PSI’s Hypersonic Materials Testbed

For over 40 years, PSI has provided technology solutions and innovative products to our government and commercial customers. Our employee-owners continue to grow the company across a range of markets applying emerging science to important problems. We play an important role in the development and transition of advanced technology from the laboratory to commercial and government use.

Physical Sciences Inc.’s Hypersonic Materials Testbed provides accessible screening to evaluate thermal protection system (TPS) materials under high temperature, high heating rate, and strongly oxidizing reentry environmental conditions. This unique capability enables subscale testing of TPS materials and measurement of oxidation/erosion rate, changes in surface and bulk material properties and optical signatures enabling rapid material assessments and verification of CFD microphysics models.

**Capability**

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**Features**

- **Lab-scale:** Rapid testing of material Thermal/Mechanical/Chemical response to high-enthalpy, high Mach number air flow
- **Clean:** Microwave Jet: No electrode erosion, minimal contamination
- **Relevant Enthalpies:** 1-13 MJ/kg (Air) producing 0.2 – 1 kW/cm² heating
- **High Flow Velocity:** Mach 3 to 12
- **Simulated Altitude:** 15 – 70 km

Physical Sciences Inc. is providing this clean, affordable testbed for hypersonic materials evaluation as a service or for sale. Please contact David Oakes (oakes@psicorp.com) for more details.
Testbed Capabilities

The testbed utilizes PSI’s MIDJet™ microwave torch to deliver a high flux, high enthalpy jet of clean, heated air to the sample under test:

**Primary Control Parameters:**
- Gas mixture: Vary $O_2:N_2$ for atmospheric simulation
- Microwave power (1-5 kW)
- Enthalpy: 1 – 13 MJ/kg
- Stagnation Temperature: 1000 – 6000 K
- Simulated altitude (pressure): 15 – 70 km (0.05 – 100 Torr)

**MIDJet™: Microwave Plasma Torch**

<table>
<thead>
<tr>
<th>MIDJet™ Parameter</th>
<th>Capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microwave Power</td>
<td>1 - 5 kW</td>
</tr>
<tr>
<td>Output Nozzle Diameter</td>
<td>1 - 10 mm</td>
</tr>
<tr>
<td>Discharge Temperatures</td>
<td>1300 - 6000K</td>
</tr>
<tr>
<td>Beam Enthalpy</td>
<td>1 - 13 MJ/kg</td>
</tr>
<tr>
<td>Beam Velocity</td>
<td>Subsonic - 3.6 km/s</td>
</tr>
</tbody>
</table>

- No electrodes: Ultra-clean processing, Highly scalable (up to 100 kW), High efficiency/reliability
- Thermal Source: Equilibrium output
  - Set enthalpy to tune heating rate and composition: $O/O_2$

Testbed System and Diagnostics

**Diagnostics:**
- 2-color Imaging pyrometer: Spatially (50 µm) and Temporally (10 Hz) resolved map of leading edge temperature
- Process Pressure: Simulated altitude
- Jet Enthalpy: Flow rate and coupled microwave power
- Bulk Sample Temperature: Imbedded thermocouple
- Optical: UV-Vis, Near-IR and FTIR spectrometers

**Coming in Summer 2022:** Instron 34-TM for In-situ mechanical strength measurement during heating

Materials Testing

Two-color Pyrometer: Sample Heating

- Spatial and temporal heating measurements

![Image of two-color pyrometer data]

Material Analysis

**Capabilities:**
- Sample mass loss: erosion
- SEM, surface profiling
- Raman spectroscopy

**Additional analysis (Future):**
- In-situ tensile strength
- Surface Analysis: ESCA, XRD, etc

Signatures

**Emission Spectroscopy: UV - IR**
- Atomic and molecular emission from erosion products
- High-enthalpy beam emission
- Reflected thermal emission

**Selectable Field-of-View:**
- Leading edge stagnation zone, direct sample emission, wake
- Physical process investigation
- Relative emissivity spectral variation
- Re-entry signature simulation

![Images of emission spectroscopy and analysis]