“Sílica pirogênica hidrofóbica AEROSIL® e silano organofuncional Dynasylan® como aditivos de alta performance em adesivos para aplicação em compósitos”

Thalita Bacci

São Paulo, 9 de Novembro de 2016

EVONIK INDUSTRIES

1. **Company profile**
2. Evonik’s Fumed Silica Technologies
3. Fumed Silica in Adhesives and Sealants
4. Evonik’s Organofunctional Silane Technologies
5. Silane Monomers vs. Silane Oligomers
6. VPS 7163
   New adhesion promoter for critical metals and plastics
7. Benefits at a Glance

Evonik – a modern structure

EVONIK INDUSTRIES

Evonik

Specialty Chemicals Segments/GmbH

Segments	Nutrition & Care	Resource Efficiency	Performance Materials	Services	Corporate / Other
	Business Lines: • Personal Care • Household Care • Comfort & Insulation • Interface & Performance • Baby Care • Health Care • Animal Nutrition	**Business Lines:** • Active Oxygens • Catalysts • Coating & Additives • Coating & Adhesive Resins • Crosslinkers • High Performance Polymers • Oil Additives • Silanes • Silica	**Business Lines:** • Performance Intermediates • Agrochemicals & Polymer Additives • Functional Solutions • Acrylic Monomers • Acrylic Polymers • CyPlus Technologies	• Administrative Services • Technology & Infrastructure	• Corporate Center • Strategic R&D

Silanes, a strong pillar within Resource Efficiency

Segment

Resource Efficiency GmbH

Business Lines

- **Silica**
- **Silanes**
- Catalysts
- Active Oxygens
- Oil Additives
- Crosslinkers
- Coating & Adhesive Resins
- Coating Additives
- High Performance Polymers

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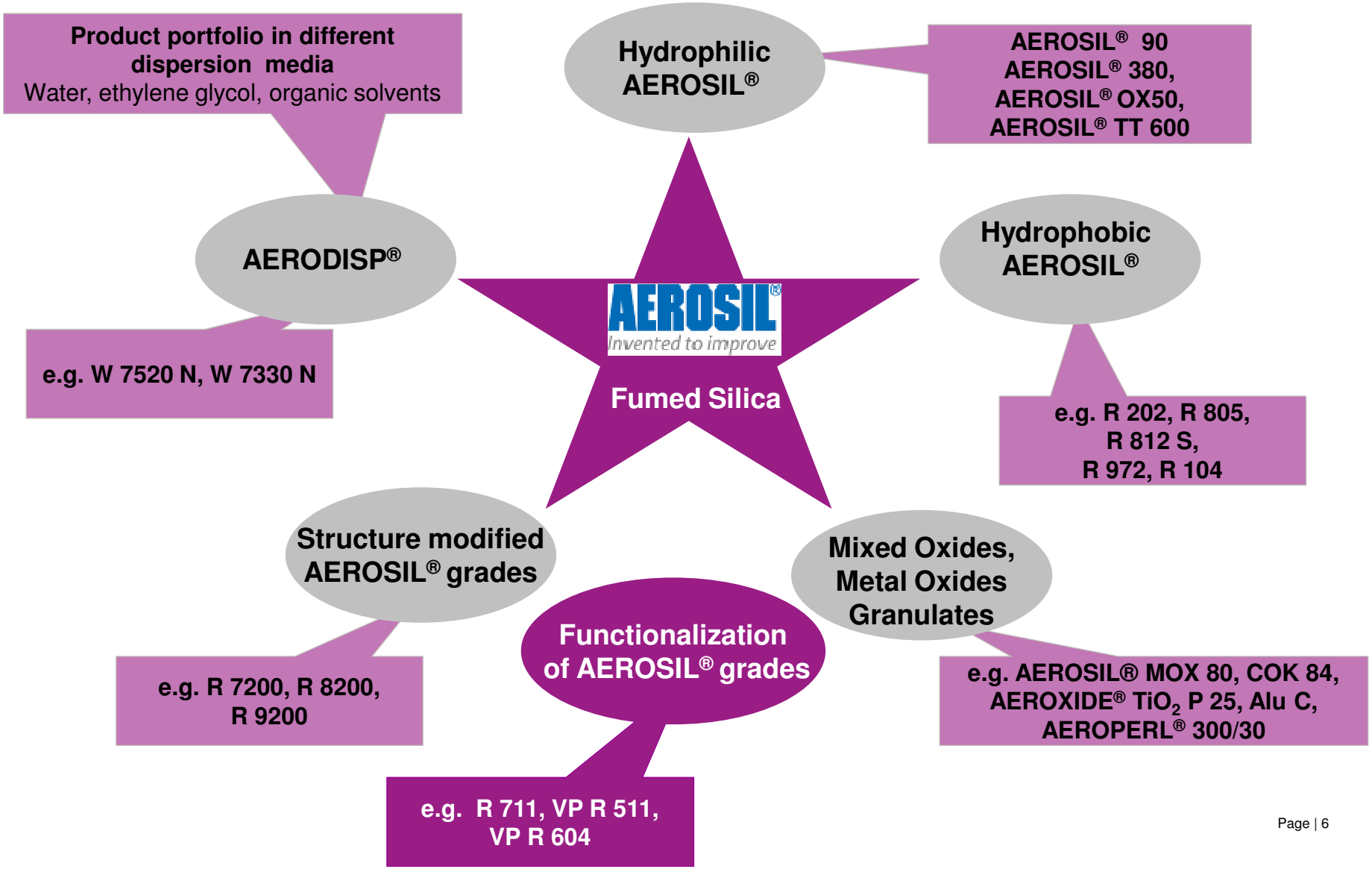
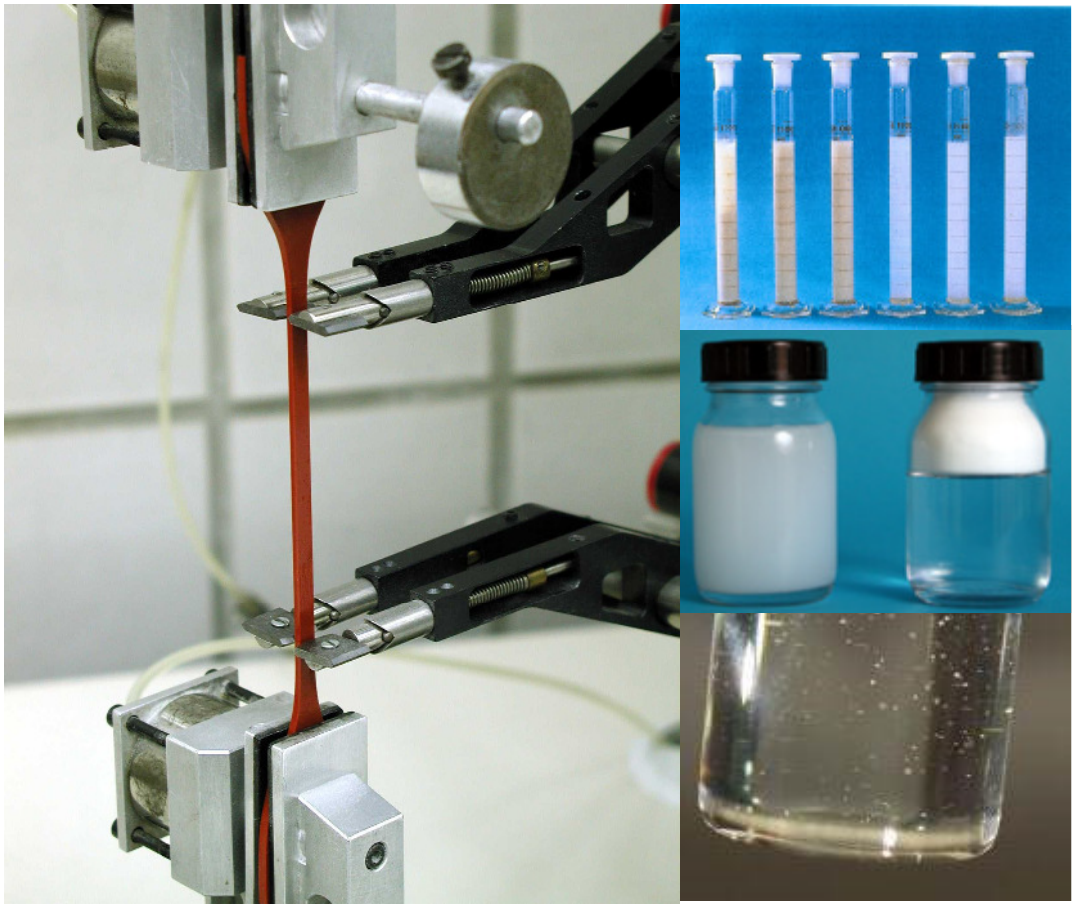
AEROSIL®: Most Versatile Product Portfolio for Adhesives & Sealants



