Materials for Infrared Optics

By Melanie Saayman
Overview

• Transmittance of IR glasses
• Comparison IR vs. Visible glasses
• Properties of some common IR glasses
  – Germanium
  – Silicon
  – Zinc Sulfide
  – Zinc Selenide
  – Magnesium Fluoride
  – Sapphire
• Concerns using lens design programs
• List of Suppliers
• References
Atmospheric Transmittance

- Water absorption
- CO₂ absorption

NIR (0.7 – 2.5 μμ)
MWIR (3.0 – 5.0 μμ)
LWIR (7.5 – 14.0 μμ)
Transmittance of IR glasses

Note: Includes surface reflection losses from uncoated materials

From Bob Fischer
Comparison: IR vs. Visible Glasses

• There are much fewer IR glasses than visible glasses.

• Refractive indices for IR glasses much higher.
  – Visible: $n = 1.45 - 2.0$
  – IR: $n = 1.38 - 4.0$

• Dispersion is often much lower for IR glasses.
  – Visible: $\nu = 20 - 80$
  – IR: $\nu = 20 - 1000$
Comparison: IR vs. Visible Glasses

• Many IR glasses are opaque in the visible.
• Most visible glasses are opaque in the IR.
• IR glasses are often heavier than visible glasses.
• IR glasses have significantly higher dn/dT values (x10 or more) - athermalizing difficult.
• IR glasses are more expensive than visible glasses (x2 or more).
Germanium

- Most common IR material
- LWIR and MWIR
- High refractive index: $n = 4.0243$
- Large $dn/dT$ (396 ppm/K) can cause large focus shift as a function of temperature.
- Expensive
Silicon

- Large $dn/dT$ – 150 ppm/K
- Primarily 3 – 5 MWIR
- Large $n = 3.4255$
- Relatively low dispersion
- Can be diamond turned (with difficulty)
Zinc Sulfide

• Common material
• LWIR and MWIR
• Cleartran in the most common commercially available zinc sulfide
Zinc Selenide

- Similar to zinc sulfide but structurally weaker
- Expensive
- Very low absorption coefficient
- Transmits in the IR and visible

Magnesium Fluoride

- Low cost
- Transmits from UV to MWIR spectral band
- Poor thermal properties
Sapphire

- Extremely hard.
  - Difficult, time consuming and expensive to manufacture.
- Transmits deep UV through MWIR.
- Very low thermal emissivity at high temperature.
- Cannot be diamond turned.
- $n = 1.6753$, $dn/dT = 10$ ppm/K
## Summary of IR Material Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Refractive Index</th>
<th>CTE (ppm/K)</th>
<th>dn/dT (ppm/K)</th>
<th>Knoop Hardness (g/mm²)</th>
<th>Spectral Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>@ 4μm</td>
<td>@ 10μm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germanium</td>
<td>4.0243</td>
<td>4.0032</td>
<td>6</td>
<td>396</td>
<td>800</td>
</tr>
<tr>
<td>Silicon</td>
<td>3.4255</td>
<td>N/A</td>
<td>2.7</td>
<td>150</td>
<td>1150</td>
</tr>
<tr>
<td>ZnS (Cleartran)</td>
<td>2.2523</td>
<td>2.2008</td>
<td>4.6</td>
<td>54</td>
<td>230</td>
</tr>
<tr>
<td>ZnSe</td>
<td>2.4331</td>
<td>2.4065</td>
<td>7.1</td>
<td>60</td>
<td>105</td>
</tr>
<tr>
<td>Magnesium Fluoride</td>
<td>1.3526</td>
<td>N/A</td>
<td>8</td>
<td>20</td>
<td>415</td>
</tr>
<tr>
<td>Sapphire</td>
<td>1.6753</td>
<td>N/A</td>
<td>5.6</td>
<td>13.7</td>
<td>1370</td>
</tr>
<tr>
<td>Gallium Arsenide</td>
<td>3.3069</td>
<td>3.2778</td>
<td>5.7</td>
<td>148</td>
<td>721</td>
</tr>
<tr>
<td>CaF²</td>
<td>1.4097</td>
<td>1.3002</td>
<td>18.9</td>
<td>-11</td>
<td>170</td>
</tr>
<tr>
<td>BaF²</td>
<td>1.458</td>
<td>1.4014</td>
<td>18.4</td>
<td>-15</td>
<td>82</td>
</tr>
</tbody>
</table>

**Note:** OPTI 521
Concerns using Lens Design Programs

• Most lens design programs use some literature source of data for IR materials, then fit the data to Sellmeier equations.

• Sometimes this data is inconsistent, coming from different measurement sources, and may not have sufficient significant digits.

• Thermal data, such as CTE and dn/dT, may vary widely for some materials, depending on who measured it.

• Often, the software does not include this data, as there is no official source.
Suppliers

- Elcan Optical Systems, Richardson, TX
- Corning NetOptix, Keene, NH
- Exotic Electro-Optics, Marietta, CA
- Optimum Optical Systems, Camarillo, CA
- II-VI Incorporated, Saxonburg, PA
- Janos Technology, Keene, NH
- DRS Optronics, Palm Bay, FL
- Coherent, Auburn, CA
- Diversified Optical Products, Salem, NH
- Telic OSTI, North Billerica, MA
References

• Wolfe and Zissis, The Infrared Handbook, Office of Naval Research (1978)
• Paul Klocek and Marcel Dekker, Handbook of Infrared Optical Materials (1991)