

ELECTRIC CURRENT ACTIVATED COMBUSTION SYNTHESIS AND CHEMICAL OVENS UNDER TERRESTRIAL AND REDUCED GRAVITY CONDITIONS

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Combustion synthesis (CS) generally involves mixing reactants together (e.g., metal powders) and igniting the mixture. Typically, a reaction wave will pass through the sample. In field activated combustion synthesis (FACS), the addition of an electric field has a marked effect on the dynamics of wave propagation and on the nature, composition, and homogeneity of the product as well as capillary flow, mass-transport in porous media, and Marangoni flows, which are influenced by gravity. The objective is to understand the role of an electric field in CS reactions under conditions where gravity-related effects are suppressed or altered. The systems being studied are Ti+Al and Ti+3Al. Two different ignition orientations have been used to observe effects of gravity when one of the reactants becomes molten. This consequentially influences the position and concentration of the electric current, which in turn influences the entire process. Experiments have also been performed in microgravity conditions. This process has been named Microgravity Field Activated Combustion Synthesis (MFACS). Effects of gravity have been demonstrated, where the reaction wave temperature and velocity demonstrate considerable differences besides the changes of combustion mechanisms with the different high currents applied. Also the threshold for the formation of a stable reaction wave is increased under zero gravity conditions. Electric current was also utilized with a chemical oven technique, where inserts of aluminum with minute amounts of tungsten and tantalum were used to allow observation of effects of settling of the higher density solid particles in liquid aluminum at the present temperature profile and wave velocity of the reaction.

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Microgravity Field Activated Combustion Synthesis (MFACS)

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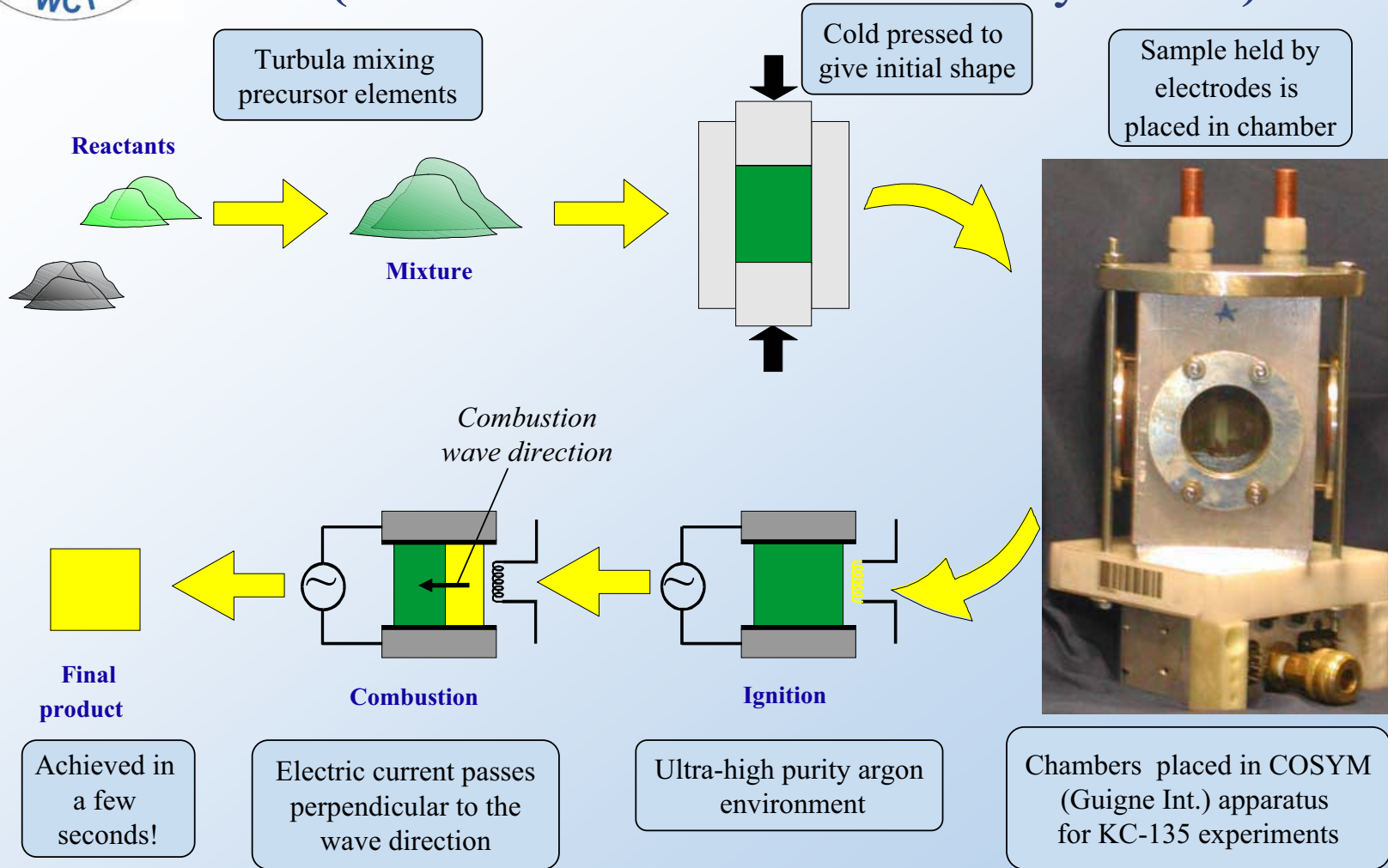
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FACS Procedure (Field Activated Combustion Synthesis)