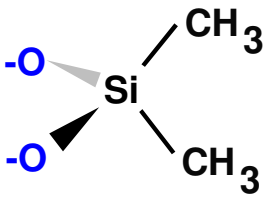
Main Effects of Fumed Silica Within the Adhesives & Sealants Industry

- Viscosity Control
- Thixotropy
- Yield Point
- Anti - Sag
- Anti – Settling
- Sprayability
- Reininforcement
- Bonding Strength
- Storage Stability
- Transparency



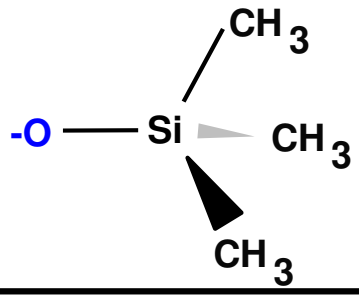
Surface Modification of Fumed Silica

AEROSIL® R 972
AEROSIL® R 974



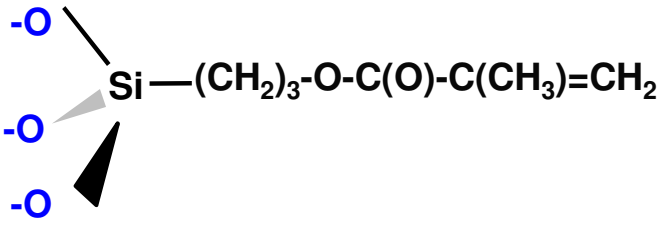
Dimethyldichlorsilane

AEROSIL® R 812



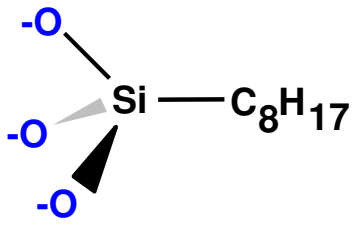
Hexamethyldisilazane

AEROSIL® R 711



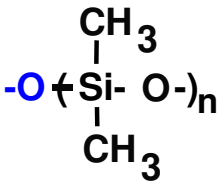
Methacryloxypropyltrimethoxysilane

AEROSIL® R 805



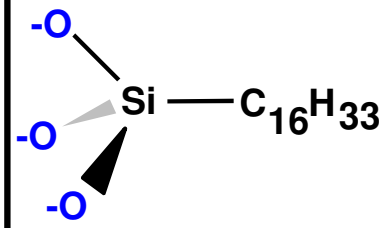
Octyltrimethoxysilane

AEROSIL® R 202
AEROSIL® R 208



Polysiloxane

AEROSIL® R 816



Hexadecyltrimethoxysilane

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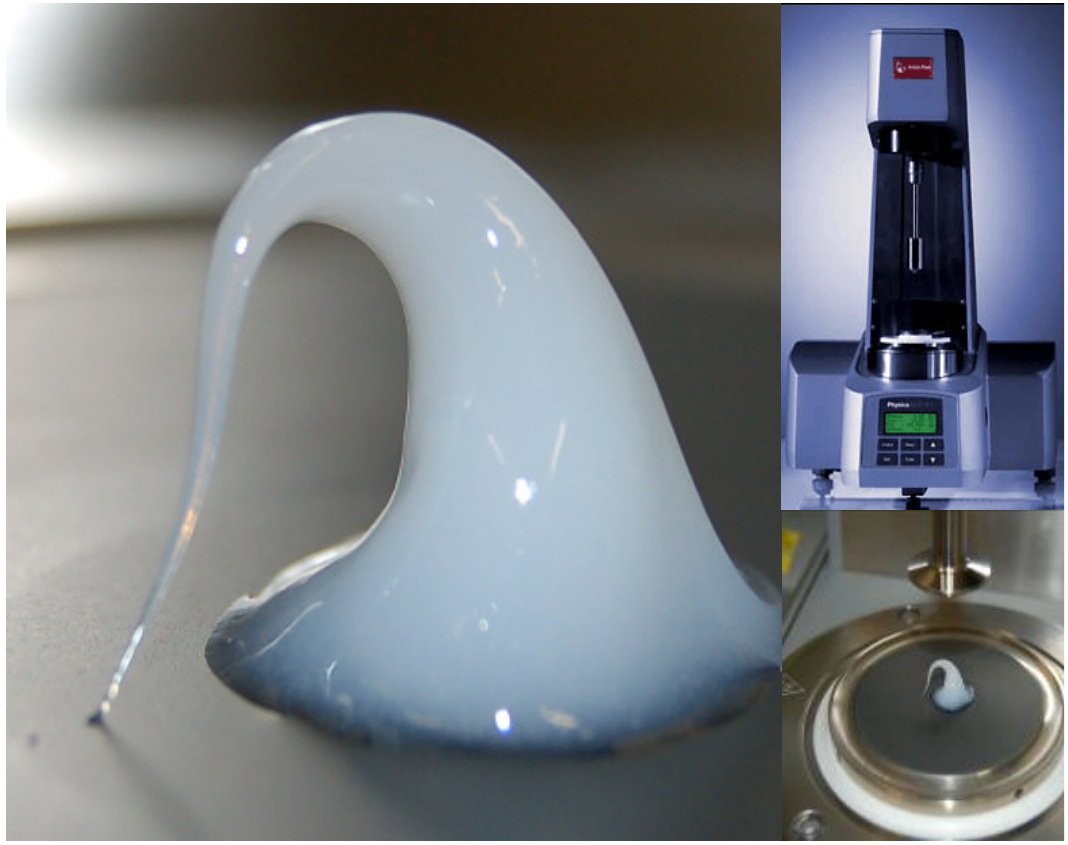
Rheological Measurements

