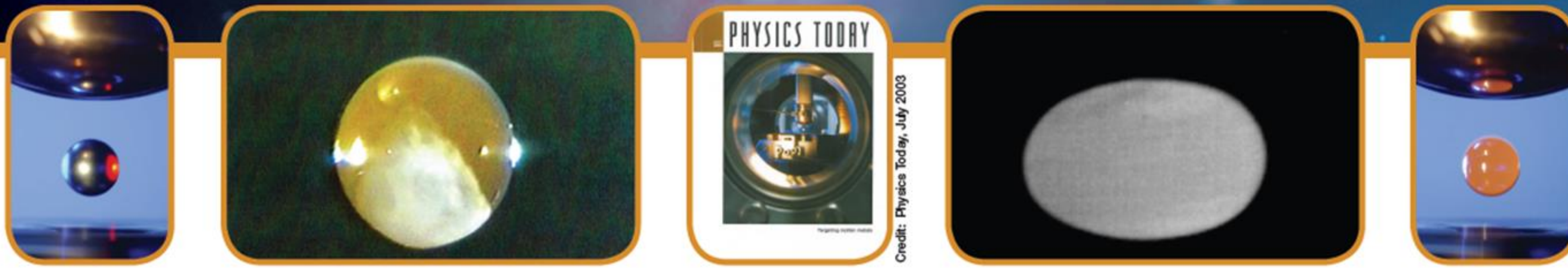
Marshall Space Flight Center

Electrostatic Levitation Laboratory



Recent Upgrades to the MSFC Electrostatic Levitation (ESL) Laboratory in Support of MaterialsLab

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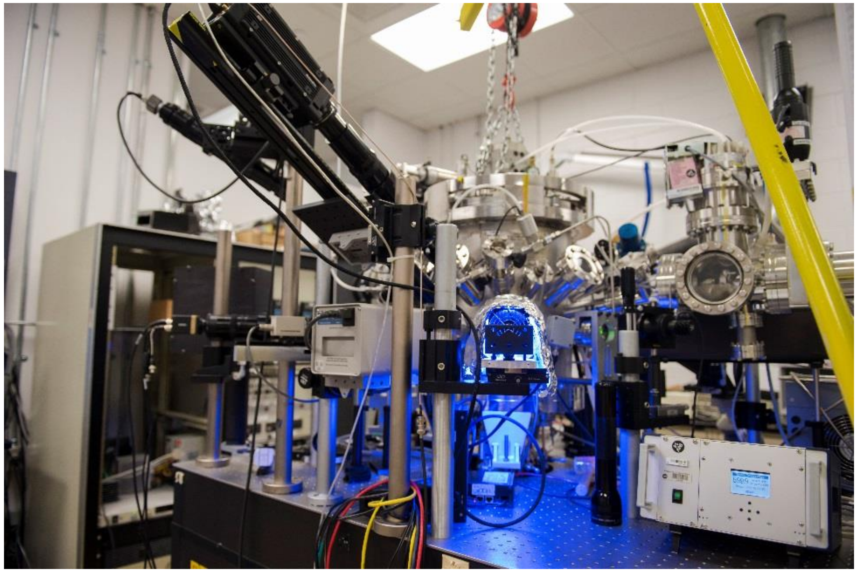
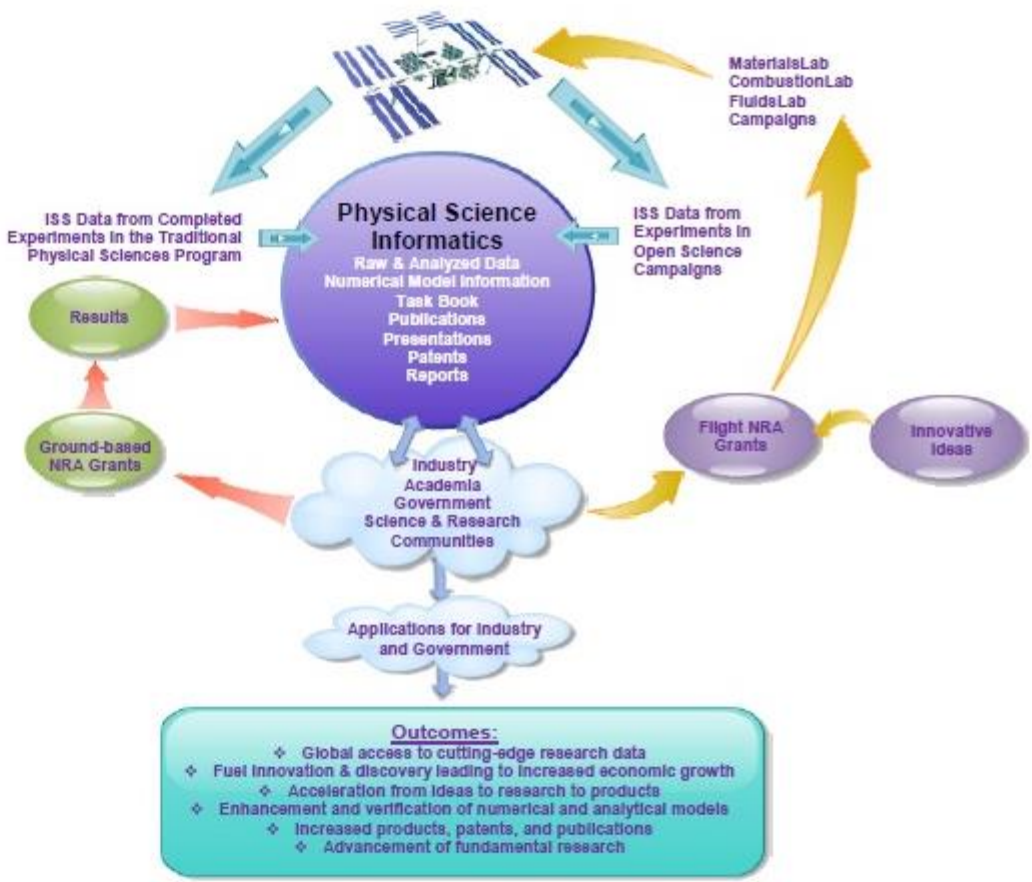
MSFC Electrostatic Levitation (ESL) Laboratory



