LSR Solutions for Market Trends

Dr. Hans Peter Wolf | Dow Silicones Deutschland GmbH
Silicone Elastomers US Summit 2018 | Cleveland, Ohio
Presentation agenda

Silicone Rubber Description

LSR 3P
- Properties
- Process
- Performance

Advanced LSR Technology
- Rheology & Cure
- Processing Experiment
- Oil-Bleeding LSR
- Low-Volatile NPC LSR

Next-Generation LSR
- LTC LSR
- LSR 3D Printing

Summary & Outlook
SILICONE RUBBER DESCRIPTION
Silicone rubber: A unique, fascinating material

Amazing materials with unique potential

• Revolutionizing our present
• Shaping our future
Silicone rubber: A unique, fascinating material

Synthetic polymers
Silicon and oxygen
Carbon
Hydrogen

The missing link
Combining the characteristics of plastics and glass
LSR PROPERTIES, PROCESS, PERFORMANCE (3P)
LSR 3P: The magic combination

- Properties
- Process
- Performance
Properties

- Hardness: 20 Shore A to 80 Shore A
- Tensile strength: Up to 12 MPa
- Elongation: 100% to 1,000%
- Tear strength: Up to 50 kN/m
- Compression set: Down to 10% (22 hr at 175°C)
- Temperature range: From -60°C to 200°C (some grades -110°C, or up to 280°C)
Properties (continued)

• Good dielectric properties over a wide temperature range

• Volume resistivity: $1 \times 10^{16}$ Ohm.cm (insulating) to 2 Ohm.cm (semi-conductive)

• Easy to pigment (translucent)

• Most grades suitable for water (KTW, WRAS)

• Ozone and UV resistance

• Low moisture pickup; excellent hydrophobic behavior

• F-LSR is resistant to fuel and many chemicals
Process: Liquid injection-molding equipment

**Injection-Molding Machine**
- Cooled barrel to 23°C
- Special LSR screw and barrel
- Spring-loaded nonreturn valve

**Dosing Pump and Mixer**
- Hydraulic or pneumatic (180/220 bar)
- Through static mixer
- Plus color additive (RBL color MB)

**Mold**
- Heated mold up to 170-220°C
- Cold runners
- Hardened steel
- Exact finishing
- Vacuum

**SILASTIC™ brand LSRs**
- Pourable to paste
- A+B (bi-component)
- 1:1 mixing ratio
- Supplied in 20 L pails or 200 L drums
Process: Rheology & processing

Shear rate, 1/s

<table>
<thead>
<tr>
<th>Viscosity, Pa·s</th>
<th>Runners/cavities</th>
<th>Injection unit</th>
<th>Static mixer</th>
<th>Dosing pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00E+00</td>
<td>1.00E+00</td>
<td>1.00E+00</td>
<td>1.00E+00</td>
<td>1.00E-01</td>
</tr>
<tr>
<td>1.00E+01</td>
<td>1.00E+01</td>
<td>1.00E+01</td>
<td>1.00E+01</td>
<td>1.00E-01</td>
</tr>
<tr>
<td>1.00E+02</td>
<td>1.00E+02</td>
<td>1.00E+02</td>
<td>1.00E+02</td>
<td>1.00E-01</td>
</tr>
<tr>
<td>1.00E+03</td>
<td>1.00E+03</td>
<td>1.00E+03</td>
<td>1.00E+03</td>
<td>1.00E-01</td>
</tr>
<tr>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>1.00E-01</td>
</tr>
</tbody>
</table>

Consumer Solutions
Performance: Productivity & quality

LSR versus HCR technology

- Fill more cavities in a shorter injection time due to low viscosity
- Reduced curing time due to addition-cure technology
- Faster demolding and automation possible due to better “hot” mechanical strength
- Mold thin membranes or complex shapes due to low viscosity
- Fits to wide range of industrial and consumer goods
Performance: Rheology & processing