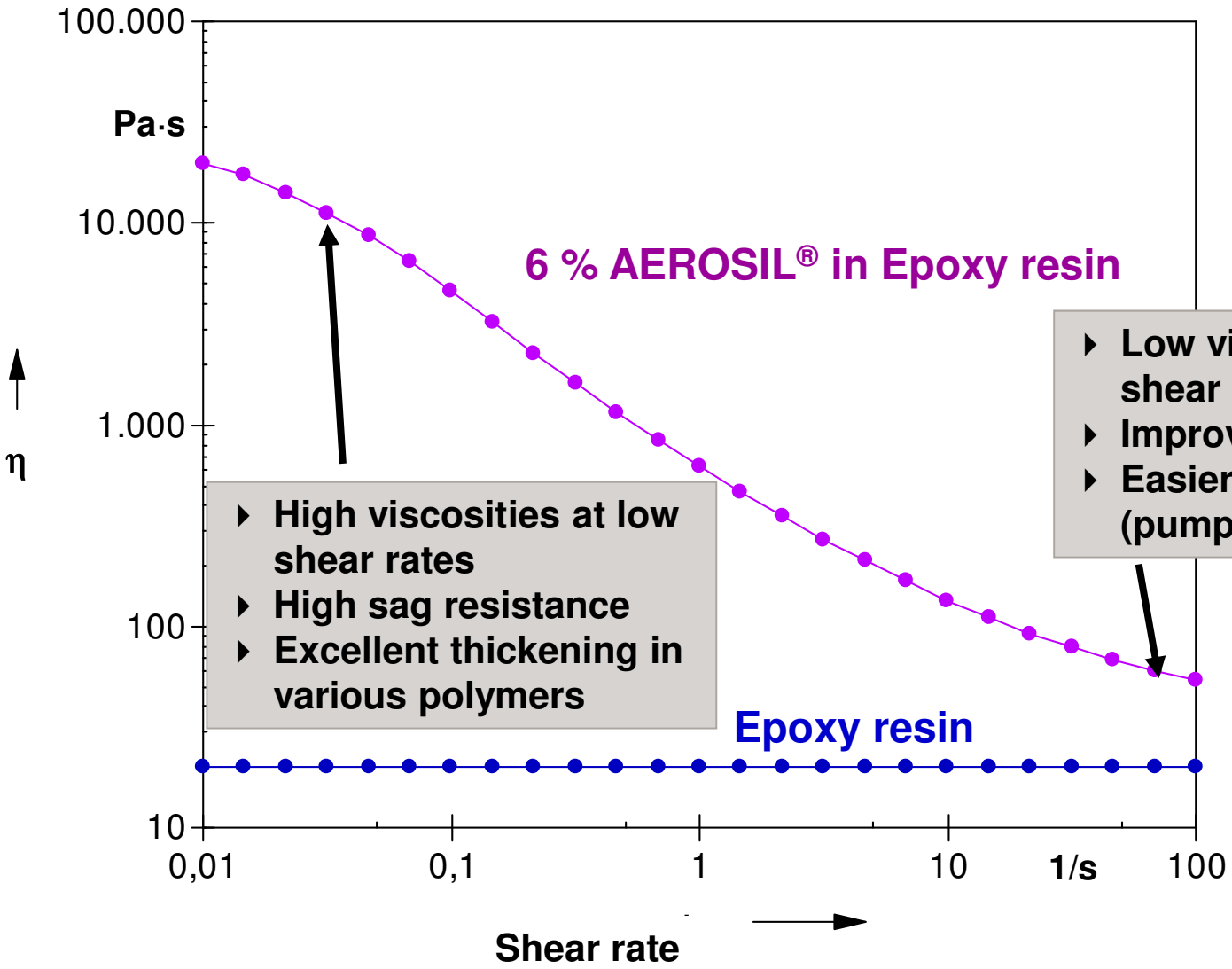
Rheometer „Anton Paar, Physica MCR 301“

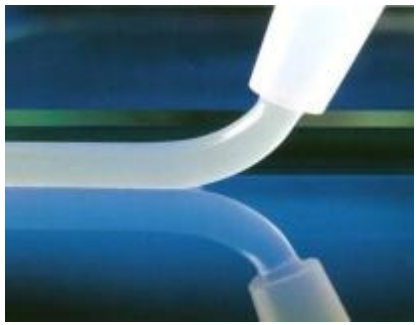
Rotational and dynamic measurements:

- Flow and viscosity curves
- Thixotropic behaviour
- Yield point
- Viscous behaviour
- Elastic behaviour



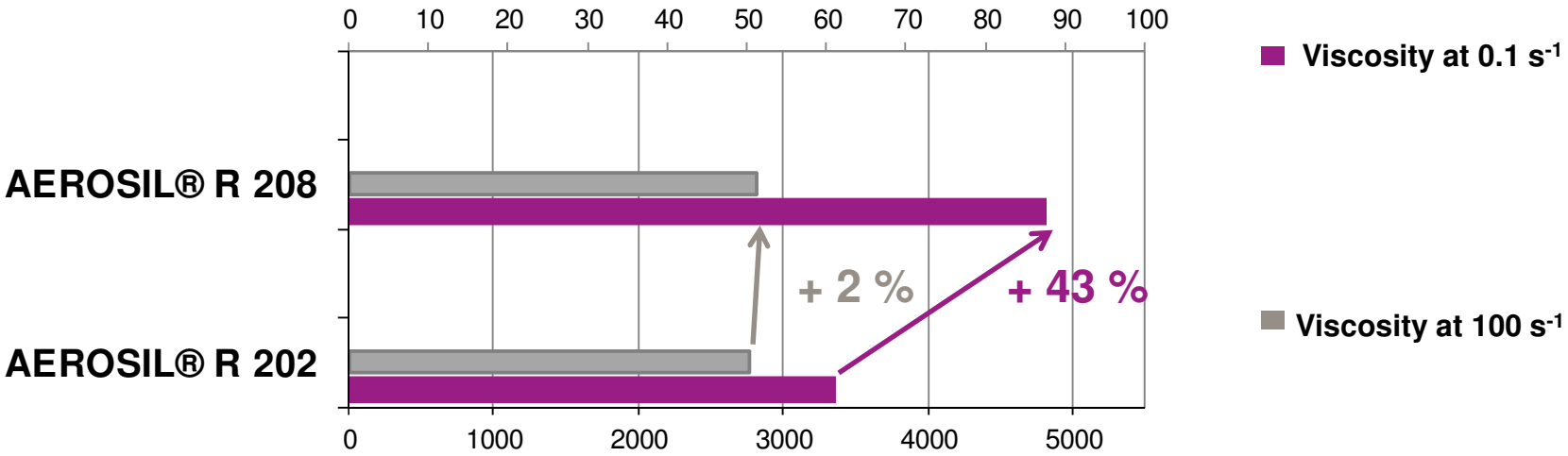
AEROSIL® Fumed Silica in EP Systems, Viscosity Curve and Anti-sag





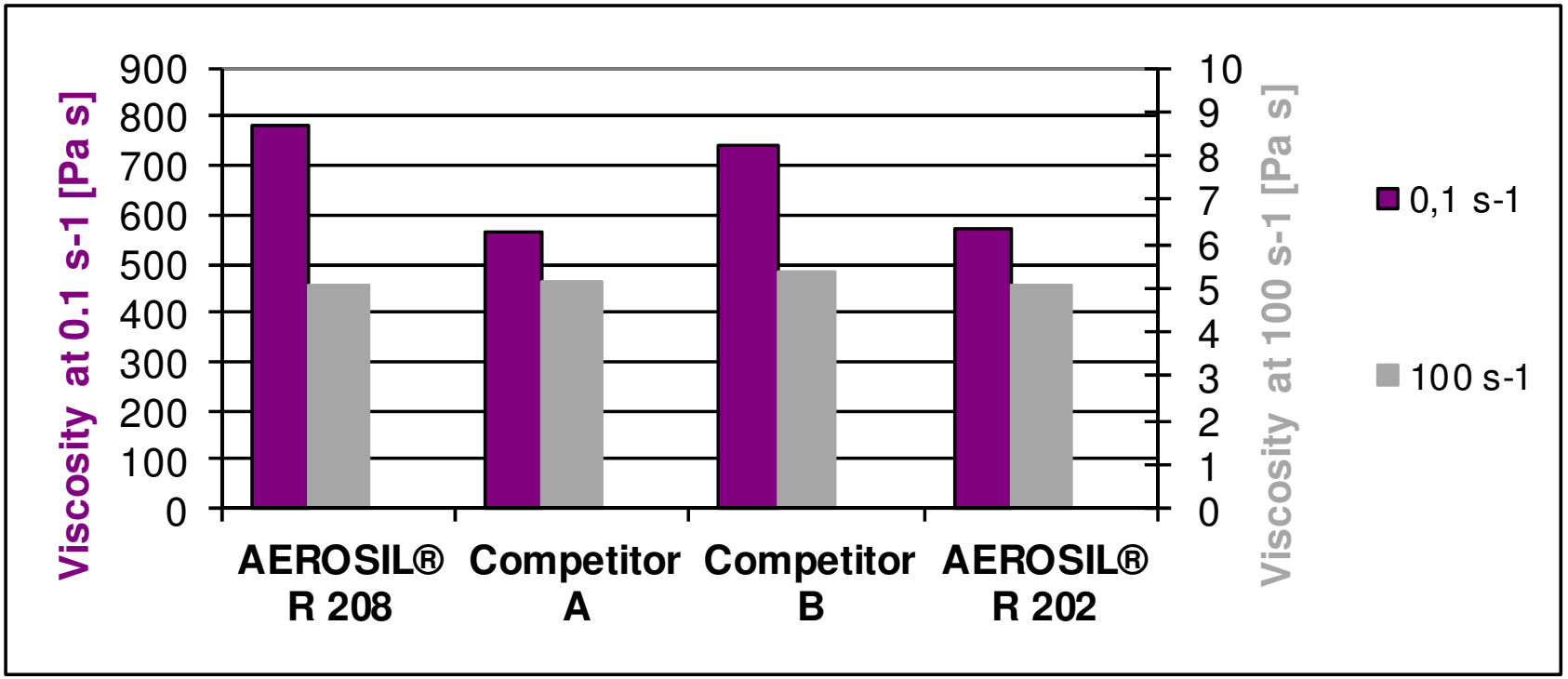
AEROSIL® R 208 – Improved Thickening Efficiency

