Precision Ceramics

Technical ceramics for demanding environments and applications:
I’m Geoff Randle

This is a presentation of the combined experiences of my colleague Steve Lyle and me with over 80 years of working with technical ceramics.
Located in USA and Europe

St Petersburg
Florida

Birmingham
England

Specialists in Technical Ceramics and CNC machining
7 continents

3 planets
PC USA Inc

- Typical components
Ceramics are being used ever more often for space and aerospace applications.

Hall Effect Thrusters:
And the ever increasing need for high performance technical ceramics
Requirements for any ceramic material:

- **Density**
  - Weight is a major factor for anything used in space
  - A critical factor for launch and operation

- **High dielectric strength**
  - By necessity as high voltages are involved

- **High thermal conductivity & High thermal shock resistance**
  - Satellites are exposed to extreme temperature fluctuations in space
  - Localised heating during firing
- **Consistent homogenous materials**
  - Critical for design and operational consistency

- **Low Thermal Expansion**
  - A low CTE is imperative to maintain dimensional stability with widely fluctuating temperatures
Other considerations:

- Able to withstand constant bombardment by Xenon ions
- Available in large sizes
- Machinable vs non machinable
  - Able to be made into complex shapes
- Reliably achieve required tolerances
- Cost!
- The accumulation of material and processing costs
- Materials that have been tried in the past:
  - Borosil
  - Macor
  - Quartz
  - Aluminum Oxide
    - All had limitations

- The most successful solutions involved these materials
  - Boron Nitride & Boron Nitride composites
# Comparative Properties

<table>
<thead>
<tr>
<th>Composition</th>
<th>Density g/cc</th>
<th>Hardness relative to each other 1-10</th>
<th>Maximum Size/Billet Availability</th>
<th>Dielectric Strength</th>
<th>Dielectric Constant K +/-5%</th>
<th>Anisotropy relative to each other 1-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP</td>
<td>1.9 +/- 0.15</td>
<td>4</td>
<td>490x490x400mm</td>
<td>&gt;25KV/mm</td>
<td>4</td>
<td>More - 6</td>
</tr>
<tr>
<td>95%BN, 5% calcium borate glass</td>
<td></td>
<td></td>
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<tr>
<td>M26</td>
<td>2.0 +/- 0.02</td>
<td>8</td>
<td>490x490x400mm</td>
<td>&gt;25KV/mm</td>
<td>4</td>
<td>Minor -2</td>
</tr>
<tr>
<td>60%BN, 40%SiO2</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>AX05</td>
<td>1.9 +/- 0.02</td>
<td>1</td>
<td>Very design dependent</td>
<td>&gt;25KV/mm</td>
<td>4</td>
<td>Most - 10</td>
</tr>
<tr>
<td>99.7% BN</td>
<td></td>
<td></td>
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<tr>
<td>Shapal High M Soft</td>
<td>2.8 +/- 0.1</td>
<td>10</td>
<td>304x304x86mm</td>
<td>&gt;25KV/mm</td>
<td>6.8</td>
<td>Least - 1</td>
</tr>
<tr>
<td>70%AlN, 30%BN</td>
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</table>
h-BN and BN-AlN composites have been the most successful in satisfying the above requirements.

- The materials are hot pressed for consistency.
- Low density.
- Low sputter erosion and some grades have secondary ion emission.
- Low outgassing rates.
- Non-wettable by molten metals.

BN is also available in large sizes and is readily machined.
- Shapal-HiM soft is one BN-AlN composite we have particular experience with and success in using

- Again hot pressed for consistency
- Relatively low density
- Tested and proven in space environments
- Very very low outgassing rates,
  - Zero porosity
- A very homogenous material

- Shapal is not available in sizes as big as pure BN
- But again is readily machined.
- **Shapal-HiM soft**

- The newest material under development for HET components
- Made by Tokuyama,
- Careful control of powder microstructure yields a high density, zero-porosity product
- Still machinable but much stronger than the traditional Boron Nitrides.
- It shares the dielectric strength and very high thermal conductivity of BNs, but its lack of porosity and vacuum impermeability are unmatched.
- Shapal has the additional advantage of being much harder when the specific insulator design requires.
- You have selected material from data sheets
- You have received a small sample of the material.
- You have possibly manufactured a small scale part to ensure everything works.
- What could possibly go wrong?
Don’t assume the selected material is available in the sizes and geometries you require.

You order and test a small scale part, then order the full size, assuming it’s from the same billet!

You want all of the parts for a program from the same billet!

You are familiar with ceramics, and use cleaning specs for other ceramic materials!

Orientation is critical in h-bn.
- Crack detection of ceramics is standard using a dye penetrant, is that a good idea?
- You want to machine yourself, you order material, please don’t forget to ask for traceable material as this may not be possible in retrospect!
- There are clone materials out there, copies of data sheets and no guarantees.
- These examples are real and have happened, please be aware!
- Boron Nitride solids are anisotropic, so have directional properties.
- Hot pressing results in orderly alignment of the platelets, the pressing direction has the strongest bonds.
- If you are sampling/designing in BN you may want to take the press direction into account
Can withstand the vibration of take-off

European space agency GOCE satellite.

Plasma engines
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