Silicones for Mold Release

Peter Stevens
Application Development Manager
Fluids / Industrial
Silicone for Mold Release

Silicone release agents are used as process aids for thermoplastics and synthetic rubbers.

For plastic films and rubber parts, silicone “slip” or antiblocking agents provide critical release properties, preventing the plastic film and rubber parts sticking to themselves as well releasing them from their molds.

Thermoplastics: Polystyrene, Polyolefins, other Hydrocarbon resins
Thermosets: Polyesters, Polyurethanes, Epoxies.
Rubbers: NBR: Acrylonitrile-Butadiene Rubber
CR: Chloroprene Rubber
SBR: Styrene Butadien Rubber
EPDM: Ethylene Propylene-Diene Terpolymer … etc
Why Silicone for Mold Release?

<table>
<thead>
<tr>
<th>Silicone chemistry</th>
<th>Effect</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>High methyl density</td>
<td>low intermolecular association with:</td>
<td>release</td>
</tr>
<tr>
<td></td>
<td>other materials</td>
<td>coverage of mold</td>
</tr>
<tr>
<td></td>
<td>silicone</td>
<td></td>
</tr>
<tr>
<td></td>
<td>low surface tension</td>
<td></td>
</tr>
<tr>
<td>Free rotation around Si-O bond</td>
<td>flexible molecule</td>
<td>durability</td>
</tr>
<tr>
<td></td>
<td>orientation at interfaces</td>
<td></td>
</tr>
<tr>
<td></td>
<td>'tear' resistant</td>
<td></td>
</tr>
<tr>
<td>Si-O bond stronger than C-C</td>
<td>chemically inert</td>
<td>non-reactive</td>
</tr>
<tr>
<td></td>
<td>heat resistant</td>
<td>high temp. Applns</td>
</tr>
</tbody>
</table>
## Mold Release agents

<table>
<thead>
<tr>
<th>Type</th>
<th>Release agent</th>
<th>Main application</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral Oil</td>
<td>Mineral Oil, Liquid Paraffin</td>
<td>Paper, Casting</td>
<td>• low heat resistance</td>
</tr>
<tr>
<td>Oil and Fats</td>
<td>Plant Oil, Natural Wax</td>
<td>Food, Plastics</td>
<td>• poor release (may use + silicones)</td>
</tr>
<tr>
<td>Fatty Acid</td>
<td>Stearic Acid, Oleic Acid</td>
<td>Rubber, Plastics</td>
<td></td>
</tr>
<tr>
<td>Ester</td>
<td>POE Fatty Acid Ester, Sorbian Fatty Acid Ester</td>
<td>Rubber</td>
<td></td>
</tr>
<tr>
<td>Amide</td>
<td>POE Alkylene Amide</td>
<td>Paper, Pulp</td>
<td></td>
</tr>
<tr>
<td>Phosphate</td>
<td>POE Alkylene Phosphate</td>
<td>Rubber</td>
<td></td>
</tr>
<tr>
<td>Metal Soap</td>
<td>Potassium Stearate, sodium oleate</td>
<td>Rubber, Plastics</td>
<td></td>
</tr>
<tr>
<td><strong>Silicone</strong></td>
<td><strong>Dimethyl Silicone, Modified Fluid, Silicone Resin</strong></td>
<td><strong>Plastics, Rubber, Casting</strong></td>
<td></td>
</tr>
<tr>
<td>Fluorine</td>
<td>Polytetrafluoroethylene</td>
<td>Food, Plastics</td>
<td>Expensive</td>
</tr>
</tbody>
</table>
Applications of Silicone Mold Release

Thermo Plastics

Food Packages

Rubbers

Die-cast

Tire

O-rings (anti-stick)
Mold Release for Thermo-Plastics and Rubbers
**Element14 PDMS Emulsions (EUR)**

**Durability** → **Better**

Better ← **Spreading**  
(coverage of mold)

<table>
<thead>
<tr>
<th>PDMS content (%)</th>
<th>PDMS Viscosity (cSt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
</tr>
</tbody>
</table>

- **a** Oil Emulsion D
- **b** TP3728
- **c** SM2128NPF *(1)*
- **d** TP-3952
- **e** LE-46
- **f** SM2169
- **g** YMR7212 *(2)*
- **h** SM2112 *(3)*

**Notes:**

*(1)* Formasil 45 if food-grade is required
*(2)* replacing SM2068A
*(3)* being reformulated to be NPF

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Complete coverage of the mold is essential for good release, especially for intricate molds. Best coverage is provided by low viscosity PDMS.