<u>Model formulation</u>: 6 % PDMS-treated Fumed Silica in Epoxy Resin Epon 828



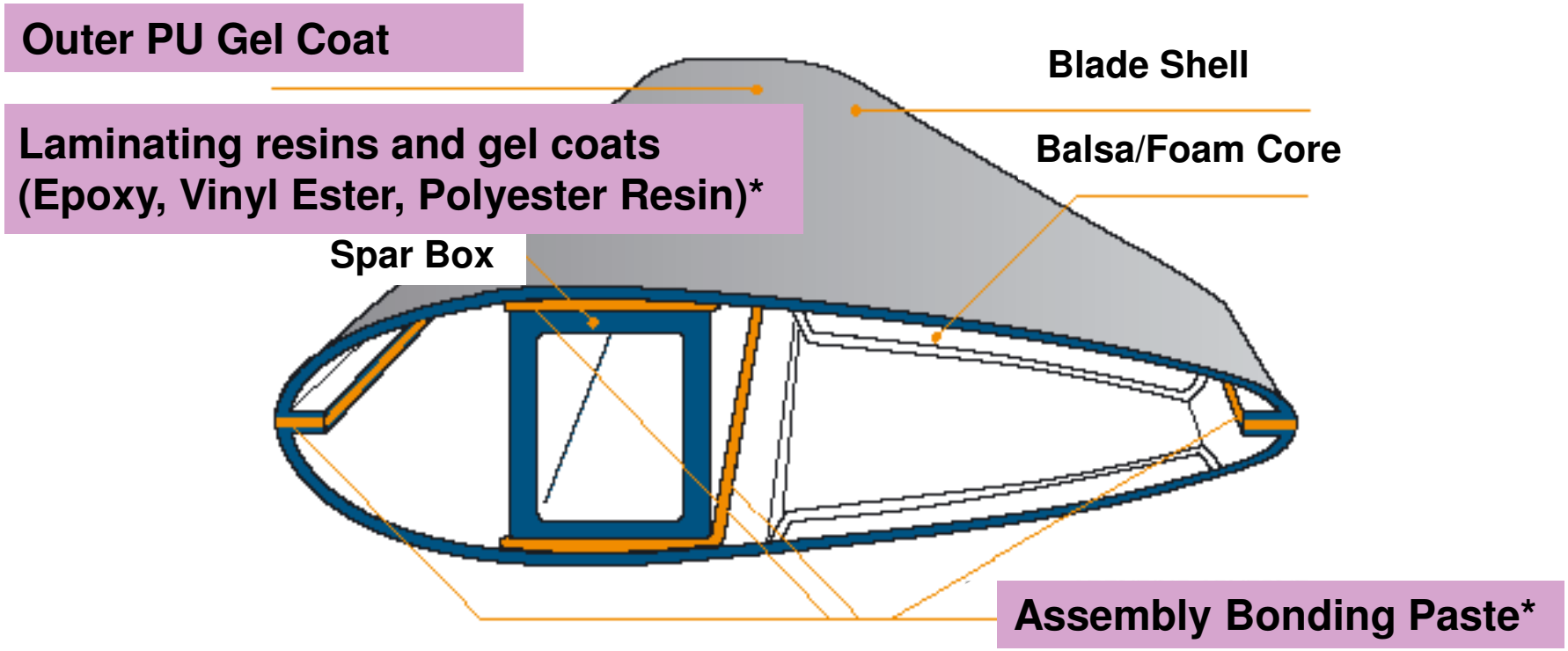
AEROSIL® R 208 gives at lower shear rates a significant higher viscosity in Epon 828 than AEROSIL® R 202

8 % Fumed Silica in Polyol-Component for Polyurethanes



AEROSIL® R 208 performs excellent in polyols

Typical Rotor Blade Cross Section



AEROSIL® containing Applications / Polymers, such as Epoxies, Polyurethanes and Vinyl Ester / Polyester

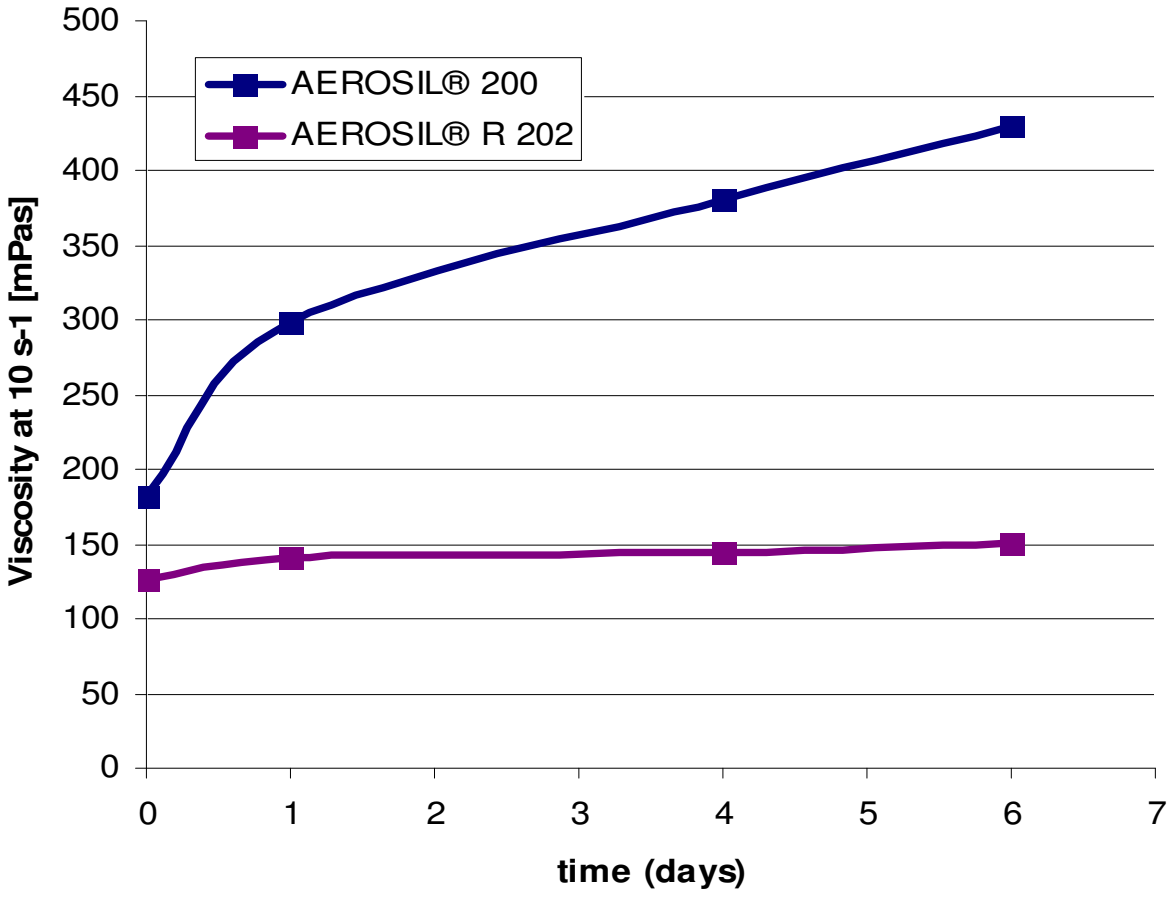
Bonding Pastes – Explanation and Use

- Large quantities of bonding pastes are used in the manufacture of wind turbine rotor blades. These bonding pastes must have good thixotropic and specific slump properties. That is why AEROSIL® fumed silicas are used as essential thixotropes in bonding pastes based on epoxy, polyurethane, vinyl ester and polyester resins.

- More precisely, the hydrophobic fumed silicas AEROSIL® R 202 and AEROSIL® R 208 are the most used high-performance thixotropes of choice in bonding pastes.

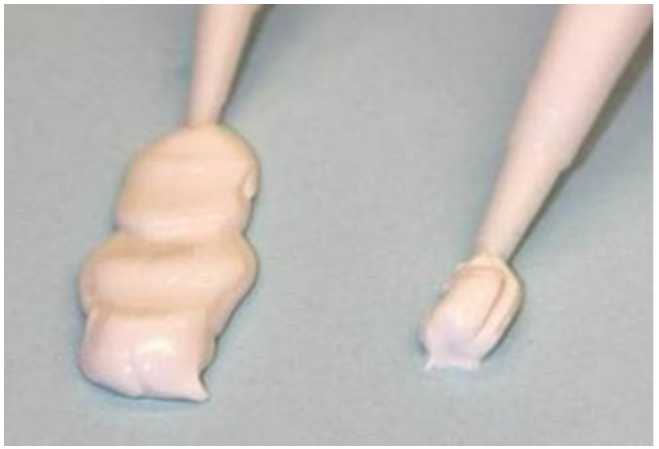
- The normal production procedure is to manufacture the upper and the lower shell of the rotor blade shell in separate moulds and glue them together by the bonding pastes.

