Health & Safety – Handling beryllium in solid form poses no special health risk. Like many industrial materials, beryllium-containing materials may pose a health risk if recommended safe handling practices are not followed. Inhalation of airborne beryllium may cause a serious lung disorder in susceptible individuals. The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Safety Data Sheet (SDS) before working with this material. For additional information on safe handling practices or technical data on beryllium, contact Materion Product Steward at 800-383-4040.

Near-net-shape mirrors give beryllium an edge.

by Thomas Parsonage

Space-related and tactical optical systems require lightweight components with exceptional long-term stability. Historically, beryllium has been the material of choice for such applications — particularly for mirrors — because of its low density and high specific stiffness.

But because beryllium is relatively high-priced, a number of other materials have come along to challenge its historical dominance in these applications. The latest challenger is silicon carbide, or, more specifically, two specialized forms of SiC.

These types of SiC reduce or eliminate the shrinkage that previously kept the material out of the competition. One new form of SiC is produced by chemical vapor deposition and was introduced by CVD Co., Woburn, Mass. The other is produced by a proprietary method involving freeze-drying an SiC slurry, a development of United Technologies Optical Systems, West Palm Beach, Fla. (L&O, "News," Aug‘89). Brush Wellman, on the other hand, champions the cause of beryllium and is the free world’s leading producer of beryllium.

Both SiC materials are expensive. When compared to the older methods of producing beryllium mirrors, the costs appear to be attractive. But that is not a complete comparison; Brush Wellman has developed near-net-shape processing methods for mirror components that
Table 1 — Beryllium Vs. SiC

<table>
<thead>
<tr>
<th>Property</th>
<th>Beryllium (0-50)</th>
<th>Precision Formed SiC</th>
<th>30% SiC/Al Metal Matrix Composite SiC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus GPA (Msi)</td>
<td>303 (44)</td>
<td>311 (45)</td>
<td>130 (18)</td>
</tr>
<tr>
<td>Density g/cm³ (lb/in³)</td>
<td>1.85 (.067)</td>
<td>2.92 (.105)</td>
<td>2.96 (.107)</td>
</tr>
<tr>
<td>Specific Modulus (Stiffness/Weight)</td>
<td>165</td>
<td>106</td>
<td>40</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion 10⁶/K (10⁶/°F)</td>
<td>11.4 (6.3)</td>
<td>2.6 (1.4)</td>
<td>12.2 (7.0)</td>
</tr>
<tr>
<td>Thermal Conductivity W/cm-hr-K (BTU/ft-hr°F)</td>
<td>2.16 (116)</td>
<td>1.56 (90)</td>
<td>1.2 (67)</td>
</tr>
</tbody>
</table>

are helping beryllium remain price competitive.

At one time, the only way to obtain beryllium components was from powder that had been compacted under vacuum and high temperature into cylindrical billets. Blanks were then cut from the billets and machined into the finished parts. The method did not utilize raw material well (the average utilization was about 30 percent), so costs were very high.

Brush Wellman’s near-net-shape processing methods have changed the old-style cost structure significantly. The company now uses a combination of hot and cold isostatic pressing (HIP and CIP), cold die pressing and vacuum sintering methods to produce near-net-shape parts, which only require final machining. In some cases, costs have been reduced by as much as 50 percent compared to parts machined from vacuum hot-pressed block.

In the CIP method, near-net-shape blanks are made from beryllium powders using flexible polymer molds. CIPping is followed by vacuum sintering. Where 100% density is required, the sintering is followed in turn by hot isostatic pressing.

HIP parts are made from beryllium powder that has been degassed and sealed in a flexible steel can that has the general shape of the finished part. The can is isostatically pressed at 1000 to 1250° C, at 15,000 psi pressure. After processing, the can is etched away with acid, and the beryllium preform is heat-treated for stabilization and final machining. Density of hot isostatic pressed parts is 100% of the theoretical value.

Cost is not the only consideration in choosing a material for a high-performance mirror in a space-based system. Light weight, specific stiffness and thermal properties are high on the list of key parameters for these components.

Both SiC and beryllium have moduli on the order of 44 to 45 million psi, but SiC is about 50% denser — 2.92 versus 1.85 g/cm³. To achieve a large reflective surface at the lowest possible density and highest stiffness-to-weight ratio, mirrors of this type are often “lightweighted.” That bit of jargon describes a mirror built with ribs or honeycomb structures behind the reflective surface to provide structural support. Beryllium mirrors can have an open-or closed-back design (see photo), whereas SiC mirrors have been, to date, manufactured only in the closed-back configuration to maximize stiffness. The manufacturing cost of producing this more complex shape offsets some of the cost advantages that SiC manufacturers are trying to achieve. For equal designs, beryllium has a specific stiffness 60% greater than SiC and 400% greater than 30% SiC/Al MMS.

Like “high cost,” “toxicity” is another label applied liberally to beryllium. In the case of solid mirror shapes, it doesn’t apply. Beryllium, like many materials used in aerospace applications, can be potentially harmful in the form of airborne particles small enough to breathe (i.e., <10 μm in diameter). Machining or grinding, therefore, requires special precautions.

But the same is true of silicon carbide. Both materials can cause lung disease if inhaled as fine dust particles at levels exceeding established safety standards. End users do not machine either material, however; parts are cut and ground by original manufacturers or a few specialty shops that have the proper ventilation equipment to keep work areas clean.

Ductility of optical equipment also comes into question in the design of systems. Silicon carbide, a ceramic, has zero ductility and thus can make no allowance for tensile or torsional forces. With elongation of 2 to 5%, beryllium can better accommodate these stresses. Beryllium’s thermal properties — coefficient of thermal expansion, specific heat and thermal conductivity — are also quite compelling in system design. For scanning, laser, FLIR and tank-sighting mirrors, for example, Brush Wellman’s Grade 0-50 HIP beryllium mirrors have been shown to vary in thermal expansion coefficient in three orthogonal directions by less than 15ppb/°C. Table 1 compares beryllium with both types of SiC for several key parameters.

While costs and physical properties of materials are important factors, the true test of any mirror is its reflectivity, and how well it maintains its reflectivity over time. In this respect, beryllium’s longevity gives it an obvious track record and simultaneously gives SiC benchmarks to shoot at.

Hardtic Laboratories of Waltham, Mass., has produced infrared scan mirrors in beryllium that have maintained 98.4% reflectivity at 10.6 μm, without change in figure, since their production five years ago. According to Peter Richard of Hardtic, test mirrors that have been cleaned more than 100 times with lens tissue and acetone did not suffer loss of reflectivity. “Beryllium has a low coefficient of expansion and is relatively homogeneous in composition, so it manifests figure stability in mirrors over a wide temperature range,” he says.

For coated mirrors, beryllium is also an appropriate material, because of its low weight, stiffness, and ability to meet reflectivity levels of the coating material. In one case cited by Richard, beryllium mirrors coated with gold exhibited reflectivity to the same degree as did the gold reference, more than 98% over the 8-12 μm spectral range. These data were reported by an independent test laboratory, Optical Systems Technology Inc.