Main levitation chamber

- The MSFC ESL Lab is a national resource for researchers developing advanced materials for new technologies
- Electrostatic levitation
  - Containerless process
    - Eliminates any container-sample interaction
    - Allows for deep undercooled of samples
- Can process elements, alloys, refractory metals, superalloys, ceramics, oxides, and glasses
- The lab typically measures thermophysical properties
  - Density, Surface tension, and Viscosity
- The lab hosts government, academic, and commercial investigators
- Provides ground-based support for US investigators with levitation experiments on ISS
  - ESA's Materials Science Laboratory Electromagnetic Levitator (MSL-EML)
  - JAXA's Electrostatic Levitation Furnace (ELF)

MaterialsLab



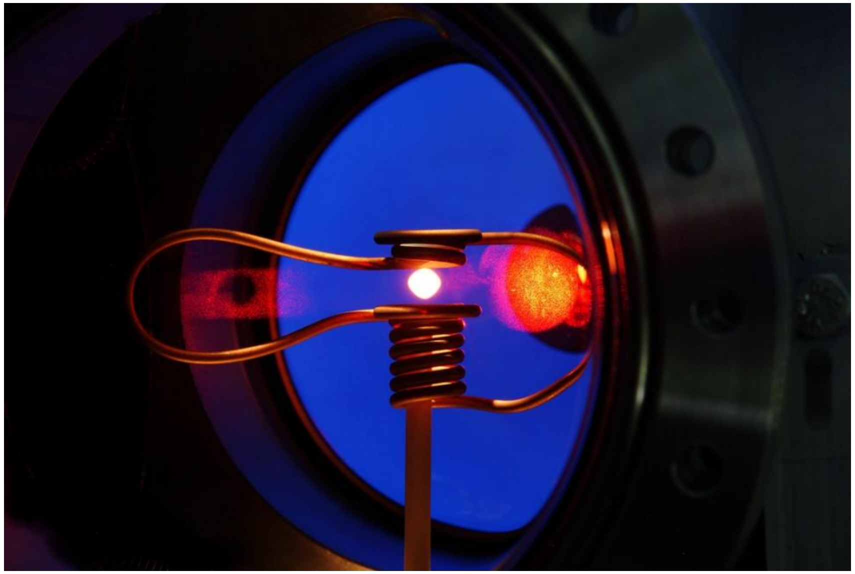
The MaterialsLab Vision – From Microgravity Science to Open Science Informatics

