been researched and assembled, and a new glass test matrix is being developed. Glass-blending algorithm for the Defense Waste processing Facility (DWPF) has been initiated. The progress is briefly explained below.

PSFC (MIT): Experimental millimeter-wave instrumentation at a frequency of 137 GHz has been set up on a laboratory furnace for the development of the new sensor capability for simultaneous temperature, conductivity, and viscosity measurements. A high efficiency, internally corrugated waveguide provides millimeter-wave access into the furnace. The waveguide is a composite of Inconel and brass tubing with the section going into the furnace fabricated from a 22-inch long, 1.25-inch diameter tube of 690 Inconel. The waveguide has been tested in ten one day furnace runs at temperatures of up to 1180 ^{o}C. This waveguide has performed well with low insertion loss (3 - 4%) to millimeter-wave radiation in the Inconel section even after the Inconel acquired a chromium oxide coating. The implication of this result is that robust access for millimeter-wave sensors to glass melters in an oxidizing environment is now experimentally established for the first time.

The experimental measurements so far have focused on solid target sensing to refine the analytical basis for simultaneous temperature and reflectivity measurements. A pyrometer measures a thermal signal that is the product of temperature and emissivity (related to reflectivity and conductivity). Additional information is needed to separate these two quantities. Progress has been made on a measurement technique that uses the incoherent thermal emission as probing radiation reflected back at the monitored surface to determine surface reflectivity, so a single pyrometer instrument can simultaneously determine both parameters. Our preliminary results on different material surfaces are consistent with the derived analysis. Measurements have also been initiated on molten glass. A molten medium provides the third parameter, motion, which will be used to develop a new viscosity monitoring capability. Initial measurements of a Hanford glass melt have shown high sensitivity to small surface displacements by coherent millimeter-wave reflection, implying that viscosity measurements are possible.

PNNL: In a parallel activity, glass chemistries covering a broad range of waste and site interests were chosen to test applications of millimeter-wave technology. A total of 22 glasses were melted/used. These included both LAW and HLW glasses (3 Hanford glasses, 6 DWPF glasses, 5 British Nuclear Fuels Limited (BNFL) glasses, 2 plutonium glasses, one iron phosphate glass) and 5 commercial glasses. Commercial glasses included flat glass, container flint, container amber, E-glass, and TV glass. Idaho site glasses were not included as the waste characterization and glass formulation continue at PNNL, SRTC, and Idaho National Engineering and Environmental Laboratory (INEEL). Once these are completed, representative Idaho glass compositions will also be included in the test matrix. Two standard (Analytical Reference Material (ARM) and DWPF Environmental Assessment (EA)) glasses were also prepared for comparison. Some of these glasses have been characterized for chemical durability (using Product Consistency Test (PCT)), viscosity, conductivity, redox, and localized glass-water interactions. Further characterization is in progress.

SRTC: In the other parallel activity, a DWPF Batch 3 glass matrix has been developed and a new glass-blending algorithm is also being developed to minimize the addition of glass forming additives to the DWPF vitrification process. Minimizing the glass former additives within the acceptable glass property limits results in the maximum amount of radioactive waste that can be incorporated into the glass. The new glass-blending algorithm assumes a device employing millimeter-wave technology can measure the properties of the glass. The glass-blending algorithm begins the development of a first principal based "Process Model" control structure. Two years of DWPF melter operating and chemistry data has also been assembled into a single comprehensive database to be used in developing the "Process Model" control structure.

PLANNED ACTIVITY

In the second year experimental work will focus on molten glass measurements and refining the millimeter-wave hardware. Higher temperature waveguide materials such as SiC will be tested for use where Inconel can not be applied so that data on higher temperature (>1200 °C) melting point glasses can be obtained. Volume measurements with waveguide immersion into the molten glass will be tested. Development of the viscosity monitoring capability will be a primary activity in the second year. A relationship between the millimeter-wave measurable displacement rates and viscosity will be established. Millimeter-wave measurements of various glasses will also be carried out to develop a database of measurable millimeter-wave properties and their relationship to glass chemistries. A test will be carried out at the research scale melter at PNNL. Database measurements will be a primary activity in the third year. Development of an advanced "Process Model" control structure will also continue into the second year. The modeling approach will be used to conduct parametric studies to define an acceptable glass-blending envelope for the DWPF. Glass blends obtained using this new model will also be compared to the Process Composition and Control System and other empirical model results being developed for the DWPF. It is planned to incorporate millimeter-wave measurements of actual glass samples into the process models such that a relationship between the actual process and the millimeter-wave instrumentation can be developed.

INFORMATION ACCESS

www.psfc.mit.edu/plasmatech/plasma_technology.html

www.id.doe.gov/emsystems/emsp/gen_multi.cfm

www.srs.gov/

http://wwwi.pnl.gov/est/emsp98/emsp_fy98_awards.html