Dispersion of Silica in Silicone Systems

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Friction and Adhesion in Wet and Dry Systems
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Consumer Solutions

Personal Background / Bio: Jens Natterodt

Education

- **Ph.D. in polymer chemistry and engineering**, University of Fribourg, Switzerland
- **Master in chemistry**, Karlsruhe Institute of Technology, Germany

Experience

- 2017 - present: **Process R&D Scientist**, Dow, Wiesbaden, Germany

Areas of expertise

- Silicones
- Silica and alumina dispersion & treatment
- Problem solving
- Continuous Improvement
- Data analysis & visualization, programming, AI

Dow Consumer Solutions at a Glance

*A premier industry leader with an unmatched portfolio of **silicone and organic technologies** powered by a **global, inclusive, customer-centric** workforce that collaborates to **deliver sustainable, innovative solutions***

Broad portfolio of chemistries with high-value innovation pipeline

Customer-centric culture enabled by digital capabilities and global inclusive workforce

Leading global silicones player[1] – an industry leader for 80 years

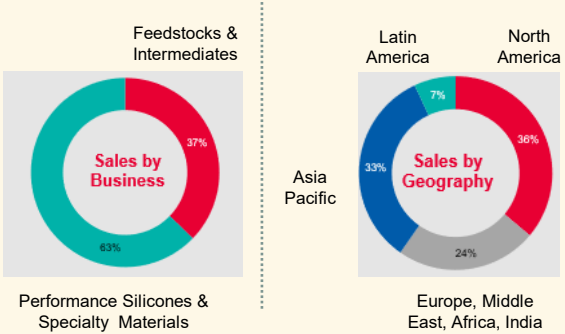
$5.1B
Revenue (2024)

~7,000
Employees

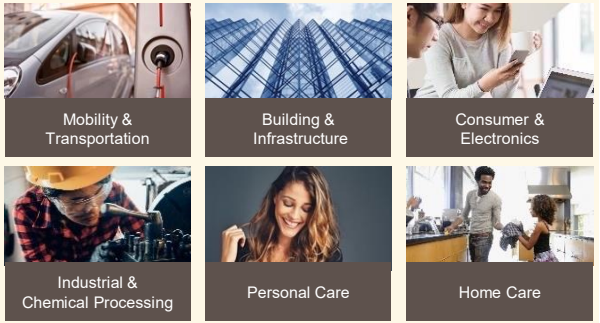
20
Manufacturing Sites

12
R&D Locations

Sales by Business and Geography



Trend-Driven Business



R&D Labs Around the Globe

North America

Midland
Michigan, United States

Carrollton
Kentucky, United States

Collegeville
Pennsylvania, United States

Latin America

Jundiaí
Brazil

Asia

Chiba
Japan

Jincheon
Korea

Shanghai
China

Singapore

Europe, Middle East, Africa and India

Barry
Wales, United Kingdom

Seneffe, *Belgium*

Wiesbaden, *Germany*

Mumbai, *India*

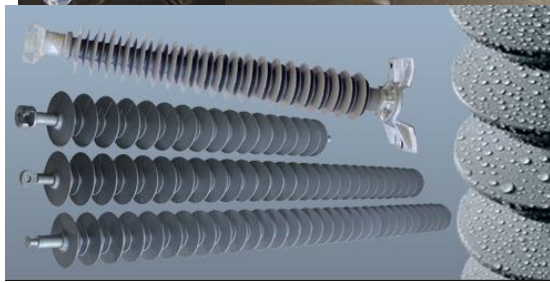
Silicone Rubber

Silicone rubber

- Silicone polymers, when cured, have poor mechanical performance – they require a reinforcing filler

Liquid Silicone Rubber (LSR)

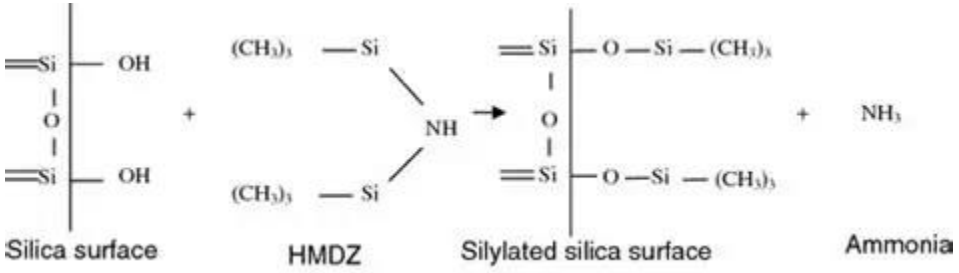
- 2-Part system
- Flowable and used in a variety of applications
- Individual parts are non-reactive by themselves but cure when mixed together
- Polymer + Reinforcing Filler + Treating Agent + Cure Package



