The MuCell® microcellular foam injection molding process for thermoplastics materials provides unique design flexibility and cost savings opportunities not found in conventional injection molding. The MuCell® process allows for plastic part design with material wall thickness optimized for functionality and not for the injection molding process. The combination of density reduction and design for functionality often results in material and weight savings of more than 20%.

By replacing the pack & hold phase with cell growth, lower stress parts are produced which have enhanced dimensional stability and substantially reduce warpage. Cell growth also results in the elimination of sink marks.

Unlike chemical foaming agents, the physical MuCell® process has no temperature limitation and does not leave any chemical residue in the polymer; making consumer products perfectly suitable for recycling within the original polymer classification and allowing re-grind material to reenter the process flow.

The numerous cost and processing advantages have led to rapid global deployment of the MuCell® process primarily in automotive, consumer electronics, medical device, packaging and consumer goods applications.

### Reduced Costs
- Reduced resin consumption
- Faster molding cycle time
- Increased yields
- Smaller molding machine
- Use of lower cost filled polyolefin material

### Design Freedom
- Thin to thick wall flow
- 1:1 wall thickness rib structure
- Material where needed for function versus flow
- Improved dimensional stability
- Less warpage

### Sustainability
- Reduced petroleum based material consumption
- Reduced molding machine energy consumption
- Ability to re-grind / re-use molded parts
- Reduced carbon footprint versus solid molding

### Faster to Market
- Fewer tooling iterations
- Predictable molded part geometry
- Ability to mold large parts as single piece
During plasticization, precisely metered amounts of supercritical fluid (SCF), typically Nitrogen or CO₂, are introduced into the polymer through injectors mounted on the plasticizing barrel.

Injection of polymer into mold cavities. Cells start to nucleate once exposed to lower pressure in the mold cavity. Molecular dispersion of SCF provides for a homogeneous closed cell structure with a solid skin layer.

Homogeneous mixing and disbursing of the supercritical fluid into the polymer through the specially designed mixing section of the plasticizing barrel, creates a single phase solution of SCF and molten polymer.

Low pressure filling of mold cavities. Pack & hold phase is replaced by controlled cell growth, which ceases once the mold cavity is filled. Cell growth results in a uniform pack pressure throughout the mold cavity.

MuCell®/ Polymer Value Match

<table>
<thead>
<tr>
<th>Good Value</th>
<th>Great Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDPE</td>
<td>Glass</td>
</tr>
<tr>
<td>PVC</td>
<td>PP Glass</td>
</tr>
<tr>
<td>TPE</td>
<td>PPO Blends</td>
</tr>
<tr>
<td>ABS</td>
<td>PSU</td>
</tr>
<tr>
<td>TPV</td>
<td>PBT Glass</td>
</tr>
<tr>
<td>PP Unfilled</td>
<td>BA6/6.6 Glass</td>
</tr>
<tr>
<td>TPO</td>
<td></td>
</tr>
</tbody>
</table>

Virtually all polymers will develop a cellular structure with the MuCell® process except for LCP. Filled materials tend to offer the greatest value as fillers act synergistically with the supercritical fluid to provide the best combination of weight reduction and cycle time reduction. Unfilled amorphous materials also foam very well and can provide good weight reductions but with less cycle time benefits than filled materials. High temperature materials such as PEEK, PEI and PSU also provide significant cost reduction based on material price.
By replacing the tradition pack & hold phase of the solid molding process with cell growth, the MuCell® process allows for uniform and locally applied pack pressure through cell growth. This allows part design to be optimized with material thickness in those areas that require strength and reduced wall thickness in areas that are not structural. Gate locations are then placed in the thin cross sections for optimized filling patterns while allowing the cell growth to provide packing in the thicker cross sections at the end of fill.

Using the same principle, nominal wall thickness can be reduced while using thicker ribs to meet structural requirements. The cell expansion will eliminate sink marks and the cell structure will prevent the formation of vacuum (shrink) voids. Rib to wall thickness ratios of 1:1 can be used with the MuCell® process.

"A part molded with the MuCell® process has a solid skin layer and microcellular foamed core which is a closed cell structure. The cell growth is more effective at packing the part than the solid pack phase which allows for increased rib to nominal wall thickness without sink marks. In most cases, it is possible to produce a sink free part with a rib thickness equal to the nominal wall thickness."