Achieved in a few seconds!

Electric current passes perpendicular to the wave direction

Ultra-high purity argon environment

Chambers placed in COSYM (Guigne Int.) apparatus for KC-135 experiments



Two Contributing Fields in CS

Gravitational field induced

- Buoyancy and phase separation
- Convective flows and heat losses

Electric field affected

- Joule heating
- Capillary and Marangoni flows

Temperature and phase distribution

Effective electrical conductivity

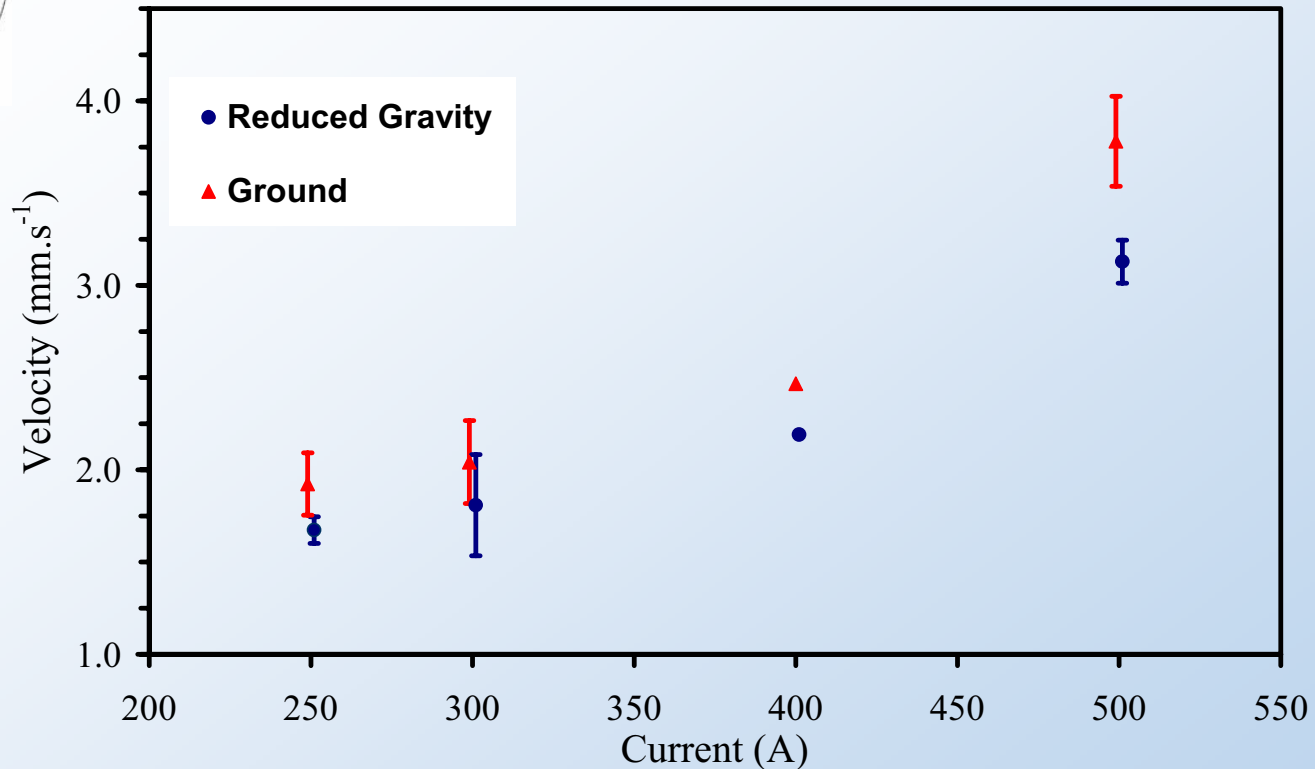
Current density distribution

Degree of field activation

- Fundamental aspects of electric field in SHS can be investigated by reducing interactions with gravitationally induced phenomena