Durability, so the release agent has to be re-applied with minimal frequency, reduces cost both directly (less release agent) and indirectly (less down-time between ‘shots’). Best durability is provided by high viscosity PDMS.

Momentive provides a range of emulsions with PDMS viscosity varying by ~10,000 x to enable customers to select the best compromise between these 2 conflicting requirements, coverage & durability, for their specific needs.
Durability

<table>
<thead>
<tr>
<th>Durability</th>
<th>Product</th>
<th>Chemistry</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>increasing</td>
<td>Emulsion D</td>
<td>Element14 PDMS</td>
<td>increasing</td>
</tr>
<tr>
<td></td>
<td>TP3728</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TP-3952</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SM 2128 NPF</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LE-46</td>
<td>silanol</td>
<td>curable</td>
</tr>
<tr>
<td></td>
<td>SM2112</td>
<td>silanol</td>
<td>branched curable</td>
</tr>
<tr>
<td></td>
<td>YMR7212</td>
<td>amino-silanol</td>
<td>substantive</td>
</tr>
<tr>
<td></td>
<td>SM2112</td>
<td>quar</td>
<td>branched curable</td>
</tr>
<tr>
<td></td>
<td>Magnasoft® 2059</td>
<td>methyl-hydrogen</td>
<td>curable</td>
</tr>
<tr>
<td></td>
<td>Magnasoft DerMa 35%</td>
<td></td>
<td>highly substantive</td>
</tr>
<tr>
<td></td>
<td>TP3207</td>
<td></td>
<td>reactive</td>
</tr>
</tbody>
</table>
Curing & Branching

Silanols (hydroxy-terminated PDMS) can condense chain-end to chain-end (‘cure’) when the emulsion dries, building to ultra-high viscosity and thus increased durability.

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 \\
\vdots & \quad \vdots \\
\text{Si} & \quad \text{O} \\
\text{Si} & \quad \text{OH} \\
\text{HO} & \quad \text{Si} \quad \text{O} \\
\text{Si} & \quad \vdots
\end{align*}
\]

TP-3207 is an emulsion of a silicone hydride that can chemically react on to surfaces providing a ‘permanent’ release coating.

TP-3207 can also be used in combination with silanol to create a branched, cured coating that is even more durable.
Substantivity

If silicones are used for release, how do they stick to the mold?!

Many surfaces, e.g. metal molds, are weakly anionic and so attract cationic release agents.

Magnasoft® 2059 is a branched, curable (i.e. highly durable) silicone that is amino-modified and so is substantive to the mold surface

Magnasoft DerMa 35% is a micro-emulsion of a quaternized silicone (i.e. permanently positively charged)

When spray applied, attention to inhalation should be given to all products, especially to amino-silicones
Over-coatability

Molded parts may need to be painted or glued.

Residual PDMS is a good release agent for paint & glue!

Solvents required to remove PDMS are commonly not Environment or Health friendly, present a flammability risk, and may swell rubber or dissolve plastic parts.

 Appropriately organo-modified silicones are over-coatable.

Recommended product: **XS53-C4070** emulsion
Emulsion % Actives

Higher % active emulsions have logistic advantages (e.g. less storage space) and are *theoretically* lower cost per kg **active** (less water) but:

- If over-applied, e.g. to ensure complete coverage of the mold, they waste more €. Are the correct dilution and application procedures in place?
- They are higher cost per kg **product** (as supplied). Who’s making the purchasing decision, the Plant Manager (€/yr) or the Purchaser (€/invoice)?

