Submersion Quenching of Undercooled Liquid Metals in an Electrostatic Levitator

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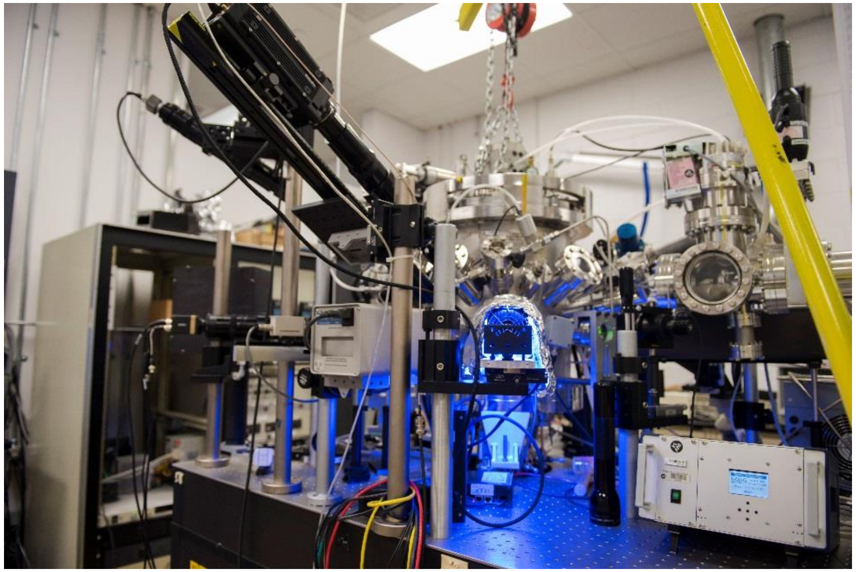
MSFC Electrostatic Levitation (ESL) Laboratory