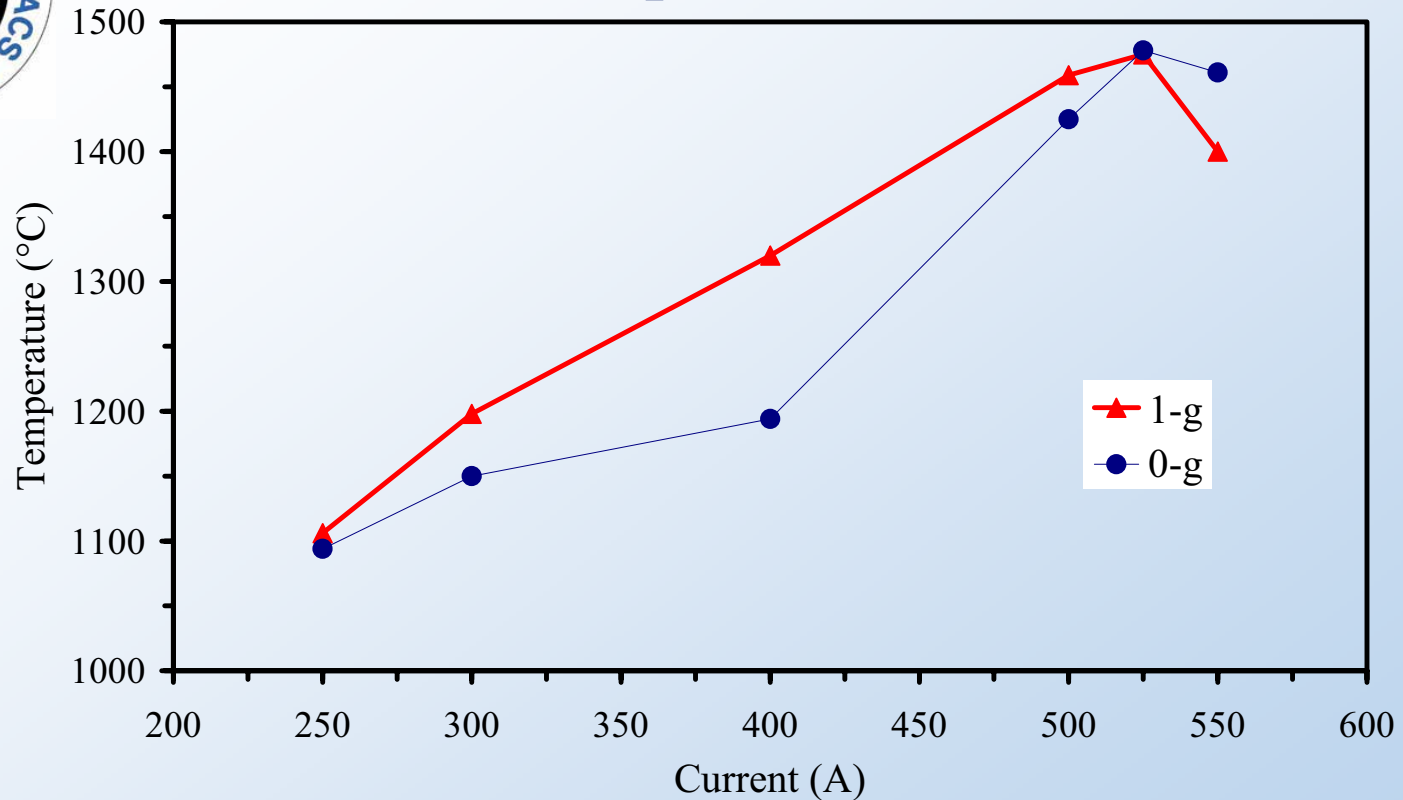
Ti+Al Wave Velocities vs. Current



- Below the threshold value 250A, reaction waves are not self propagating
- At 250A higher percentage of waves extinguished in reduced gravity conditions, probably due to reduced convection
- 1-g experiments had higher velocities than the 0-g, with increasing currents.