Storage Stability of AEROSIL® in MS-Polymer Formulations

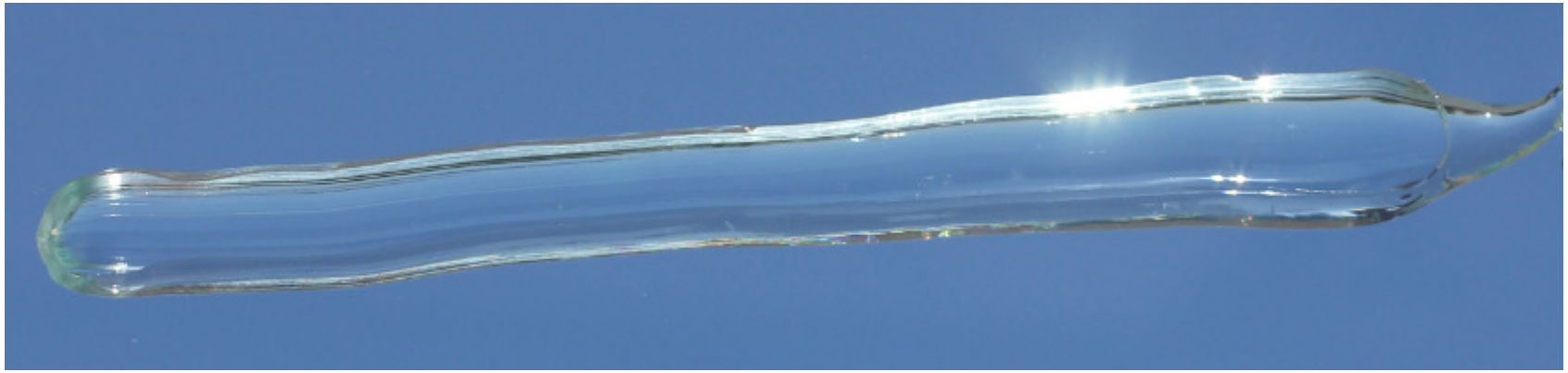


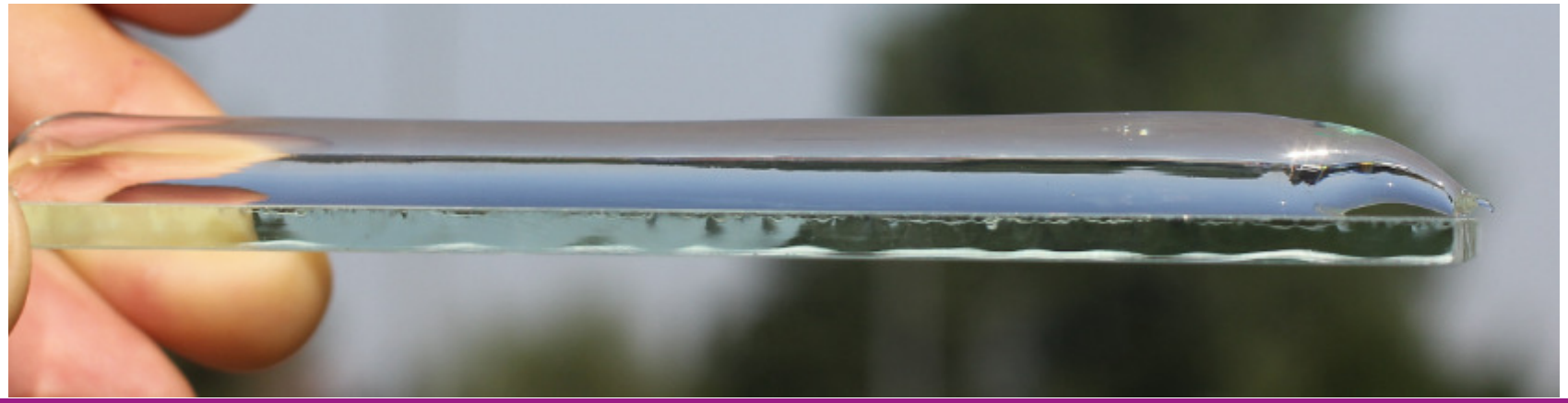
* Viscosity of MS-Systems after storage at RT

- Hydrophobic AEROSIL® increases the storage stability of MS-Polymer-products significantly
- Nearly constant viscosity levels are achievable with AEROSIL® R 202 over time.



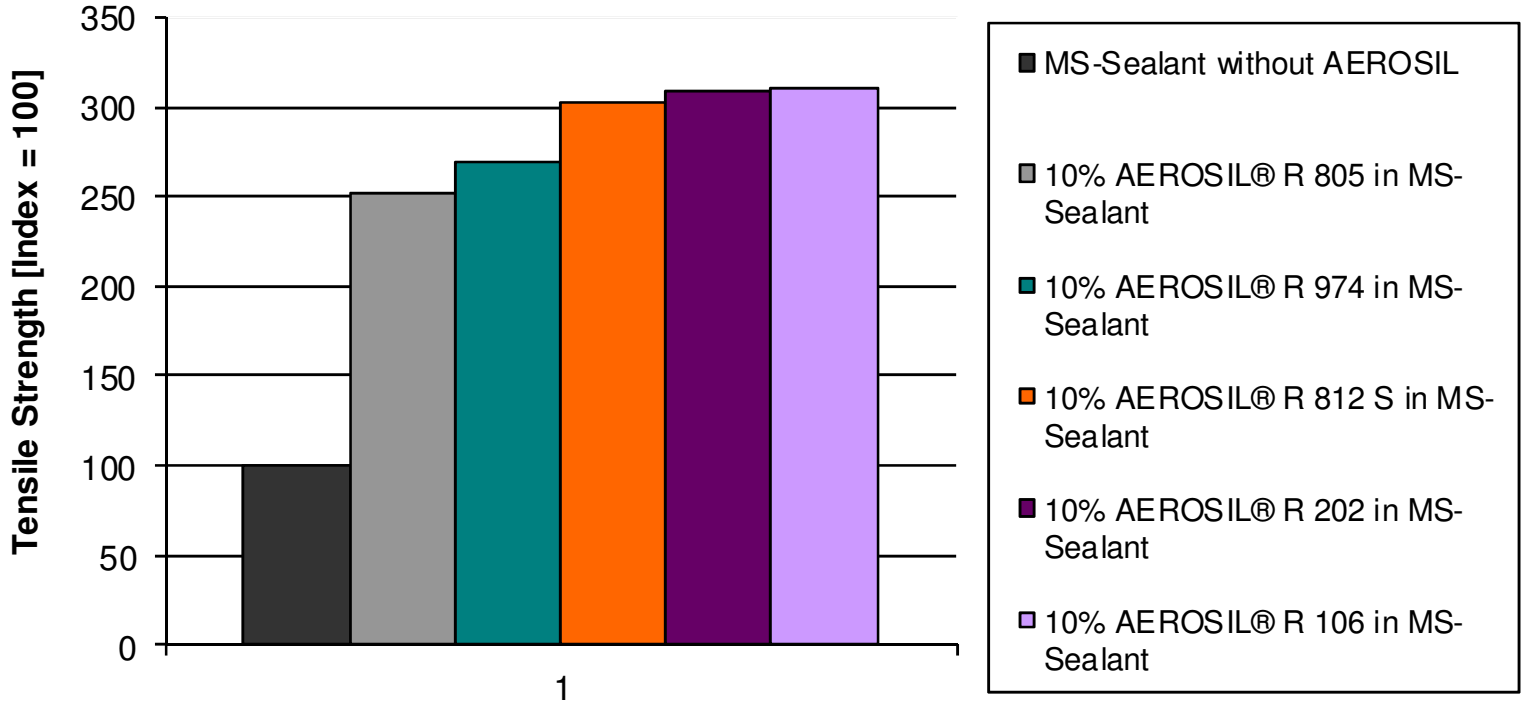
Special AEROSIL® fumed silica for transparent SMP-systems





AEROSIL® R 805, AEROSIL® R 812 S and AEROSIL® R 106 are mostly recommended for transparent hybrid products !

Tensile Strength of Transparent MS-Sealant With AEROSIL® Fumed Silica



*** Performance of formulation w/o AEROSIL® = Index 100**

AEROSIL® improves the tensile strength of MS-Sealant significantly !