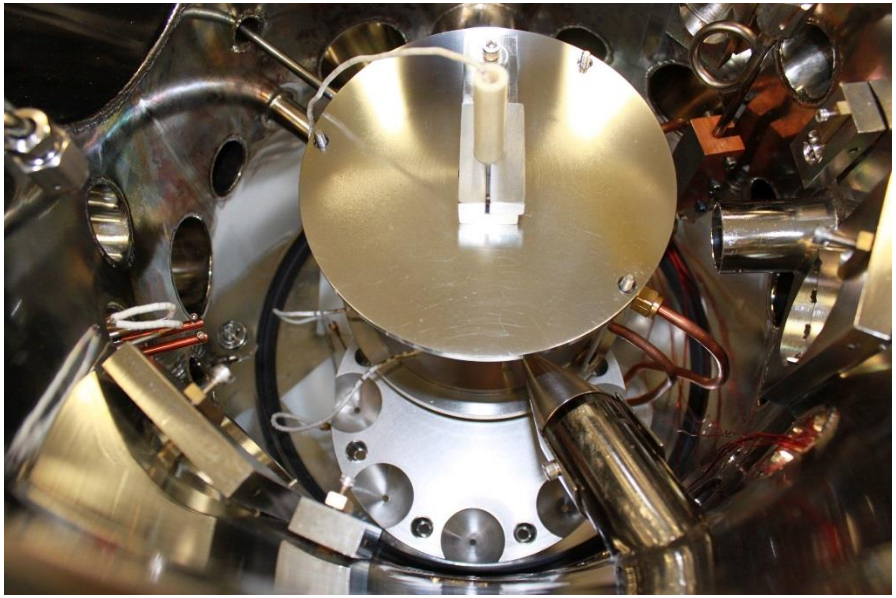


Main levitation chamber

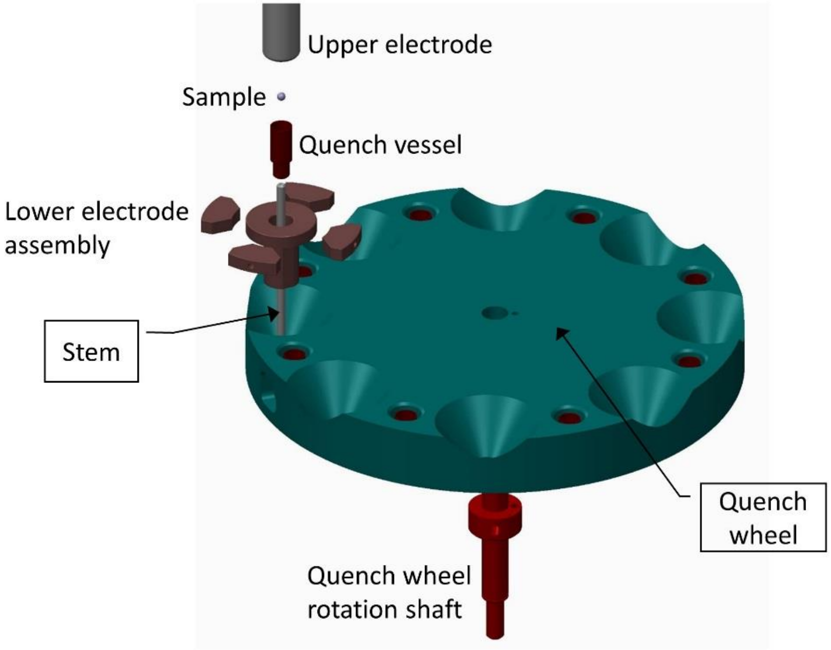
- The MSFC ESL Lab is a national resource for researchers developing advanced materials for new technologies
- Electrostatic levitation
  - Containerless process
    - Eliminates any container-sample interaction
    - Allows for deep undercooled of samples
- Can process elements, alloys, refractory metals, superalloys, ceramics, oxides, and glasses
- The lab typically measures thermophysical properties
  - Density
  - Surface tension
  - 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

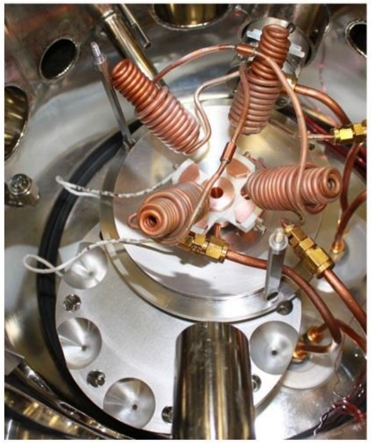
- First submersion quench system inside an electrostatic levitator
- Allows samples to be dropped into a quench vessel that can be filled with a low melting point material, as a quench medium
  - Thereby allowing rapid quenching of undercooled liquid metals
- Quench vessels can be raised or lowered using 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



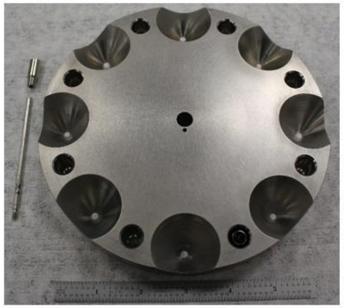
Exploded View of Rapid Quench System



(a)