Thermophysical Properties Reference Experiment

Title / Proposer	Measurement	Samples	Objectives	Impact
A Novel Way to Measure Interfacial Tension Using the Electrostatic Levitation Furnace / Narayanan	Interfacial Tension	Zr, Au, Pt	A novel method to measure interfacial tension (IFT). Use of Faraday instability via electrostatic forcing to measure the IFT between a liquid and its surrounding atmosphere.	Novel measurement technique useful for several materials and applicable to several industrial processes (semiconductors, oil recovery, welding, etc.).
Round Robin - Thermophysical Property Measurement / Matson	Density, Surface Tension, Viscosity	Zr, TiZrNi, Steel, FeNi, Pt, Au, Zr w/ 3% O_2 in solution	Understand and control the sources of measurement error and to provide a baseline dataset for quantifying uncertainty in measurements (both space- and ground-based).	Baseline dataset (ensures the highest quality data). Proposed materials have industrial applications (casting, nuclear fuel rods, metallic glass).
Microgravity Investigation of Thermophysical Properties of Supercooled Molten Metal Oxides / Weber	Density, Surface Tension, Viscosity	Al_2O_3, $Ca_{12}Al_{14}O_{33}$, $CaAl_2O_4$, $CaSiO_3$, $MgSiO_3$, $Al_6Si_2O_{13}$, $FeSiO_3$, $YbAlO_3$, $YbLa_2Al_5O_{12}$, etc.	Accurate measurements of thermophysical property data for molten metal oxides. A greater understanding of the glass transition and of the requirements for optimizing and processing.	High value-added glass materials that are used in photonics, lasers, optical communications, and imaging applications.
Thermophysical Properties and Transport Phenomena Models and Experiments in Reduced Gravity / Hyers	Density, Surface Tension, Viscosity	$Bi_{12}SiO_{20}$, $Bi_{12}GeO_{20}$	Advance the understanding of photorefractivity. Measured properties will be used to model and test theories about the effect of processing on microstructure and material characteristics.	Potential to enable several new kinds of photonic devices, e.g. holographic storage, adaptive optics, phase-conjugate mirrors, beamed energy.
Diffusion Coefficients of Dopants in Si and Ge Melts / Ostrogorsky	Diffusion Coefficients	Ge; Diffusing species: Ga, B, Sb, Si	Investigate and measure the diffusion coefficients of several dopants in Ge.	Differences in size and electronic structure of the selected dopants will influence properties and diffusion rates. Applications include novel transistors, detectors, and photovoltaics.

EML Investigators

- Robert Hyers (University of Massachusetts)
  - Unified Support for THERMOLAB - ISS, ICOPROSOL, and PARSEC
  - Objectives:
    - Provide magnetohydrodynamic (MHD) modeling support of macroconvection in various materials for three ESA sponsored projects
      - PARSEC
      - THERMOLAB – ISS
      - ICOPROSOL
- Kenneth Kelton (Washington University in St. Louis)
  - NASA Research under ESA-Based Investigations THERMOLAB and ICOPROSOL
  - Objectives
    - Determine the influence of liquid and solid short-range order on the nucleation barrier.
    - Correlate the nucleation kinetics with the local structure of the liquids.
- Douglas Matson (Tufts University)
  - Electromagnetic Levitation Flight Support for Transient Observation of Nucleation Events (ELFSTONE)
  - Objectives:
    - Investigate the effect of fluid flow on the solidification path of peritectic structural alloys.
    - Research the influence of convection on the formation of different microstructure in a wide range of commercial alloys.