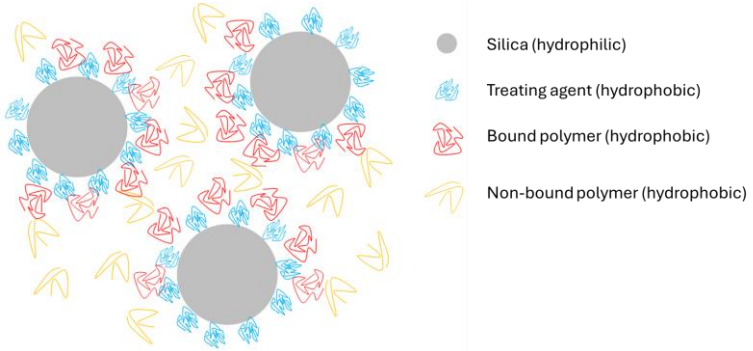
LIQUID SILICONE RUBBERS - CHEMISTRY

- Silica particles get hydrophobized via in-situ reaction with treating agent (siloxane polymer + silica + treating agent)

- Silica particles are broken down during the high-shear in-situ reaction to achieve their optimum reinforcing capability



J Mater Sci 42, 8418–8425 (2007). https://doi.org/10.1007/s10853-007-1788-2



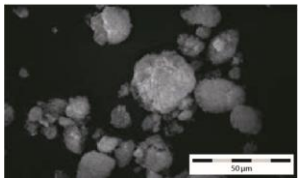
Particle Size and Rheology in LSR

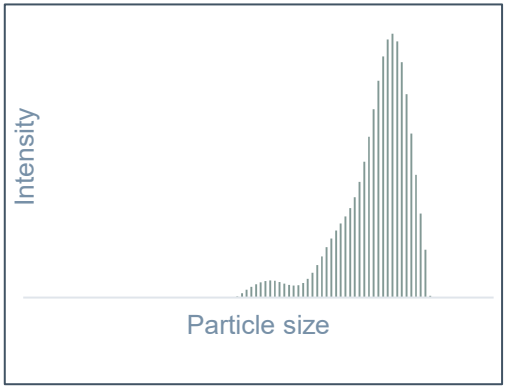
Little shear during mixing

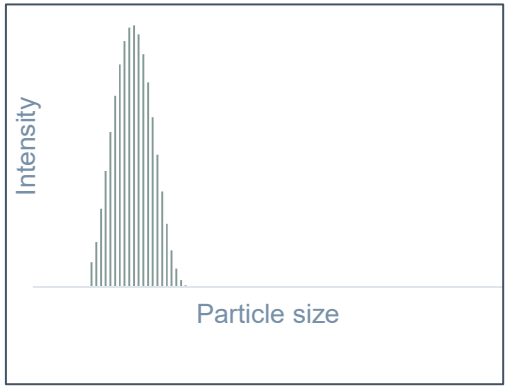
Poor flowability

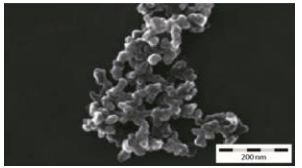
High shear during mixing

Good flowability







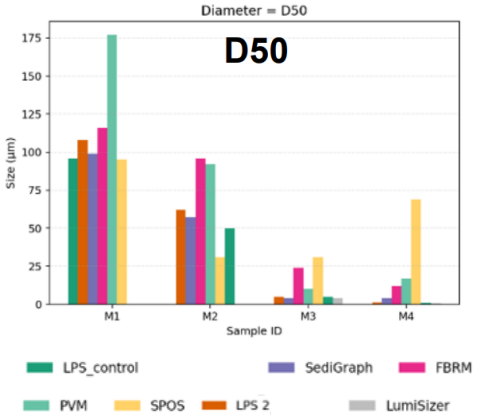


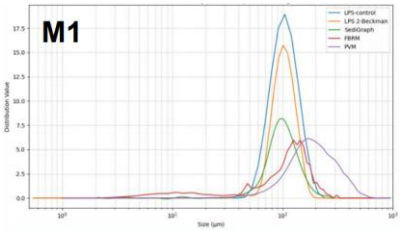
Particle size distribution impacts material properties (rheology, tribology, physical properties)

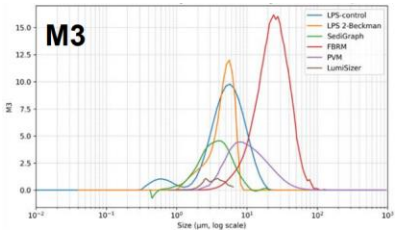
→ How can particle size be measured in a consistent and repeatable way?