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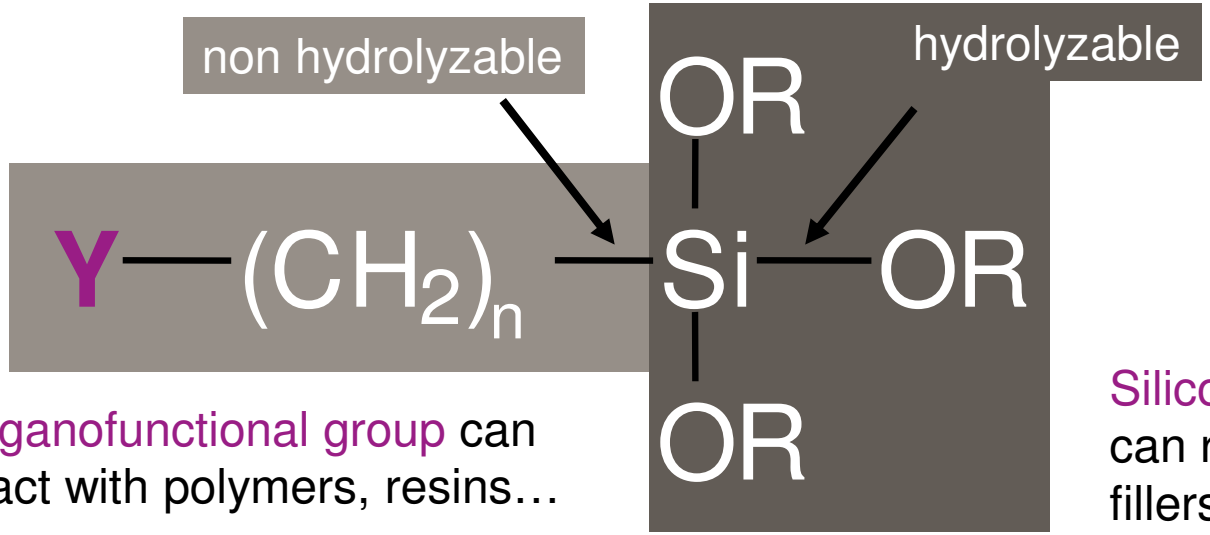
What are Organofunctional Silanes? Bifunctional Molecules!

$Y—(CH_2)_nSi(OR)_3$

n = 0, 3
R = CH_3, C_2H_5, $(CH_2)_2OCH_3$
Y = Organofunctional group



Organofunctional group can react with polymers, resins…

Silicon functional group can react with inorganic fillers, metals, glass…

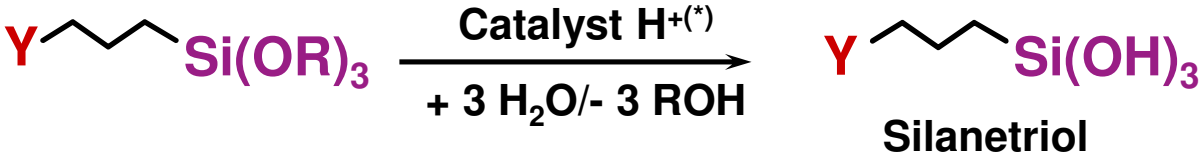
Silanes combine „the organic and inorganic world“ for adhesives, sealants and silicones !

Mode of action of organofunctional silanes

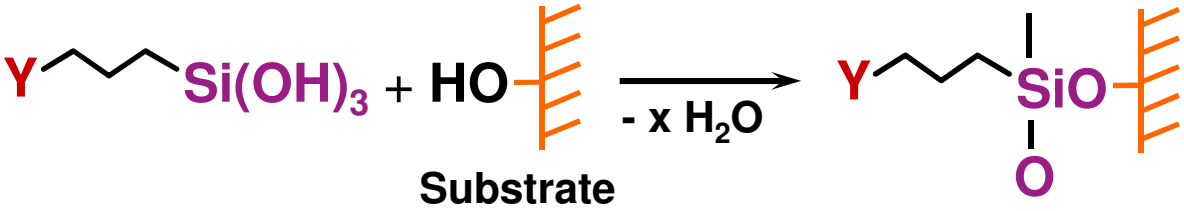
Silanes are used as: Primer 0.05 – 5 % in water or alcohol/water (pH = 3 - 5)

Additive 0.05 – 2 % without solvent

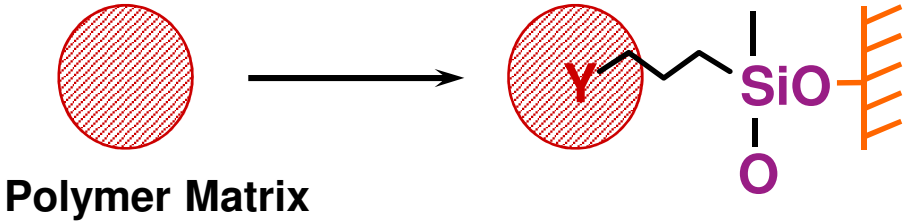
1. Stepwise hydrolysis



2. Bonding by condensation



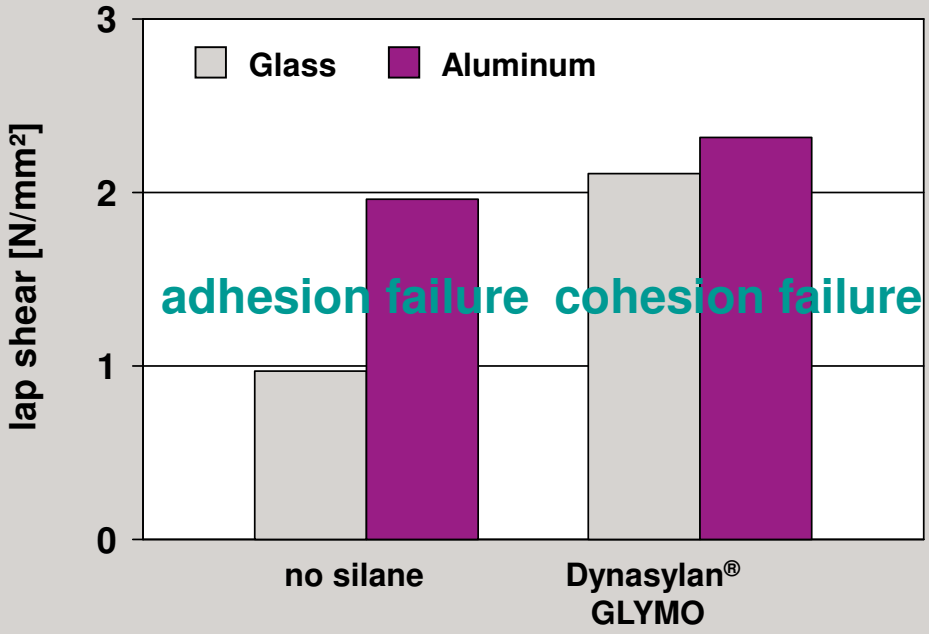
3. Filmforming and interaction with polymer matrix via Y

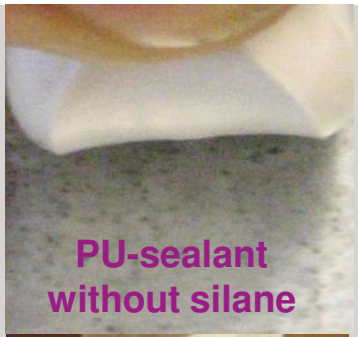


(*)exception: aminosilanes

Example for Efficient Adhesion Promotion

Lap shear of 1 comp. PU-sealants on aluminum and glass, with and without Dynasylan® Silanes





PU-sealant with Dynasylan® GLYMO

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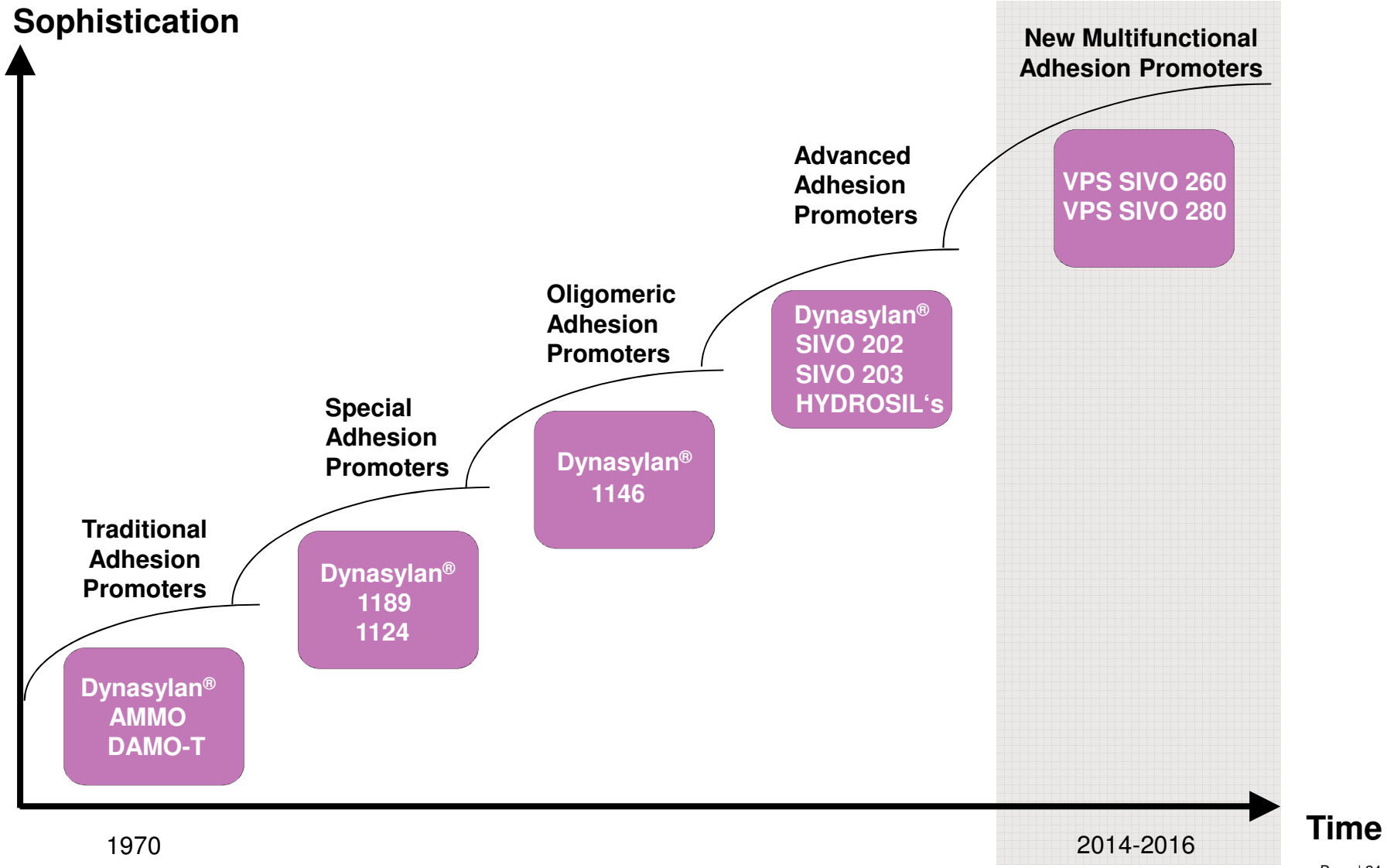
Five Generations of Functional Silane Adhesion Promoters Developed by Evonik