Heated Sample Droplet in Materials Science Laboratory Electromagnetic Levitator (MSL-EML). Photo Credit: ESA/DLR

PARSEC: Peritectic Alloy Rapid Solidification with Electromagnetic Convection

THERMOLAB – ISS: Thermophysical Properties of Liquid Metallic Alloys – Modeling of Industrial Solidification Processes and Development of Advanced Products

ICOPROSOL: Thermophysical properties and solidification behavior of undercooled Ti-Zr-Ni liquids showing an icosahedral short-range order

ELF Investigators

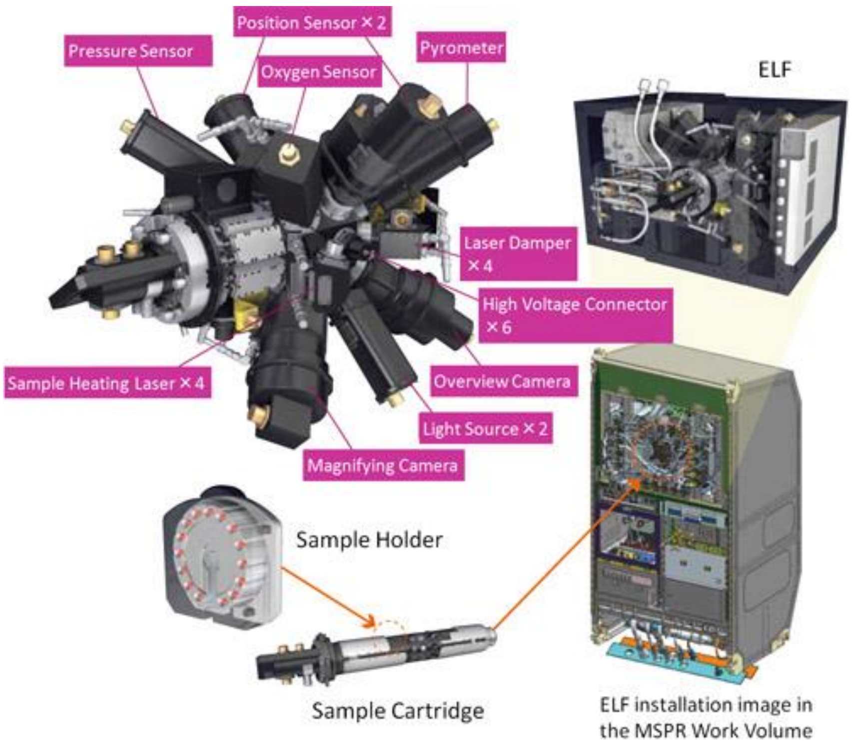
- Robert Hyers (University of Massachusetts)
  - Thermophysical Properties and Transport Phenomena Models and Experiments in Reduced Gravity
- Douglas Matson (Tufts University)
  - Round Robin - Thermophysical Property Measurement
- Ranga Narayanan (University of Florida)
  - A Novel Way to Measure Interfacial Tension Using the Electrostatic Levitation Furnace
- Richard Weber (Materials Development, Inc.)
  - Microgravity Investigation of Thermophysical Properties of Supercooled Molten Metal Oxides

Levitated sample in the ELF ground unit. Photo Credit: JAXA.

Model of ELF hardware.