PARTICLE SIZE CHARACTERIZATION TECHNIQUES

Several techniques have been explored to measure particle sizes



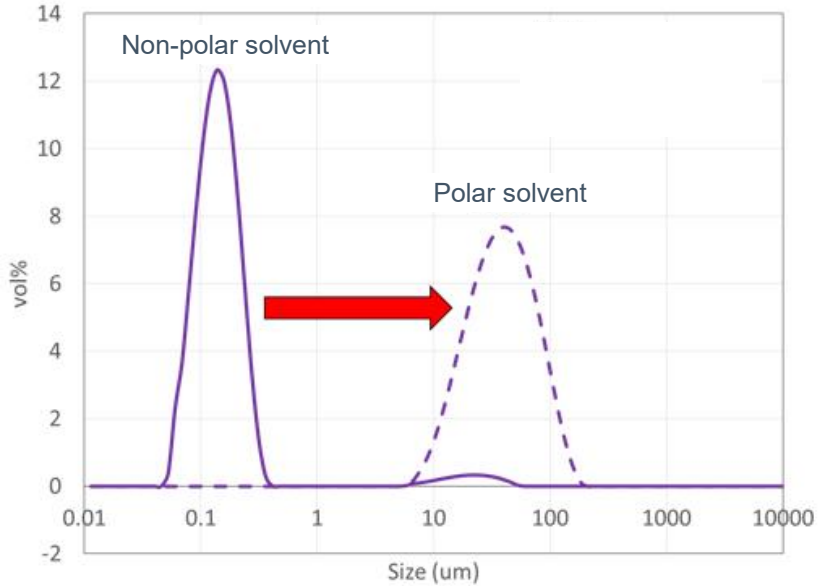




- Depending on the characterization method, particle sizes vary significantly (factor 10 and more). Better consistency for large particles (M1) vs small particles (M3)
- Light scattering typically shows most consistent results
- However, also via light scattering, results are often not consistent.

How Solvent Polarity Affects Silica Dispersion in Silicone Systems

Solvent choice critically impacts particle size distribution and dispersion quality in silicone formulation

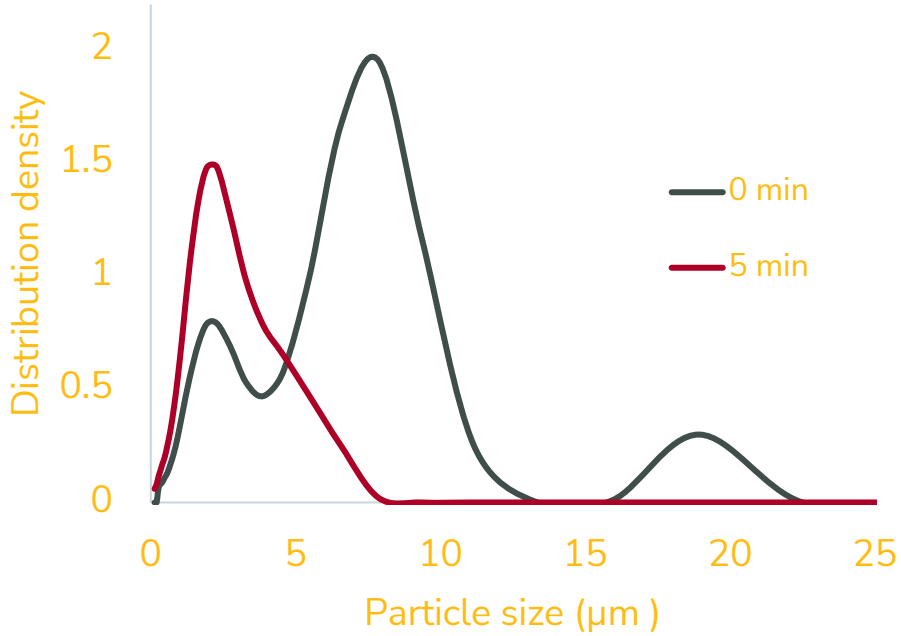


- In non-polar solvents hydrophobized silica particles are typically well dispersed
- In polar solvents, particles tend to build agglomerates

Actual dispersion of the product (treated silica in high-viscosity siloxane) is unknown and cannot be determined via light scattering without the addition of a solvent.

PSD via Light Scattering: Impact of Mixing Time

Measured particle size distribution is impacted by the mixing time in the PSD analyzer



- Particle interactions through van der Waals bonds or hydrogen bonds.
- Bi-modal distribution; after 5 minutes mixing in the PSD analyzer, mono-modal distribution.
- Strong mixing in the PSD analyzer can open up van der Waals and hydrogen bonds of agglomerates, forming aggregates

SUMMARY

🔍 Research Gap

Most published studies measure particle size distribution (PSD) in aqueous media, leaving non-polar environments—such as silicone systems—underexplored.

⚙ Technical Challenge

Accurately determining PSD of silica in silicone remains difficult due to limitations in current measurement techniques.

📊 Impact on Applications

The relationship between PSD and key material properties (rheology, tribology, physical performance) is not yet fully understood, highlighting the need for further research.

💡 Future Direction

Advancing measurement methods for non-polar systems will enable better correlation of PSD with functional properties, supporting innovation in silicone-based materials.

Acknowledgements

- Dow Consumer Solutions Process R&D and Analytical Science Team
- IFPRI Workshop Organizers

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