Differences in Wall Thicknesses

Filling from “thin to thick”

Recommended injection with MuCell®
Injection in solid (with MuCell® still possible)

Wall to rib ratio 1:1 possible

Conventional Design
MuCell® Design

TYPICAL CYCLE TIME REDUCTION WITH MUCELL®

<table>
<thead>
<tr>
<th>Solid Molding</th>
<th>Total 30 Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection</td>
<td>3 sec</td>
</tr>
<tr>
<td>Pack &amp; Hold</td>
<td>4 sec</td>
</tr>
<tr>
<td>Cooling</td>
<td>17 sec</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MuCell®</th>
<th>Total 22 Seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection</td>
<td>1.5 sec</td>
</tr>
<tr>
<td>Pack &amp; Hold</td>
<td>0.5 sec</td>
</tr>
<tr>
<td>Cooling</td>
<td>14 sec</td>
</tr>
<tr>
<td>Motions</td>
<td>6 sec</td>
</tr>
</tbody>
</table>
MuCell® Molding Technology

The complete process solution providing for lighter and more accurate plastic parts at lower production costs

Climate Control Bezel | Material: Glass filled ABS
- Elimination of sink marks
- 1:1 ribs to nominal wall
- Machine clamping force reduced from 250 tons to 75 tons
- 23% cycle time reduction
- 10% weight reduction

Thin Wall Margarine Container | Material: 70 MFR PP
- 6% weight/material reduction
- 15% reduced injection pressure, reducing washout and allowing for thinner in mold label
- Enhanced freedom of design, thicker sealing lip at the end of fill
- Machine clamping force reduced by 50%

Cover Plate | Material: Filled ASA
- Premium quality surface features
- No sink marks/weld lines
- 30% reduction of material/weight
- 18% reduction of cycle time

Printer Bonnet | Material: 20% GF PPO/PS
- Uniform shrinkage and reduced stress result in improved dimensional stability
- Dimensional compliance achieved with fewer mold iterations

<table>
<thead>
<tr>
<th>Key Dimensions</th>
<th>Std Dev Solid</th>
<th>Std Dev MuCell®</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height</td>
<td>(32.43)</td>
<td>0.0100</td>
</tr>
<tr>
<td>Width</td>
<td>(87.33)</td>
<td>0.0145</td>
</tr>
<tr>
<td>Length</td>
<td>(32.43)</td>
<td>0.0155</td>
</tr>
</tbody>
</table>
APPLICATIONS FOR ALL INDUSTRIES

EMC Connector | **Material:** Glass Fiber Reinforced PBT
- 11% weight / material reduction
- 18% cycle time reduction
- Improved pin retention force
- Smaller standard deviation, consistent pin hole size

Power Tool Base | **Material:** PA 6, PA 66
- 70% warpage improvement
- 8% weight / material reduction
- 18% cycle time reduction

Pallet | **Material:** PP/HDPE
- 10% reduced weight / material
- Warp reduction for fit / operation of lid
- Machine clamping force reduced by 50 – 70%

Footwear | **Material:** TPU
- Light weight sole components, below 0.3 g/cm³ density
- 40% improved rebound (ASTM D2632)
- Use of high performance resin with lower weight
The MuCell® capable injection molding machine consists of Nitrogen or CO2 supply, a SCF metering and control system, and a specialized plasticizing unit including positive screw control and a shut off nozzle.

**IMPLEMENTING THE MUCELL® PROCESS**

Field retrofit of existing injection molding machines by qualified Trexel technicians. The upgrade consists of a new, MuCell® capable plasticizing unit, positive screw position control, installation and training.

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**MODULAR MUCELL® UPGRADE (MMU)**

Field retrofit of existing injection molding machines by qualified Trexel technicians. The upgrade consists of a new, MuCell® capable plasticizing unit, positive screw position control, installation and training.

**OEM SYSTEM**

For new injection molding machine applications, the following licensed Trexel OEM partners can provide a turnkey MuCell® injection molding system.

- **MILACRON**
- **ENGEL**
- **KraussMaffei**
- **ARBURG**
- **JSW**
- **HAITIAN**

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About Trexel

The exclusive provider of the MuCell® Microcellular Foam Injection Molding Technology

The MuCell® Microcellular foaming technology was originally conceptualized and invented at the Massachusetts Institute of Technology (MIT) and in 1995 Trexel was granted an exclusive worldwide license for the further development and commercialization of the technology. Today, Trexel is the exclusive provider of the MuCell® microcellular foam technology for injection molding and maintains an extensive global patent portfolio. Trexel provides world-class engineering support, training and other design and processing services, as well as the equipment and components integral to the MuCell® process.

From the global headquarters in Boston, Massachusetts, Trexel operates a state of the art plastics processing development laboratory, supporting plastics processors with the definition and implementation of leading and differentiating plastic molding technologies.

In support of a global client base, Trexel operates subsidiaries in Europe, Japan and Southeast Asia with competent plastics processing engineering capabilities. Trexel’s worldwide subsidiaries are augmented by a network of competent independent representatives and distributors.