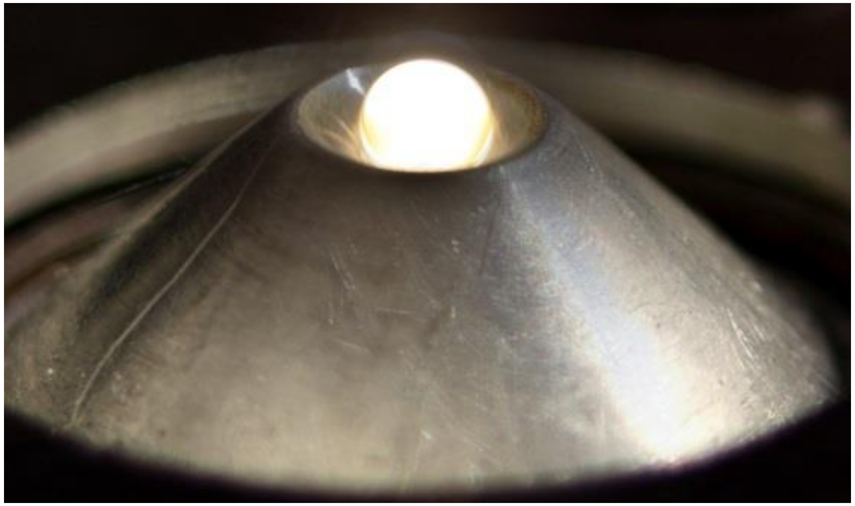
JAXA ELF

- Electrostatic Levitation Furnace (ELF)
  - Installed on the Kibo module
  - Thermophysical properties of high-temperature melts
- Designed to measure the thermophysical properties of oxidized materials
  - Oxide materials are often very difficult to levitate in ground-based electrostatic levitation
- Atmosphere
  - Runs up to 2atm of Air, Nitrogen, or Argon
  - Minimum of 0.2atm
- The MSFC ESL Lab provides ground-based support for MaterialsLab Investigators with ELF experiements



MSFC Support of ELF Experiments

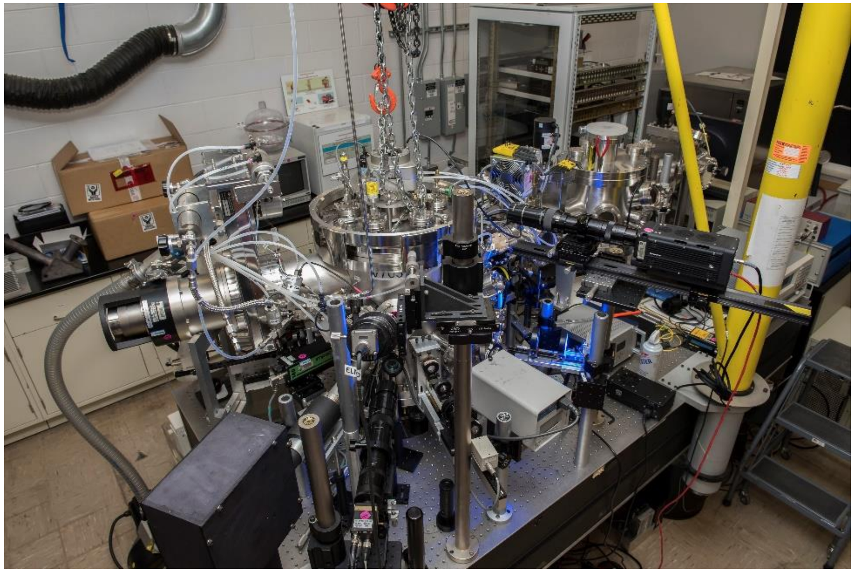
- Ground-Based Testing
  - Requires an aerodynamic levitator
- Sample Fabrication
  - The MaterialsLab support will require a great deal of sample fabrication
  - To accomplish this a laser hearth was built
  - A higher capacity arc melter is currently being built



Sample aerodynamically levitated. Photo Credit: MDI

Pressurized Operation

- The ESL lab’s main levitation chamber was designed to run pressurized
- It has been pressure-rated by NASA safety
  - Up to ~5 atm
- MaterialsLab support will require the ESL lab to perform experiments under pressure
- The lab has had recent success melting a heavy metal fluoride material while in a nitrogen atmosphere