New LSR technology retains low viscosity prior to injection into cavity

Lower injection pressure

Higher injection speed
• Repeatable process
• Wide process window
• Fast processing for only quality parts
ADVANCED LSR TECHNOLOGY
Rheology & cure

Injection pressure, bar

Injection speed, cm³/s

XIAMETER™ RBL-2004-50 LSR

SILASTIC™ RBL-9200-50 LSR

Degree of vulcanization

Time, sec

Core temperature, °C

Degree of vulcanization

Time, sec

170°C

150°C

r=1 mm

r=2 mm

r=3 mm

Consumer Solutions
Double injection speed at given pressure for new LSR type (SILASTIC™ RBL-9200-50) relative to old LSR type (XIAMETER™ RBL-2004-50) and competitor LSR
ADVANCED LSR TECHNOLOGY

Oil-bleeding LSR
Oil-bleeding LSR

Electrification Acceleration

EU28 sales shares for passenger vehicles – engine propulsion system design

Electric sales share = almost 25% (BEV/REX/FCEV/PHEV)

IHS Markit expects a real tipping point for electric cars by 2025+, with the “hype” phase ending.

Source: IHS Markit VPaC 2018 H1 (prelim)

New Vehicle Architectures

Automated driving enabled by many sensor configurations

Source: IHS Markit Autonomous Driving Service

Graphics © 2018 IHS Markit. All Rights Reserved. Used with permission from IHS Markit.
Oil-bleeding LSR

Processing benefits with new LSR technology

![Graph showing processing benefits with new LSR technology](image)

- **Radial seal: Good**
- **Radial seal: Poor**
ADVANCED LSR TECHNOLOGY

Low-volatile non-post-cure (NPC) LSR
**Conventional LSR**

**Conventional LSR technology** must be post-cured to evaporate silicone volatiles to below regulated threshold concentrations.

**Drawback:** Additional process step and handling, leading to higher cost-in-use and increased risk of cross-contamination.
Low-volatile NPC LSR

Post-cure: A source of article variability.

Factors impacting volatile content in final article:

- Purity of LSR raw material, initial volatiles concentration [Dx]0
- Post-cure process:
  - Temperature and time (typically 200°C/4 hrs)
  - Loading of oven
  - Fresh air supply and turnover rate
- Product design, surface/volume ratio

Non-post-cure LSR: An option for enhanced consistency and safety.
Low-volatile NPC LSR

*SILASTIC™ NPC 9300-xx Liquid Silicone Rubber*

*SILASTIC™ NPC 9300-xx Series LSRs* have been developed to meet requirements of food and infant care regulated applications (BfR, FDA) without post-cure.

**High safety threshold** to European and U.S. volatiles and extractables regulations.

Typical volatile compounds content *without* post-cure: 0.25%*

Low-volatile NPC LSR
*SILASTIC™ NPC 9300-xx Liquid Silicone Rubber*

NPC technology can enhance productivity, consistency and consumer safety!

NEXT-GENERATION LSR TECHNOLOGY

Low-temperature-cure (LTC) LSR
At low temperatures down to 100ºC-120ºC, the cure rate of conventional LSR is slowed down significantly.
LTC LSR low-temperature cure rate

Step-change in cure rates at temperatures down to 100ºC-110ºC.

Pot life is >72 hours.

Potential benefits:
- 2K co-molding of thermosensitive thermoplastics (PE/PP)
- Incorporation of actives (healthcare) and sensitive components (electronics)
LTC LSR cure rate & acceleration

Optimize cure rate at low temperatures for optimum process cycle times.

**Complementary approach:**
On/off addition of “acceleration additive” to SILASTIC™ LTC 9400 Series LSR through color dosing.

![Normalized torque vs. Time graph](image)

- **Normalized torque**
  - 1.2
  - 1
  - 0.8
  - 0.6
  - 0.4
  - 0.2
  - 0

- **Time, sec**
  - 0 20 40 60 80 100 120 140 160

- **Temperature**: 110°C

- **Standards**
  - 3 2 1 0

**SILASTIC™ LTC 9400 Acceleration Additive**
(0-3%)

(SILASTIC™ LTC 9400 Series LSR, 72 hr pot life)
Effects of temperature on LTC LSR

LTC LSR shows fast temperature activation throughout full temperature range.