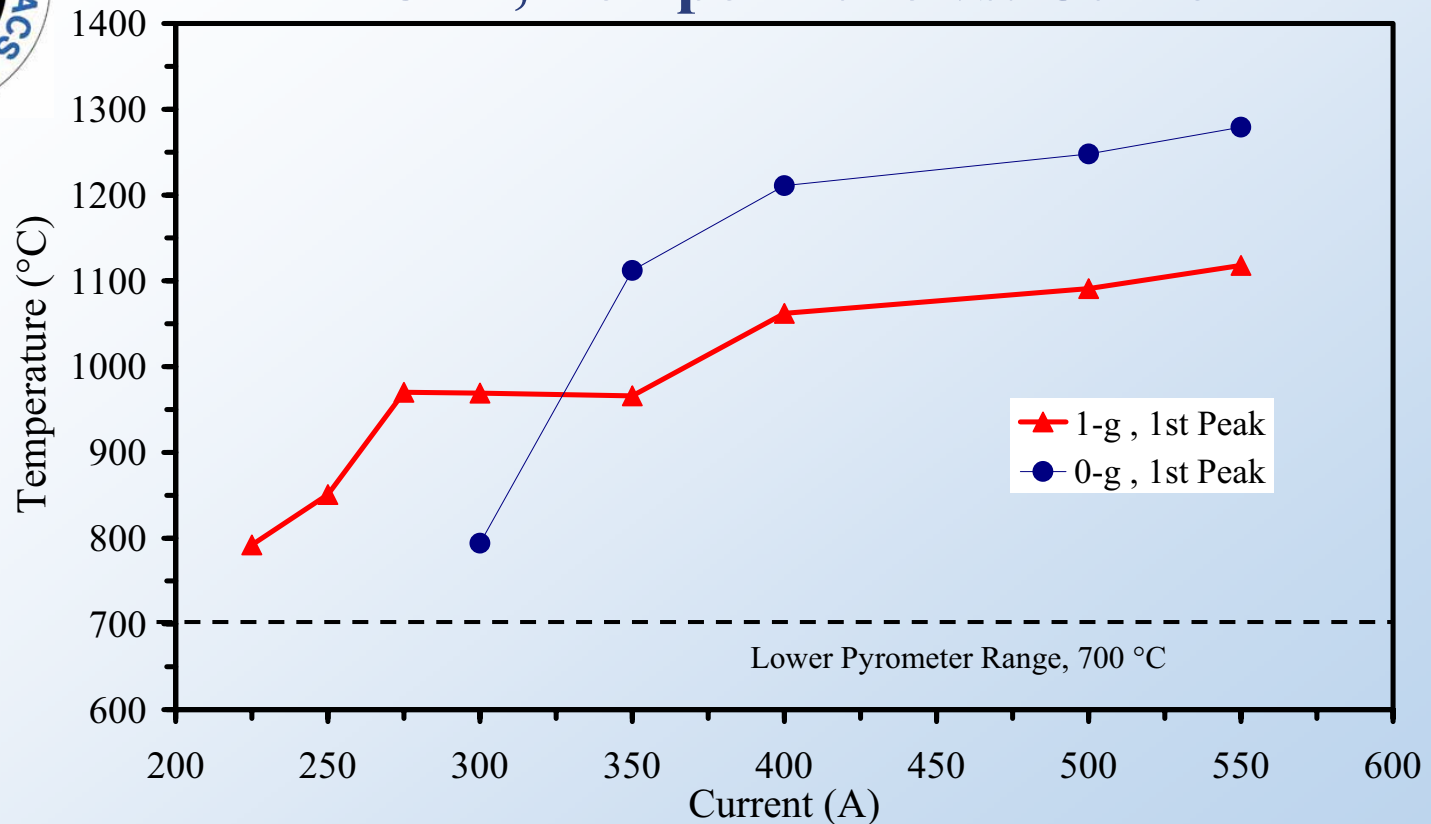
Ti + Al Temperature vs. Current



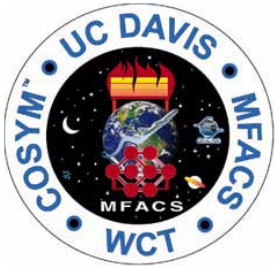
- Experiments in 1-g have higher temperatures for most currents.
- Cavities are created above 500A resulting in possible erroneous temperature measurements
- Temperature and velocity data show comparable trends with increasing current



