Submersion Quenching of Undercooled Liquid Metals in an Electrostatic Levitator

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MSFC Electrostatic Levitation (ESL) Laboratory

- 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
  - 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)
- Will provide ground-based support of upcoming MaterialsLab research
  - Specifically the Thermophysical Properties theme
- The lab’s main levitation chamber has a broad range of capabilities
  - Creep measurement
  - Triggered nucleation
  - Solidification velocity measurement
  - Oxygen partial pressure control
  - Ability to run in a gaseous environment up to 5atm
  - Rapid quench
Rapid Quench System

• First submersion quench system inside an electrostatic levitator
• Allows samples to be dropped into a quench vessel that can be filled with a low melting point material, as a quench medium
  — Thereby allowing rapid quenching of undercooled liquid metals
• Quench vessels can be raised or lowered using the same stem that is used to launch samples
• Up to 8 quench vessels can be loaded into the quench wheel
• Wheel is indexed with servo motors that are controlled with LabVIEW software
Exploded View of Rapid Quench System

(a) Exploded View Diagram

(b) Actual Setup

(c) Isolated Component
Motivation

- To preserve transient microstructures for quantitative metallographic analysis
- To freeze-in metastable phases for solidification path determination
- To rapidly solidify reactive melts while minimizing internal fluid flow
- To reduce fragmentation of structures associated with splat quench techniques
- To eliminate coarsening of microstructures to define as-solidified dendrite shape
- To reduce both solid and liquid diffusion processes to observe partitioning in-situ

FeCrNi sample quenched after second recalescence
Quench Medium

- **Indalloy 46L**
  - 61.0Ga - 25.0In - 13.0Sn - 1.0Zn
  - Liquidus = 7.6 C
  - Thermal Conductivity = ~15 W/mK
    (estimated by manufacturer)

- **Gallium-Indium alloys have been proposed for similar studies by Koseki and Flemings**
  - T. Koseki and M.C. Flemings,
    “Solidification of Undercooled Fe-Cr-Ni Alloys III: Phase Selection in Chilling”,
Quench Sequence – Superheated Zr
Quench Sequence – Si58Co42
Future Work

• Eliminate surface dross
• Improve tracking of surface features to locate impact point/fluid closure point
• Calibrate quench rate as a function of depth below sample surface
• Optimize removal of quench medium from sample surfaces post-test
• Improve timing of droplet release from levitation field to minimize flight time