Space Life and Physical Sciences Research and Applications Division (SLPSRA)

35th Annual Meeting of the ASGSR

Programmatics – SLPSRA Physical Sciences:
Materials and Biophysics Status

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November 21, 2019
## MSFC Materials and Biophysics
### Research Overview

### MSRR - SCA
- **MSRR/SCA - GEDS** - German
- **MSRR/SCA - GTS** - Su
- **MSRR/SCA - FAMIS** - Hofmann
- **MSRR/SCA - TP Properties Diffusion** - Ostrogorsky

### Levitation
- EML - THERMOLAB/PARSEC/ELFSTONE - Matson
- EML - THERMOLAB/ICOPROSOL/QUASI - Kelton
- EML - THERMOLAB/ICOPROSOL/PARSEC - Hyers
- EML & ELF - ELF2 EML Round Robin - Matson
- ELF - ELF1 Interfacial Phenomena - Hyers
- ELF - ELF3 Non-Linear Optical Materials - Hyers
- ELF - ELF4 Interfacial Tension - Narayan
- ELF - ELF5 Supercorroded Molten Oxides - Weber
- ELF - ELF6 Titanates and Oxides - Weber

### SUBSA
- MSG/SUBSA - Brazing of Al Alloys - Sekulic
- SUBSA - CETSOI Team - Beckermann
- CSLM/SUBSA - SM2 Trans Mstructure - Voorhees

### H/W, Integration and PI Support
- **SCA Development - Reagan**
- **ESL Ground Test Support - Sansoucie**
- **RSD H/W - Depew**
- MaterialsLab SUBSA/PFMI SAA Fabrication
- **MICS - Stephens**
- **MSFC Diagnostic Lab Support**

### Informatics, PSI
- **PSI Informatics - Stephens**
- **PSI-B1 Phase Field Modeling (CLSM) - Asadi**
- **PSI-B2 Mushy Zone (PFMI) - Eshraghi**
- **PSI-B3 Phase Coarsening Models (CLSM) - Wang**
- **PSI-C1 Solidification Patterns (IDGE, MICAST/CSS) - Zaeem**
- **PSI - D1 - Adv M&S Growth Dynamics (IDGE) - Ankit**
- **PSI-E1 P-S-P Rel Solders (ISSI) - Pathak**
- **PSI-E2 - Spurious Grain Form (MICAST/CSS, PFMI) - Tewari**

### PFMI
- **MSG/PFMI - FC1 Correlations - Wegst**
- **MSG/PFMI - FC2 Mstructure Evolution - Dunand**

### Proteins and Biofilms
- **LMM - M81 Transport - Delucas**
- **LMM - M82 Nucleation - Vekilov**
- **LMM - M83 Growth Rate Dispersion - Snell**
- **RTPCG - SDT - Delucas, Carter, Snell, Mueser, Quirk**
- **ESA Protein Team - Vekilov**
- **BioServe - BF1 Biofilm Growth Mechanisms - Zea**
- **BioServe - BF2 Biofilm Growth - McLean**
- **MSG/RSD - Amyloid Fibril Formation - Hirsa**

### DECLIC
- **DECLIC/DSI-R - DSI-R SPADES - Trivedi**
- **CETSOL/DECLIC - Karma**

### Ground-Based Modeling & Development
- **ICESAGE - Volz**
- **SETA Team - Genau**
- **Varying Crosssections - Poirier/Tewari**
- **ParSiWal - Derby/Volz**

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### ICESAGE - Volz
- SETA Team - Genau
- Varying Crosssections - Poirier/Tewari
- ParSiWal - Derby/Volz
Materials Science and Biophysics Research Accommodation on ISS

- Materials Science Research Rack (MSRR)
- MSL/LGF Sample Cartridge Assembly (SCA)
- ESA MSL Low Gradient Furnace (LGF)
- ESA STES - PCAM
- MWA – Portable Glovebag
- SUBSA Thermal Chamber
- PFMI Directional Solidification Unit
- Express Rack
- Microgravity Science Glovebox (MSG)
- JAXA Electrostatic Levitation Furnace (ELF)
- CNES DECLIC Facility – green
- Directional Solidification Insert (DSI) - red
- ISS - ElectroMagnetic Levitator (EML)
- Techshot Multi-Use Variable Gravity Platform (MVP)
- Ring-Shear Drop (RSD) Hardware in MSG
- ZIN Burst Seal Sample Pouch
- MSL/LGF Sample Cartridge Assembly (SCA)
- Group Activation Pack (GAP)
- Plate Habitat (PHAB)
- Bioserve Incubator Well Plates, Group Activation Pack (GAP) Plate Habitat (PHAB)
Materials Science Research on ISS

- Materials Science Research on ISS continues to provide insight into dynamics that may significantly affect viability and performance characteristics of advanced manufacturing processes in either microgravity or reduced gravity environments.
  - Pore Formation and Mobility Investigation (PFMI)
    - Dynamics of mushy zone porosity in a thermal gradient
    - Marangoni convection in the region of pores
  - Gravitational Effects on Distortion in Sintering (GEDS)
    - Liquid phase sintering, start of ISS operations 11/5/19
  - Coarsening in Solid-Liquid Mixtures (CSLM)
    - Dendrite Fragmentation and Morphology during Melting and Solidification – development (SUBSA)

- Multiple ISS-based benchmark solidification experiments are being used to anchor multi-scale models of microstructure evolution (e.g. phase field, cellular automata-finite element, dendritic-needle-network) relevant to process-structure-property-performance (PSPP) linkages at the microscale and above

- ISS-based thermophysical properties measurements (e.g. density, specific heat, surface tension and viscosity) of metals, semiconductors, oxides and glasses are also providing key inputs to multiscale modeling of manufacturing processes.
  - ISS-EML can provide accurate thermophysical properties that are used in models of casting, welding, and metal additive manufacturing.
  - JAXA ELF can be used to study metal oxides, which are precursors to high value-added glass materials that are used in photonics, lasers, optical communications, and imaging applications.