Dynasylan® 1146 is a Multifunctional Silane System™

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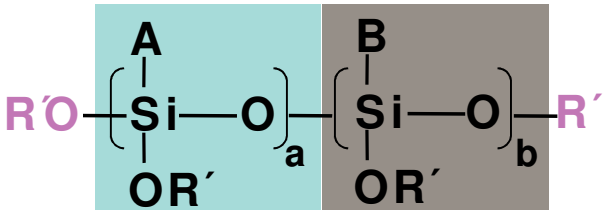
Two functions = One product

A + B



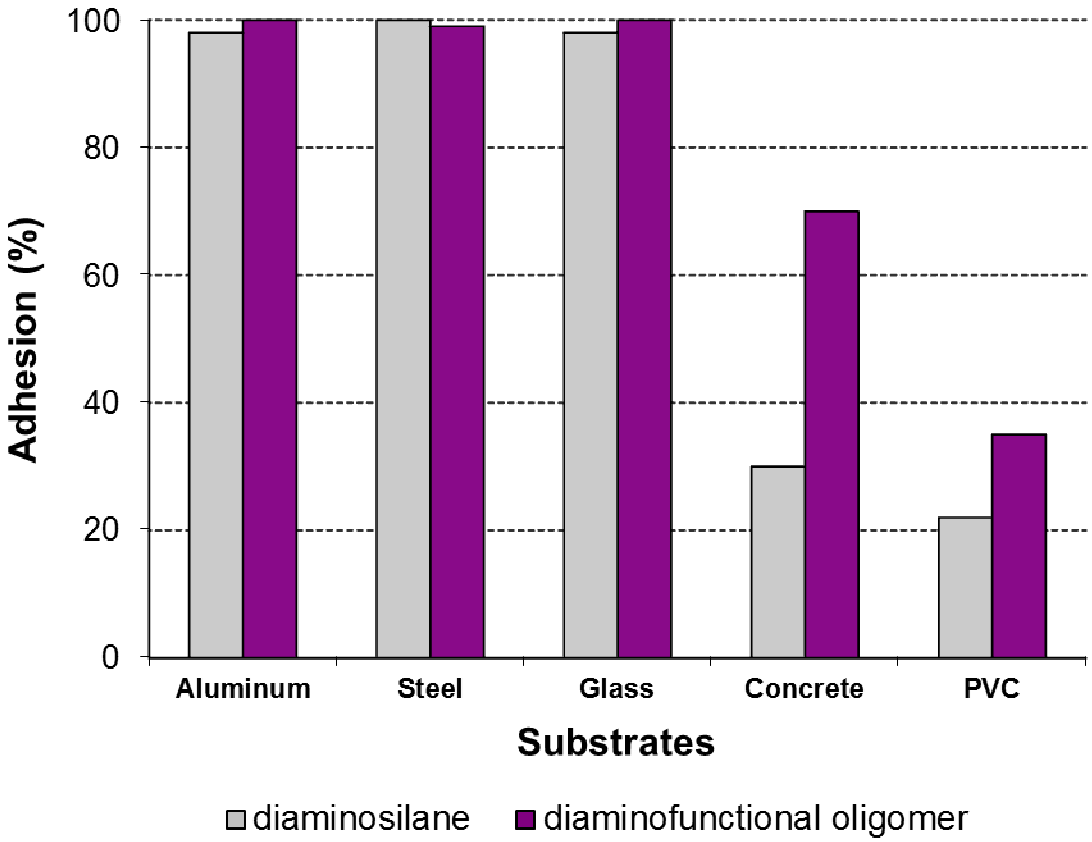
A, B = organofunctional groups
OR = methoxy or ethoxy

- Chemical multifunctionality within one product
- Storage stable, low viscous liquid, easy dosing
- Reduced VOC
- High flash point, no evaporation (enhanced product processability and safety)
- Better compatibility to polymers/resins
- One diffusion rate and one reactivity
- Improved film forming properties on fillers
- Excellent reactivity and surface modification
- Polymer by OECD definition

Key Benefits

1. Better performance & low VOC content
2. Multifunctionality („two in one“!)
3. Safer handling & less environmental impact
4. Low water uptake during storage

Dynasylan® 1146 influence on adhesion performance? Good !



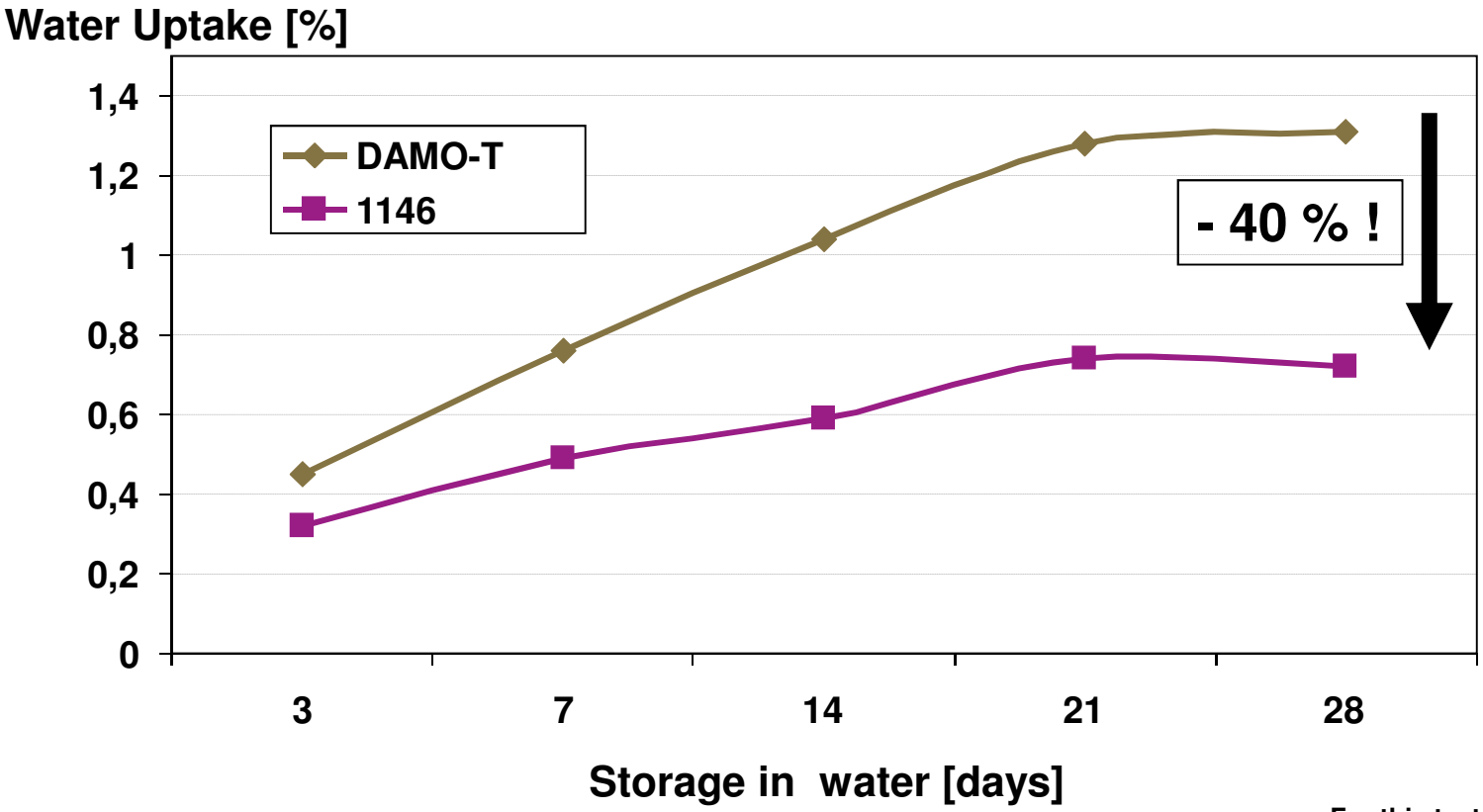
- Improved adhesion on critical substrates
- Significantly improved wet adhesion
- High performance adhesives & sealants can be formulated for critical substrates

