PRECISION LENS MOLDING OF CHALCOGENIDE OPTICS

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PRECISION LENS MOLDING OF CHALCOGENIDE OPTICS

✓ Global markets are looking for low cost materials that satisfy infrared imaging requirements and can be manufactured in commercial quantities (IR equipment sales up, prices coming down).

✓ Chalcogenide materials offer a clear path for new product development and high tech applications due to their unique properties and ability to be tailored to specific customer needs.

✓ Recent developments in low cost preforms and molding technology enable rapid changes in the market.
INFRARED TRANSMISSION

Infrared Atmospheric Transmission Spectrum
for a 1.8 km horizontal path at sea level with 40% relative humidity
THERMAL IMAGING SPECTRA

IR windows for thermal imaging

8~12 µm covers max. radiation for e.g. human bodies
3~5 µm covers max. radiation for e.g. fighter exhaust

WHY CHALCOGENIDES?

All IR materials have trade-offs

- Alkali Halides: ideal transmission, low dispersion, extremely hygroscopic, very soft
- Silver/Thallium Halides: good transmission, extremely soft, HIGHLY toxic
- Alkaline earth fluorides: slightly hygroscopic, poor LWIR transmission, unique n, v and dn/dT
- Ge: high index, near zero LWIR dispersion, opaque when heated and huge dn/dT (0.0004/K)
- ZnSe, ZnS (clear): Good transmission, moderate dn/dT, but high dispersion and scatter
- GaAs, CdTe: Unique combination of n and v, but expensive and hard to get in large aperture
- Chalcogenide (IRG) glasses: Good transmission (can include visible), scalable, moldable, tunable properties, sensitive to thermal effects

Source of data: SCHOTT NA
MATERIAL COMPARISONS

Chalcogenides have their strength in $dn/dT$ and color correction of optical systems

- Ge lens systems are optimized for 20°C; CC takes place with mechanical parts
- Ge will lose transparency with temp. above 100°C
- Ge has limited ability to correct color
- Ge is appreciative to process
- Ge is a proven DLC receptor
- High refractive index
- Lower refractive index
- Brittle $\Rightarrow$ high CTE
- Scratch resistance
- Use of ChG in lens system $\Rightarrow$ excellent color correction
- Excellent transmission
- Low $dn/dT$
- High volume production (FLM)
- Constant transmission for $-50 \leq T \leq +100°C$

Source of data: SCHOTT NA
OPTICAL PROPERTIES

$dn/dt$ For Different Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>$dn/dt [10^{-6}/K]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalcogenides</td>
<td>30</td>
</tr>
<tr>
<td>Germanium</td>
<td>424</td>
</tr>
<tr>
<td>Diamond</td>
<td>16</td>
</tr>
<tr>
<td>Sapphire</td>
<td>6</td>
</tr>
<tr>
<td>Silicon</td>
<td>159</td>
</tr>
<tr>
<td>Zinc Sulfide</td>
<td>43</td>
</tr>
<tr>
<td>Zinc Selenide</td>
<td>63</td>
</tr>
</tbody>
</table>
WHY MOLDING?

Precision Lens Molding Benefits

• Manufacture of complex shapes not possible with conventional grinding & polishing
• Lower ramp up costs for high volume applications than single point diamond turn or conventional polishing
• Lower unit manufacturing cost than single point diamond turn for low rate initial production through high volume
• High fidelity reproduction
NEW IR MOLDING CAPABILITIES

• Joint development program between Edmund Optics® and Fisba Optik AG
• Focused on development of Precision Lens Molding (PLM) and Finished Lens Molding (FLM) competencies for IR products
• Completely new facility in Tucson, AZ
• Class 1000 clean facility, localized class 100
• Toshiba GMP-311 PLM machines with Scara robot and tray handler
Equipment Capabilities

- Toshiba GMP 311V
- Vacuum molding capability
- Auto loader and tray handler enables efficient mid to high volume production
- Single cavity and multi cavity tooling
- Non conventional approach for tool development empowers manufacture of diffractives and special features