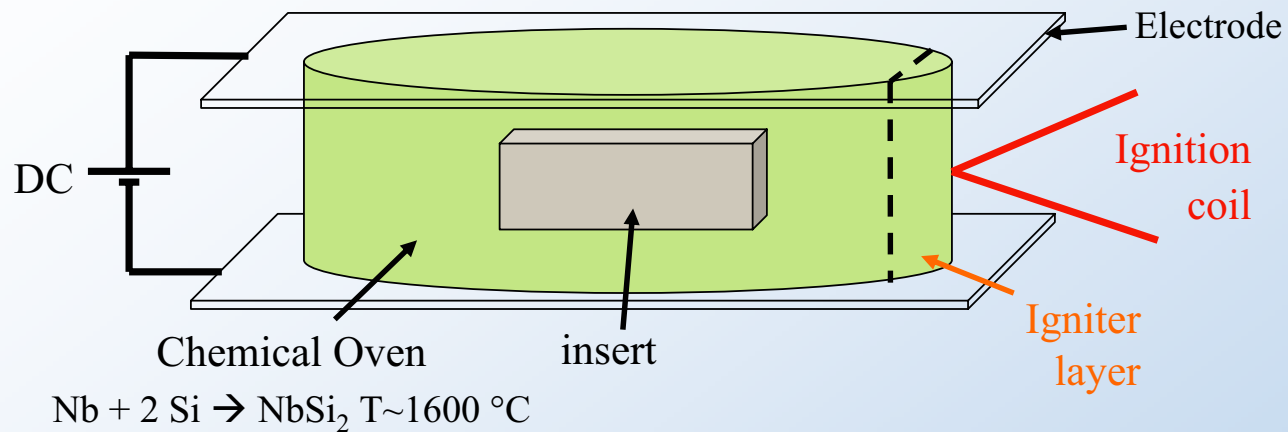
Ti + 3 Al, Temperature vs. Current



- Presence of increased liquid (3 moles Al) alters the behavior of the system and pronounces the effects of gravity
- 0-g exp. @ 225, 250, 275 A are below 700°C
- Switch in maximum temperatures with increased current occurs sharply above 300A at 0-g.

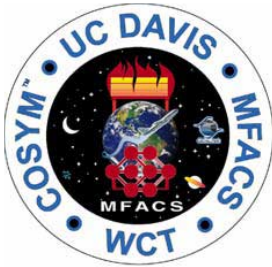


Chemical Oven (CO) Inserts



- CO allows for larger amounts of liquid in the insert therefore gravitational effects are accentuated with minimal deformation caused by the presence of liquid
- Shows effects of gravity on *settling* of the denser solid metals in liquid Al

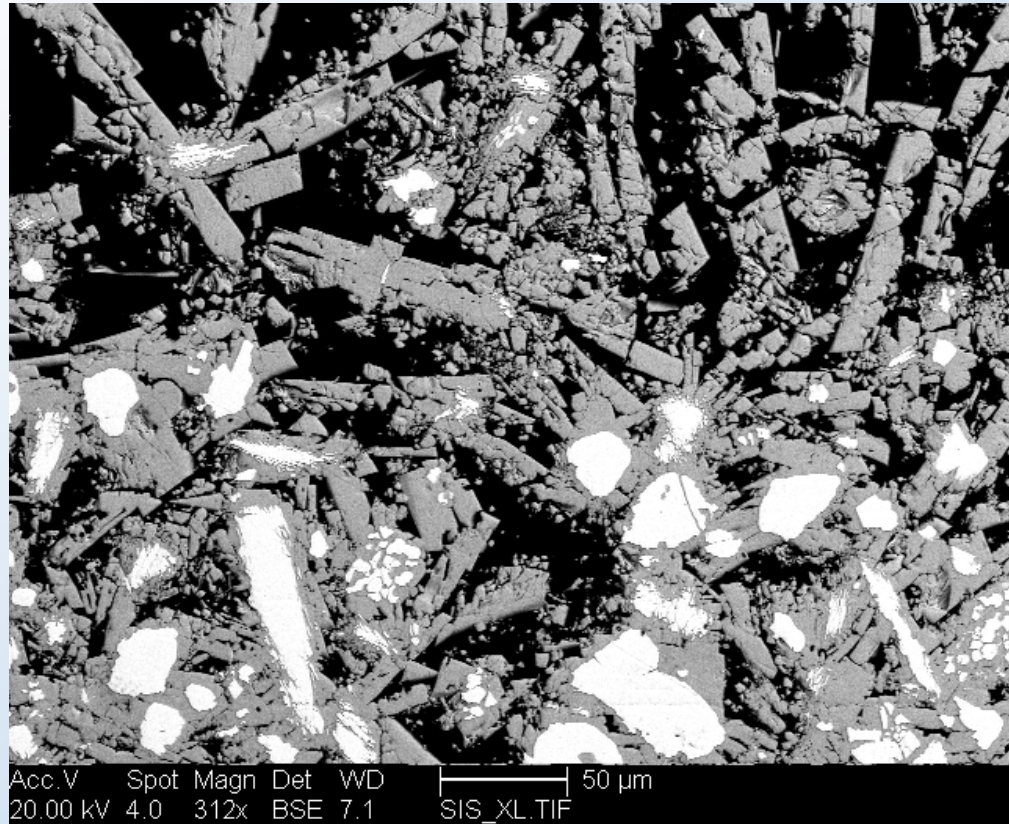
Insert content	Al	W	Ta	WC	TaC
Density (g/cm ³)	2.70	19.35	16.40	15.63	14.30