For the adhesion test, it was applied, washed, rinsed surfaces and cured for 14 days - ambient conditions.

Dynasylan® DAMO-T

Dynasylan® 1146

Dynasylan® 1146 improves water resistance from a finally cured A&S



For this test, the hybrid sealant was stored in H_2O at 23ºC

Dynasylan® 1146 improves hydrophobicity, thus minimizes water uptake !

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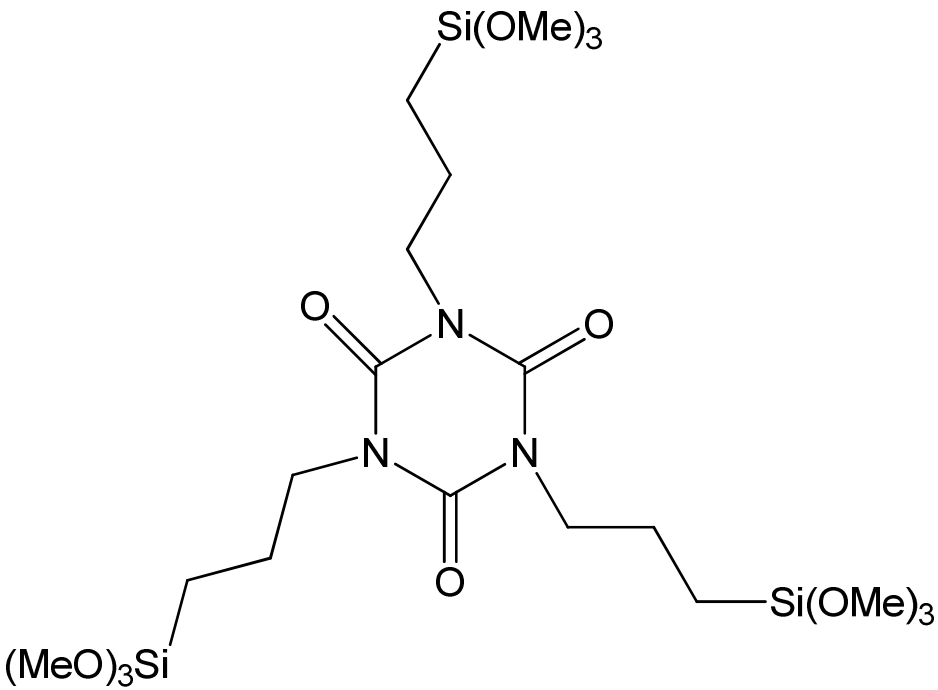
VPS 7163 = N,N,N-Tris (3-trimethoxy-silylpropyl) triisocyanurate



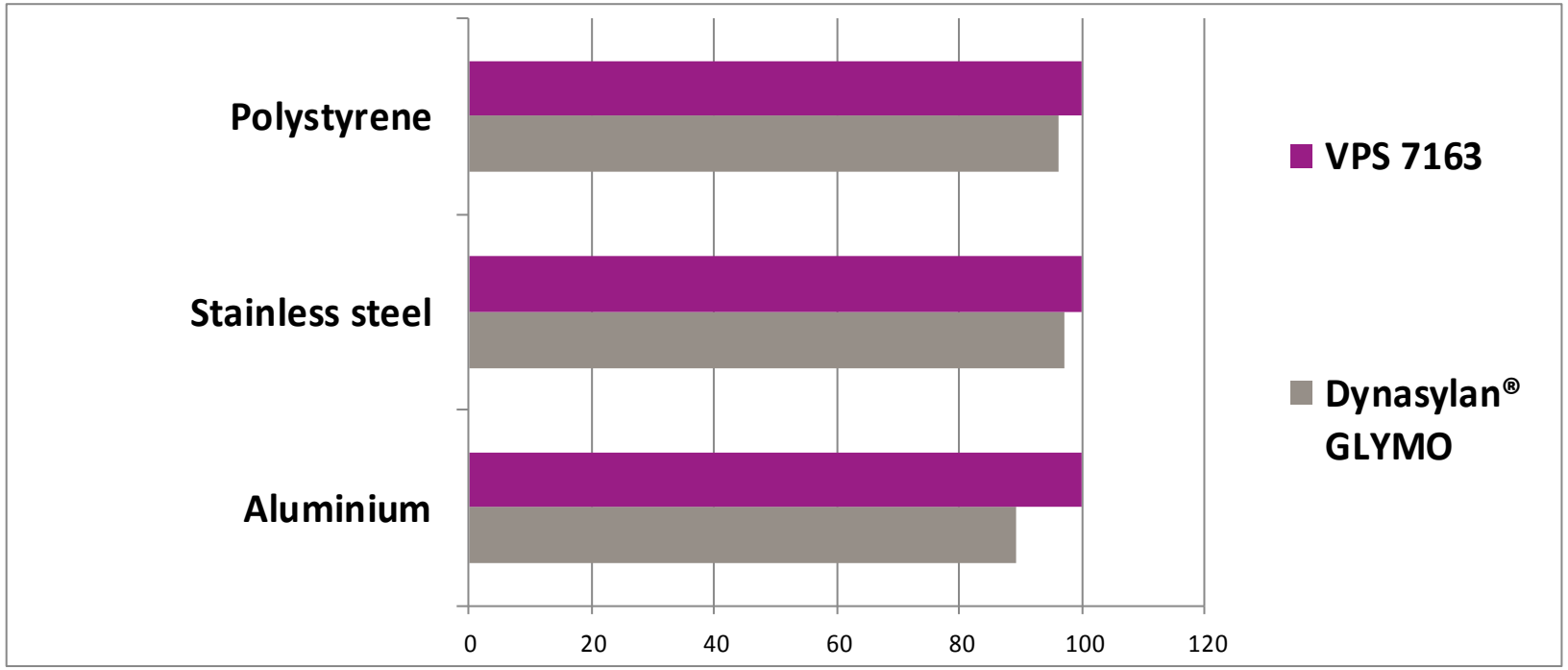
Performance / technical data

- Low volatility
- High thermal stability
- Good adhesion on metal, glass, plastics
- Good crosslinker
- colorless transparent liquid

Applications

- Primer for coatings, adhesives & sealants
- Adhesion promoter for PU & silicones
- Co-adhesion promoter for SMP
- Hotmelt adhesives (e.g. EVA, PA, PU …)
- Adhesion promoter in EP, ….

Improved Adhesion Performance in 2 Component Polyurethane Adhesive



Rel. Lap Shear Performance [%]

Silane addition:1 %

Improved adhesion performance of VPS 7163 in Polyurethane's !

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Benefits at a Glance

AEROSIL® R 208 showed an outstanding rheology in epoxy, polyurethane, SMP and other systems

AEROSIL® R 805, AEROSIL® R 812 S, AEROSIL® R 106 can be used in highly transparent adhesive and sealants

To illustrate Evonik's efforts for green solutions for silanes, significant less alcohol will be released upon moisture by using oligomeric silanes (low VOC)

The high efficient adhesion promoter Dynasylan® 1146 provide additional benefits in labeling, flexibility, joint curring and imparts excellent water shielding properties

VPS 7163 act as low volatile and heat resistant adhesion promoter and crosslinker with excellent adhesion properties on critical substrates in PU, silicone and other systems

EVONIK Contacts for Dynasylan® & AEROSIL® in Adhesives & Sealants

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