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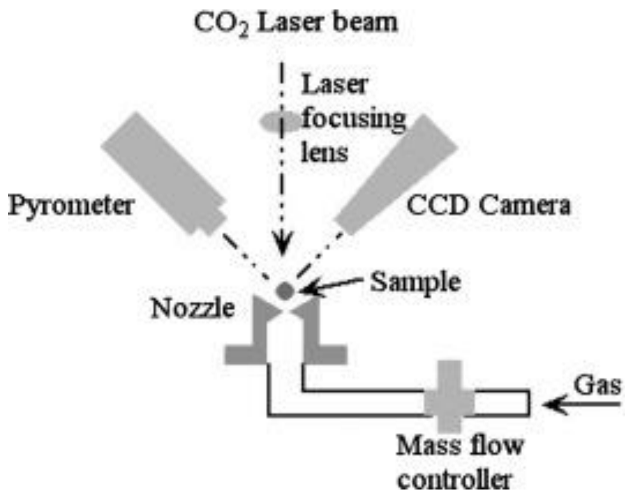
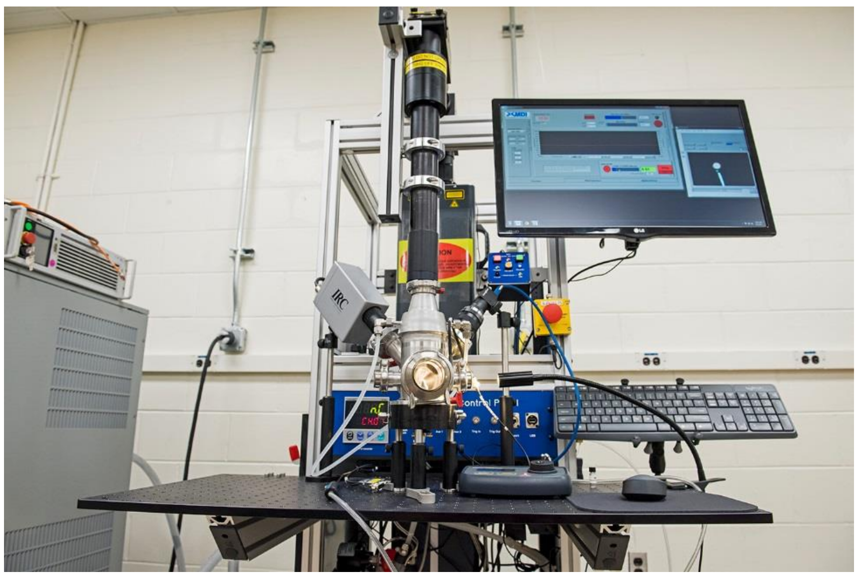
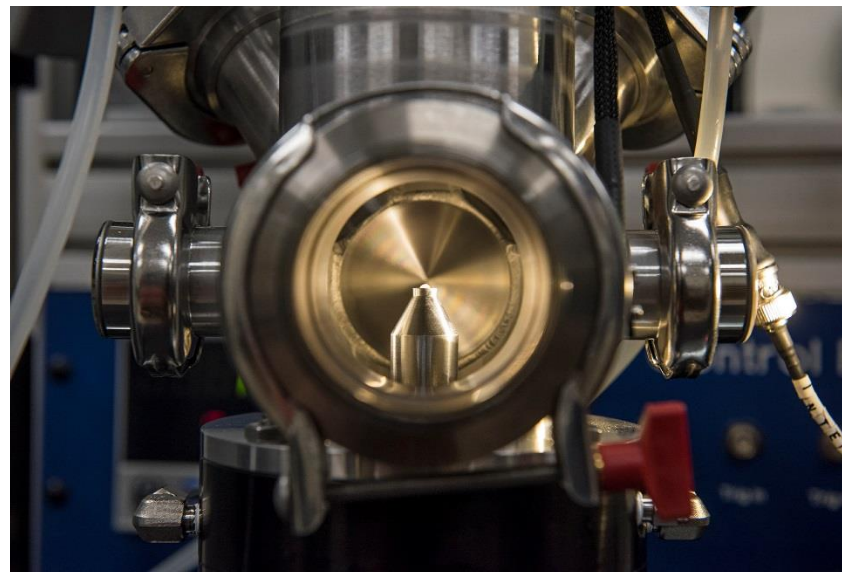
Aerodynamic Levitation

- Uses a conical nozzle and gas jet to levitate small (~2-3mm) samples
- The MSFC ESL Lab will use aerodynamic levitation for laser screening and volatility testing in support of ELF experiments



Aerodynamic Levitator[1]