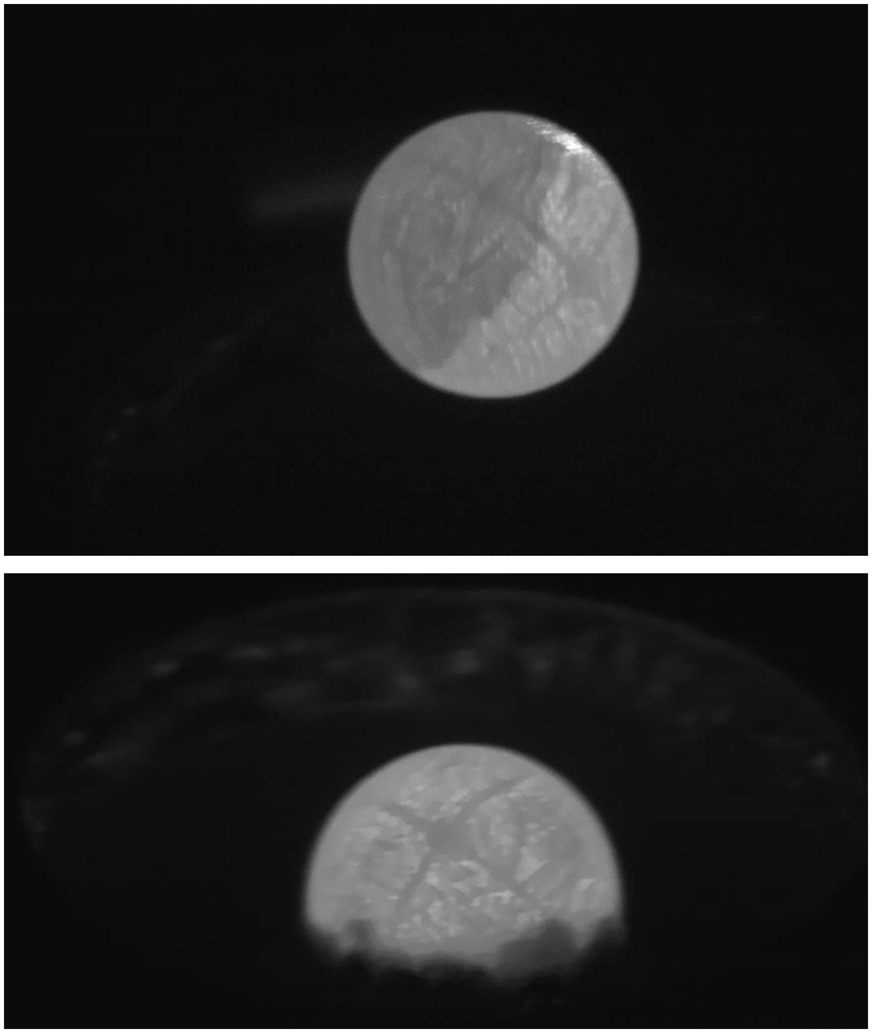


(b)



(c)

Motivation



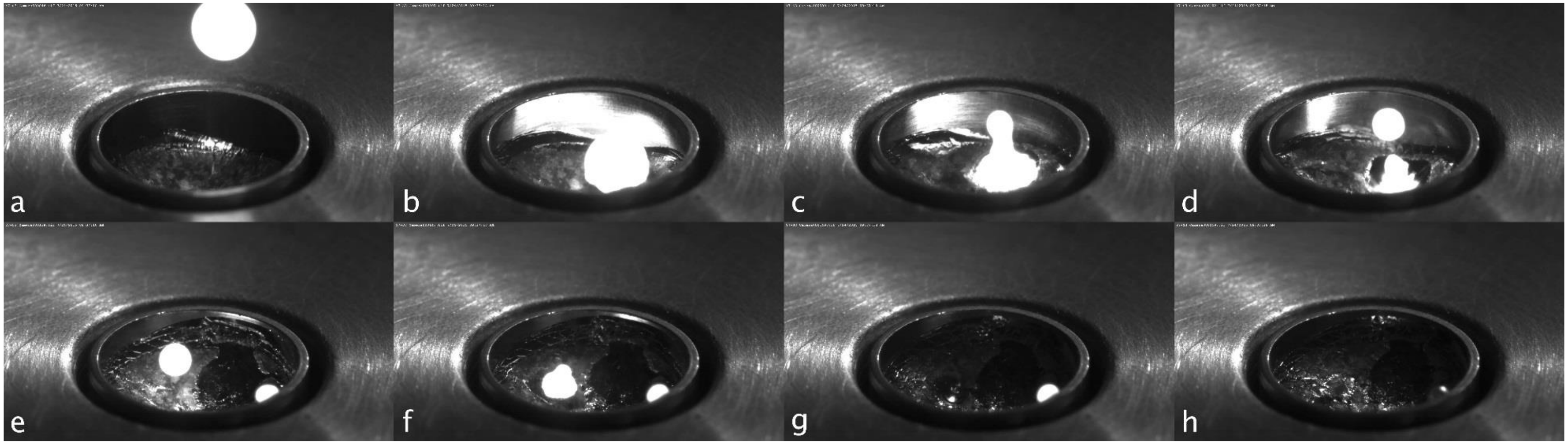
FeCrNi sample quenched after second recalesence