- The ISS can also be used as a platform to conduct targeted experiments to better understand the observed or predicted effects of microgravity or reduced gravity on materials production and repair processes needed to sustain extended duration Gateway or lunar surface operations.
  - Microgravity Investigation of Cement Solidification (MICS) – MWA and MVP
  - BRAZing of Aluminum alloys IN Space (BRAINS) – development (SUBSA)
International Space Station Electromagnetic Levitator (ISS-EML)
• Since operations began in early 2015, the ISS-EML has consistently provided materials science data
• ISS-EML is currently processing Batch 2.4
• Batch 3 is planned to be launched late next year
• There are over 10 project teams with experiments on ISS-EML
  – Each with from a few to over 30 Investigators
• There are 3 US Co-Investigators, each of which is on at least 2 project teams

Japan Aerospace Exploration Agency (JAXA) Electrostatic Levitation Furnace (ELF)
• JAXA-ELF launched to ISS in 2016
• 4 US ELF projects (first scheduled to launch Spring 2020)
• 2 JAXA ELF projects with US Co-Investigators
  – ELF1 Interfacial Phenomena (molten steel and oxide melt) – Hyers
  – ELF6 Properties of Non-equilibrium Titanates and Oxides – Weber
Biophysics Research on ISS – Proteins & Biofilms

Protein Crystal Growth

- Microgravity missions have shown that crystals of some proteins (and other complex biological molecules such as viruses) grown on orbit are larger and have fewer defects than those grown on Earth.
- Real-time protein crystal growth (RTPCG) experiments are planned to evaluate the success of an iterative protein crystallization process on-orbit, using ISS crew in coordination with ground principal investigators to provide a better mechanism for screening crystallization conditions in microgravity.

LMM - MB1, LMM - MB4 Transport – DeLucas

Validate the hypothesis that the improved quality of microgravity-grown biological crystals is the result of slower protein transport and predilection for incorporation of protein monomers higher protein aggregates

LMM MB3, MB6: Growth Rate Dispersion—Snell

Validate the hypothesis that growth rate dispersion could be an indicator of crystals whose quality could be improved in microgravity

LMM MB2, MB5: Solution Convection and Nucleation Precursors – Vekilov

To test if the absence of shear flow affects the concentration and properties of the nucleation precursors and establish the mechanisms of these effects

RSD-Amyloid Fibril Formation – Hirsa

Investigate amyloid fibril formation nucleation and growth upon perturbing the native structure of a protein by hydrodynamic shear forces, using a containerless bioprocessing facility and optical imaging techniques.

Biofilms

Elucidate mechanisms of gravity-sensing in bacteria by comparing the structure and composition of biofilms generated in microgravity to those grown on earth. Develop knowledge of biophysical mechanisms of material/microorganisms interactions that can influence/inhibit the formation of biofilms on substrates. Characterize biofilm mass, thickness, morphology and the associated gene expression of microbial species growing on different substrate materials.

BF1: Biofilm Growth Mechanisms  “SPACE BIOFILMS” – Zea

The Space Biofilms project aims to characterize biofilm inside the International Space Station in a controlled fashion, assessing changes in mass, thickness, and morphology. The space-based experiment also aims at elucidating the biomechanical and transcriptomic mechanisms involved in biofilm formation in space. To search for potential solutions, different materials and surface topologies will be used as the substrata for microbial growth.

Fungal biofilms (mold) will be grown in 24-Well Plates.
Bacterial biofilms will be grown in BioServe's Fluid Processing Apparatus (FPA) contained in Group Activation Packs (GAP).
2018 – 2019 Materials Science and Biophysics In Review

- **SpX-14**
  - 4/2/18
  - GEDS

- **SpX-15**
  - 6/29/18
  - ChemG

- **NG-10**
  - 11/17/18
  - ChemG

- **SpX-16**
  - 12/5/18
  - LMM MB2, MB5

- **SpX-18**
  - 7/25/19
  - RSD/AFF

- **NG-12**
  - 11/4/19
  - BF1

- **EML Batch 2.2**
  - OpsEND 5/2018

- **EML Batch 1.3**
  - OpsEND 10/2018

- **MICS-MVP**
  - OpsEND 12/27/18

- **EML Batch 2.3**
  - OpsEND 6/2019

- **EML Batch 2.4**
  - Ops 10/2019 -?

- **GEDS – C5**
  - OpsEND 11/6/19

- **EML Batch 2.3**
  - OpsEND 6/2019

- **BF-1 GAP**
  - OpsEND 11/14/19

- **MWA-MICS**
  - OpsEND 7/2018

- **DSI-R**
  - OpsEND 11/18

- **LMM MB2, MB5**
  - OpsEND 3/15/19

- **ELF-1**
  - OpsEND 9/19

- **SpX-16**
  - 1/14/19
  - DSI-R RHD

- **ChemG**
  - MICS-MVP

- **ChemG**
  - LMM MB1, MB4

- **SpX-15**
  - 8/3/18
  - ChemG

- **MWA-MICS**