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

Unuvar, C.1; Fredrick, D.1; Anselmi-Tamburini U. 1; M.; Manerbino, A.3;
Guigne, J. Y.3; Munir, Z. A.1; Shaw, B. D.2
1Department of Chemical Engineering and Materials Science,
2Department of Mechanical and Aeronautical Engineering,
University of California, Davis
3Guigne Int. Ltd., 685 St. Thomas Line, Paradise, Newfoundland A1L 1C1, Canada

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.

Conference-Workshop on Strategic Research to Enable NASA’s Exploration Missions
June 22 - 23, 2004; Cleveland, Ohio USA
Microgravity Field Activated Combustion Synthesis (MFACS)

Unuvar, C.\(^1\); Fredrick, D.\(^1\);
Anselmi-Tamburini U. \(^1\); M.; Manerbino, A.\(^3\);
Guigne, J. Y.\(^3\); Munir, Z. A.\(^1\); Shaw, B. D.\(^2\)

\(^1\)Department of Chemical Engineering and Materials Science,
\(^2\)Department of Mechanical and Aeronautical Engineering,
University of California, Davis
\(^3\)Guigne Int. Ltd., 685 St. Thomas Line, Paradise, Newfoundland A1L 1C1, Canada

NASA # NCC3872
FACS Procedure
(Field Activated Combustion Synthesis)

1. **Reactants**
   - Turbula mixing precursor elements

2. **Mixture**
   - Cold pressed to give initial shape
   - Sample held by electrodes is placed in chamber

3. **Combustion**
   - Electric current passes perpendicular to the wave direction
   - Combustion wave direction

4. **Final product**
   - Achieved in a few seconds!

5. **Ignition**
   - 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
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.
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.
• 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

<table>
<thead>
<tr>
<th>Insert content</th>
<th>Al</th>
<th>W</th>
<th>Ta</th>
<th>WC</th>
<th>TaC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/cm³)</td>
<td>2.70</td>
<td>19.35</td>
<td>16.40</td>
<td>15.63</td>
<td>14.30</td>
</tr>
</tbody>
</table>
0.1W+Al insert, NbSi2 CO ignition from the bottom

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