- 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

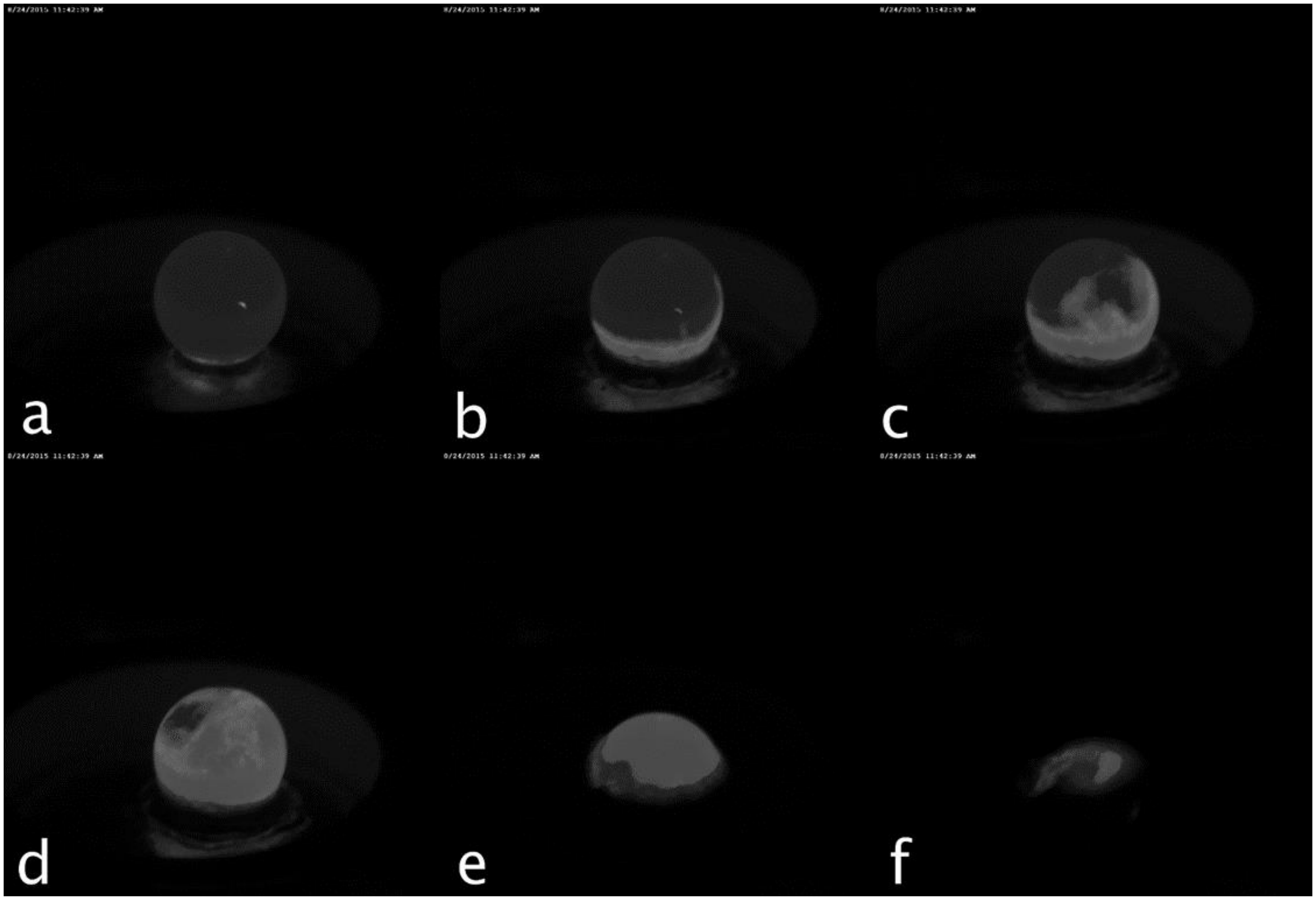
Quench Medium

- 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”, *Metallurgical and Materials Transactions A*, 28A (11) (1997), 2385-2395.

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