LTC LSR is less sensitive to temperature gradients.

Enables fast deep-section cure at elevated temperatures.
LTC LSR shows the same benefits for processing as SiLASTIC™ RBL-9200-50:

Higher injection speed at the same injection pressure!
Applications & solutions

Bottle ventilation valve: SILASTIC™ LTC 9400-50 LSR presented at Fakuma 2017

• Fast cure demonstrated for bottle ventilation valves of high wall thickness

• SILASTIC™ LTC 9400 Acceleration Additive introduced at 0.5%

Simulated by SIGMASOFT: Temperature distribution after 20 sec
Oil-bleeding LTC LSR grade: Developed for automotive sealing

- 50 Shore A, 2% oil
- Low compression set; non-post-cure

Case study:
- Automotive cable seal; wall thickness: 8 mm
- Fast deep-section cure achieved with SILASTIC™ LTC 9402-50 LSR
- Heating time reduced by up to 30%
Co-molding of low-temperature melting plastics:
- **Low heat-deflecting temperatures** (HDT) for plastics such as PC, PP, PE
- Need for low-temperature cure + adhesion to avoid plastic deformation

Low-temperature cure **combined** with selective adhesion technology:
- **Adhesion confirmed** to polycarbonate (e.g., SABIC LEXAN grades)
NEXT-GENERATION LSR TECHNOLOGY

LSR 3D printing
New method of additive manufacturing
silicone elastomers

**EVOLV3D™ LC 3335 LSR**

Thermal-curing silicone elastomers for 3D printing processes

Mechanical properties of printed samples in good agreement with conventional processing:

- Production of functional prototypes
- Small production series of complex parts
- Easy transfer into conventional injection-molding processes for mass production

Benefits:

- Fast prototyping
- Production of complex parts
- New design options
Liquid Additive Manufacturing (LAM) 3D Printer developed by cooperation partner German RepRap GmbH (www.germanreprap.com).

### Selected Specifications

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Platform</strong></td>
<td>(X/Y/Z) 260 x 320 x 200 mm</td>
</tr>
<tr>
<td><strong>Travel speed</strong></td>
<td>10 to 300 mm/s</td>
</tr>
<tr>
<td><strong>Nozzle diameter</strong></td>
<td>0.4 mm</td>
</tr>
<tr>
<td><strong>Print speed</strong></td>
<td>10 to 150 mm/s</td>
</tr>
</tbody>
</table>

**First commercialized customer project:**
- I.L.E. Innovation Lab Ecco with Quant-U
- Learn more at [www.quant-u.com](http://www.quant-u.com)
- Launched by I.L.E. April 2018
Examples
About EVOLV3D™ LC 3335 LSR for 3D printing

• Do you want to produce prototype parts with relevant LSR for serial production in less than 1 day?
• Do you want to produce customized parts with high-strength LSR?
• Do you want to run mass additive production for parts with endless design freedom?

EVOLV3D™ LC 3335 LSR is formulated to run via 3D printing process with final performance comparable to injection-molded parts.
Summary

- Volatiles
The information contained in this communication does not constitute an offer, does not give rise to binding obligations, and is subject to change without notice to you. The creation of binding obligations will occur only if an agreement is signed by authorized representatives of Dow and your company. Any reference to competitor materials contained in this communication is not an endorsement of those materials by Dow or an endorsement by the competitor of Dow materials.

To the fullest extent permitted by applicable law, Dow disclaims any and all liability with respect to your use or reliance upon the information. DOW DOES NOT MAKE ANY WARRANTY OR REPRESENTATION, EXPRESS OR IMPLIED, WITH RESPECT TO THE UTILITY OR COMPLETENESS OF THE INFORMATION AND DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. DOW DISCLAIMS LIABILITY FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES.

©™Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow

© 2018 The Dow Chemical Company. All rights reserved. 88251/88004