↑
wave
direction



0.1W+Al insert, NbSi₂ CO ignition from the *bottom*



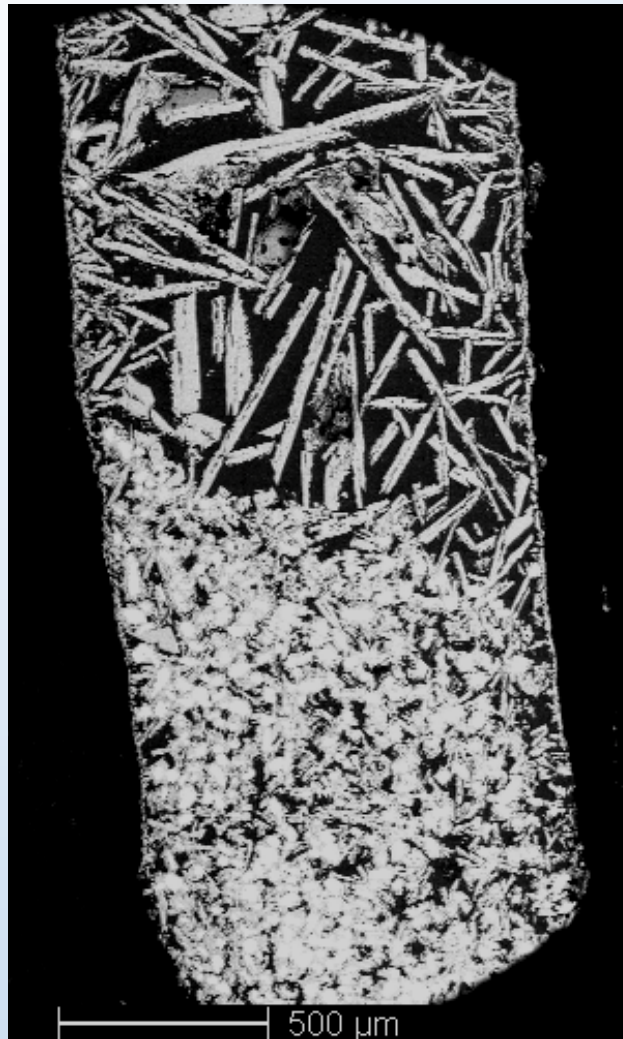
- Settling of W towards bottom
- Large precipitates of intermetallic compound



↓
wave
direction



0.1W+Al insert, NbSi₂ CO ignition from the *top*



- Settling of W with the direction of *gravity* not the *wave*
- Large ppt's of intermetallic (Composition differences to be analyzed along insert)



Missions to Mars and the Moon

- Products required for extended stays: Structural, Electrical, Aerospace, etc.
 - Transport final products → Expensive!
 - Produce from available raw materials to final shape on site!
- Field Activated Combustion Synthesis (FACS) is an economical and time efficient on-site process
- By understanding the fundamentals behind this process, advanced materials can be created in various gravitational fields