For these reasons, lower active (typically 35%) emulsions are much more widely used (~10x greater volume), and so benefit from economies of manufacturing scale.

The higher the % actives, the more difficult to formulate a stable emulsion = more costly emulsification system.

...the theoretical cost benefit of higher % actives may not be realized.
Mold Release for Food Packages

- **Formasil® 45**
  (emulsion of Element14 PDMS)

- **Silwet® surfactants:**
  - L-7230 = more release
  - L-7200 = more water soluble
Mold Release for Die Casting
Die-cast products

Aluminum (mp ~580 °C)

Zinc (mp ~390 °C)

Magnesium (mp ~595 °C)
What is Aluminium Diecasting

• Aluminium Diecasting:
  – Aluminium parts for the automotive and aviation industry
  – High Throughput
  – High Temperature

  – Next Processing Steps
    • Mechanical & chemical Cleaning
    • Glueing or Welding
    • Painting
Die-cast Market Chain

Momentive

Alkyl-aryl Silicone Fluids and Emulsions

Non-Silicone RM Producers

Graphite, Surfactant, Mineral Oil, Wax, Al Powder, Boron Nitride, etc

Formulators

Henkel-Acheson, Chemtrend, etc

Die-Cast Producers

from Aluminum:
Cylinders, Crank case, Valve case, Wheels, etc. (primarily automotive)

from Magnesium:
Cellular Phone casing, PC Housing etc. (primarily Electrical)

Die cast release agents consist of Silicone, Graphite, Wax, Mineral Oil, etc.
Silicone is generally the principal RM in Die cast release agents
Requirements for die-cast release agent

- Heat resistance: The larger the molded part, the more heat
- Release: The more detailed the part the more critical
- Over-coatability: Less cleaning prior to painting, glueing, etc.
- Residues: Minimal residues = more molding ‘shots’ before cleaning

![Diagram of different silicone types with chemical structures]

- Dimethyl Siloxane
- Alkyl Silicone
- Alkyl Aryl Silicone
- Phenyl Silicone

Heat Resistance

Lubrication
Die-cast mold release products

**Fluids (100%)**

<table>
<thead>
<tr>
<th>Product</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>XF42-C3698</td>
<td>Small Parts</td>
</tr>
<tr>
<td>XF42-B3629</td>
<td></td>
</tr>
<tr>
<td>XF42-334</td>
<td>Large Parts</td>
</tr>
</tbody>
</table>

**Emulsions (~50%)**

<table>
<thead>
<tr>
<th>Emulsion</th>
<th>Base oil</th>
<th>Performance</th>
<th>Main application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Heat Resistance Release Lubricity Paintability</td>
<td></td>
</tr>
<tr>
<td>XS53-C4070</td>
<td>XF42-C3968</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>TSM6363</td>
<td>XF42-B3629</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>TSM6362</td>
<td>XF42-334</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>
Focus Products - Europe

General use

<table>
<thead>
<tr>
<th></th>
<th>Oil Emulsion D</th>
<th>↑</th>
<th>SM2128NPF</th>
<th>coverage</th>
<th>LE-46</th>
<th>YMR7212</th>
<th>durability</th>
<th>SM2112NPF</th>
<th>↓</th>
</tr>
</thead>
</table>

Durable, substantive
Magnasoft 2059

Food Grade
- Formasil® 45 (emulsion of Element14 PDMS)
- Silwet® surfactants:
  - < water solubility release >
    - L-7200
    - L-7230

Over-coatable
XS53-C4070

Die-casting

<table>
<thead>
<tr>
<th>Part size:</th>
<th>&lt; Small</th>
<th>Large &gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ready-to-use</td>
<td>XS53-C4070</td>
<td>TSM6363</td>
</tr>
<tr>
<td>For emulsification</td>
<td>XF42-C3968</td>
<td>XF42-B3629</td>
</tr>
</tbody>
</table>
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