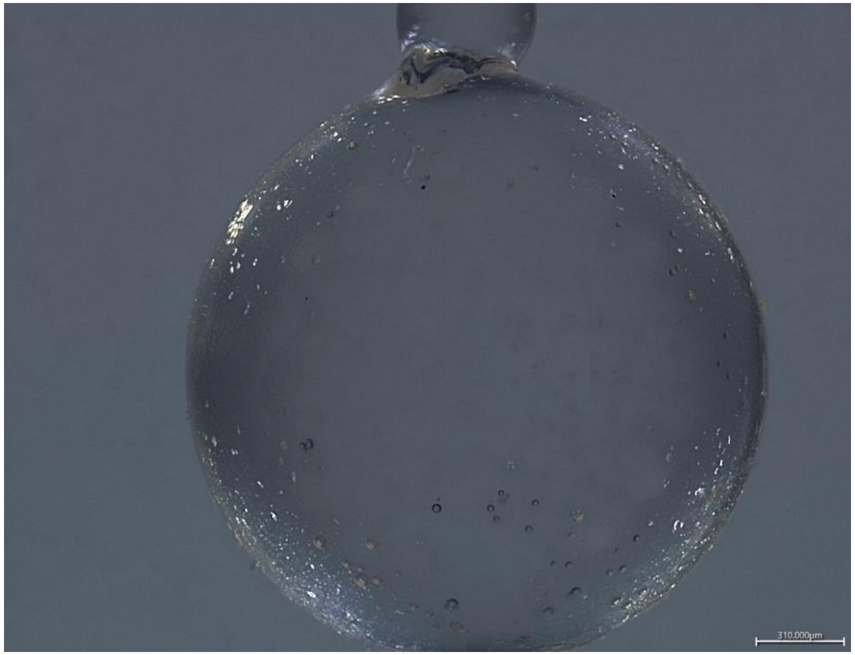




1. From Materials Development, Inc. (MDI)

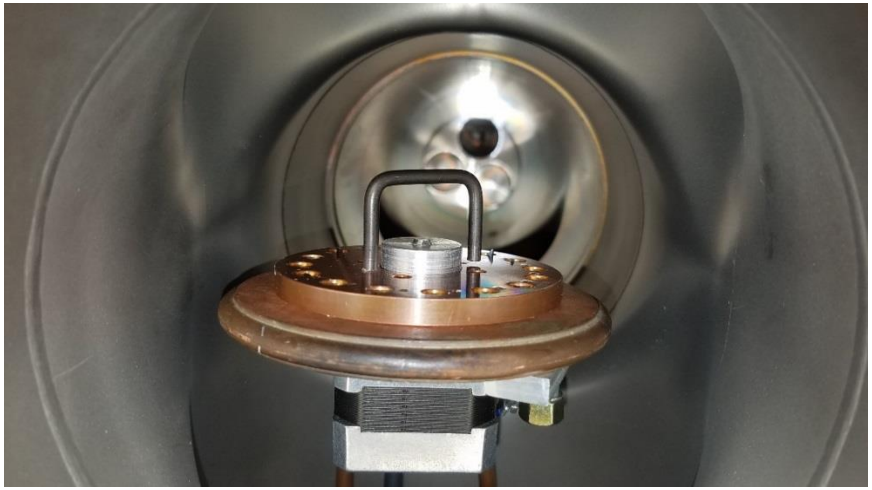
Sample Preparation

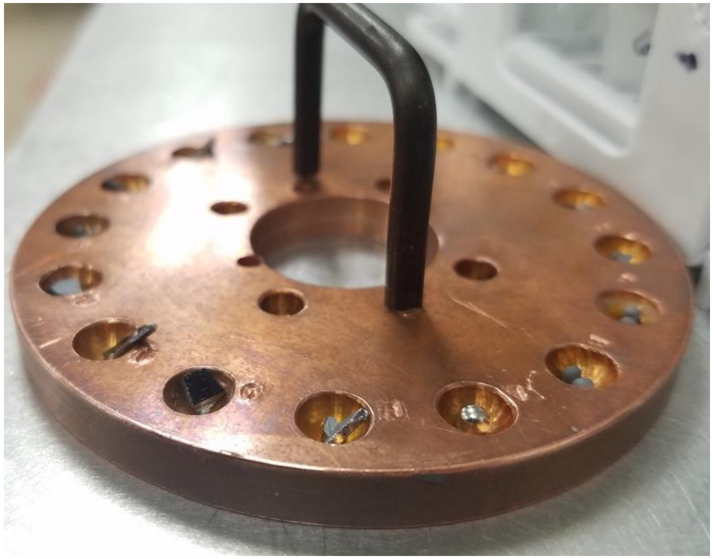
- Sample preparation is very important for quality of experiment data
- The MSFC Lab has two methods of sample preparation
  - Arc melter
  - Laser hearth
- Arc melting is done under an argon atmosphere
  - ~0.5 atm
- The laser hearth can prepare samples in high-vacuum or in a gaseous atmosphere



Glass sample prepared by laser hearth.

Laser Hearth





Questions

- Questions?