Image Source: FISBA
IR MOLDING CAPABILITIES

Manufacturing Capabilities

- Planar, spherical, aspheric surfaces
- Positive, negative, or meniscus lens designs
- Flow modelling and tool compensation programs
- Manual (low volume) or automated (mid – high volume)
- Precision equal to or better than industry standard

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>Manufacturing Cost</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planar - Convex (sphere or asphere)</td>
<td>++</td>
<td>Rotationally symmetric</td>
</tr>
<tr>
<td>Bi-convex; spherical - aspheric</td>
<td>++</td>
<td></td>
</tr>
<tr>
<td>Bi-convex; aspheric - aspheric</td>
<td>++</td>
<td>Only slightly more expensive than sph - asph</td>
</tr>
<tr>
<td>Meniscus (spherical or aspheric)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Bi-concave; spherical - aspheric</td>
<td>-</td>
<td>Post processing may be required</td>
</tr>
<tr>
<td>Bi-concave; aspheric</td>
<td>--</td>
<td>Very high risk</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Surface Description</th>
<th>Standard Quality</th>
<th>Precision Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>3 - 30mm</td>
<td>3 - 30mm</td>
</tr>
<tr>
<td>Aspheric Figure Error (fringes @ 633nm)</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Irregularity (fringes @ 633nm)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Vertex Radius</td>
<td>+/- 1%</td>
<td>+/- 0.1%</td>
</tr>
<tr>
<td>Decenter (mm)</td>
<td>±0.015</td>
<td>±0.005</td>
</tr>
<tr>
<td>Wedge (arcmin)</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Center Thickness Tolerance (mm)</td>
<td>±0.030</td>
<td>±0.015</td>
</tr>
<tr>
<td>Diameter Tolerance(mm)</td>
<td>±0.025</td>
<td>±0.010</td>
</tr>
<tr>
<td>Surface Quality</td>
<td>60-40</td>
<td>20-10</td>
</tr>
</tbody>
</table>
IR MOLDING RESULTS

First Pressings Results

- 25mm meniscus lens
- CX asphere, CC sphere
- Uncorrected tool surfaces

- Tool – 0.67λ power, 0.20 λ Irregularity
- Lens – 0.52λ Power
- Lens – 0.33λ Irregularity
IR MOLDING DEVELOPMENT TO MEET YOUR APPLICATION NEEDS

- Ball preforms and net shape preforms
- Simple geometries – planar, spherical, aspheric
- Complex shapes under development – diffractives
- Free form shapes in development plan – arrays

<table>
<thead>
<tr>
<th>Lens Geometry</th>
<th>Preform Type</th>
<th>Ball Preform</th>
<th>Plano Plano</th>
<th>Lenslet (Plano - Convex)</th>
<th>Lenslet (Bi-Convex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bi-Convex</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Equal Meniscus</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive Meniscus</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Negative Meniscus</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bi-Concave</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FLM VS. PLM

FLM Considerations
- Lower process costs than precision lens molding (no post processing)
- Higher yields (less handling)
- Higher preform costs

PLM Considerations
- Large clear aperture requirements
- Tight diameter tolerances
- Special features (datums, fiducials, segmenting)
COMPETITIVE COSTING ANALYSIS

Results Matrix

✓ Provides comparison between SPDT, FLM, and PLM processing
✓ Compared 5 different lens volumes – 7.5mm to 25mm diameter
✓ Compared 12 different quantities – 25 pieces to 100,000 AU
✓ Analyzed with NRE separate & amortized over order quantity
✓ Crossover point is highly dependent on lens volume & order quantity

Assumes 25 mm diameter x 8 mm OAL meniscus optic
Summary

✓ Global markets are looking ..........

The Opportunity Exists

✓ Chalcogenide materials ... for new product development ....

The Opportunity Is Real

✓ Recent developments in low cost preforms ....

The Opportunity Is Now

Applications

Energy Conservation | Automotive | Security / Sensing | Medical Monitoring | Firefighting | Industrial | Defense

Select Images: sofradir-ec.com
HOW CAN I HELP YOU?

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