

Evonik Silane Technology for Composite Applications

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Smart Materials – Functional Silanes
Evonik Corporation



Agenda

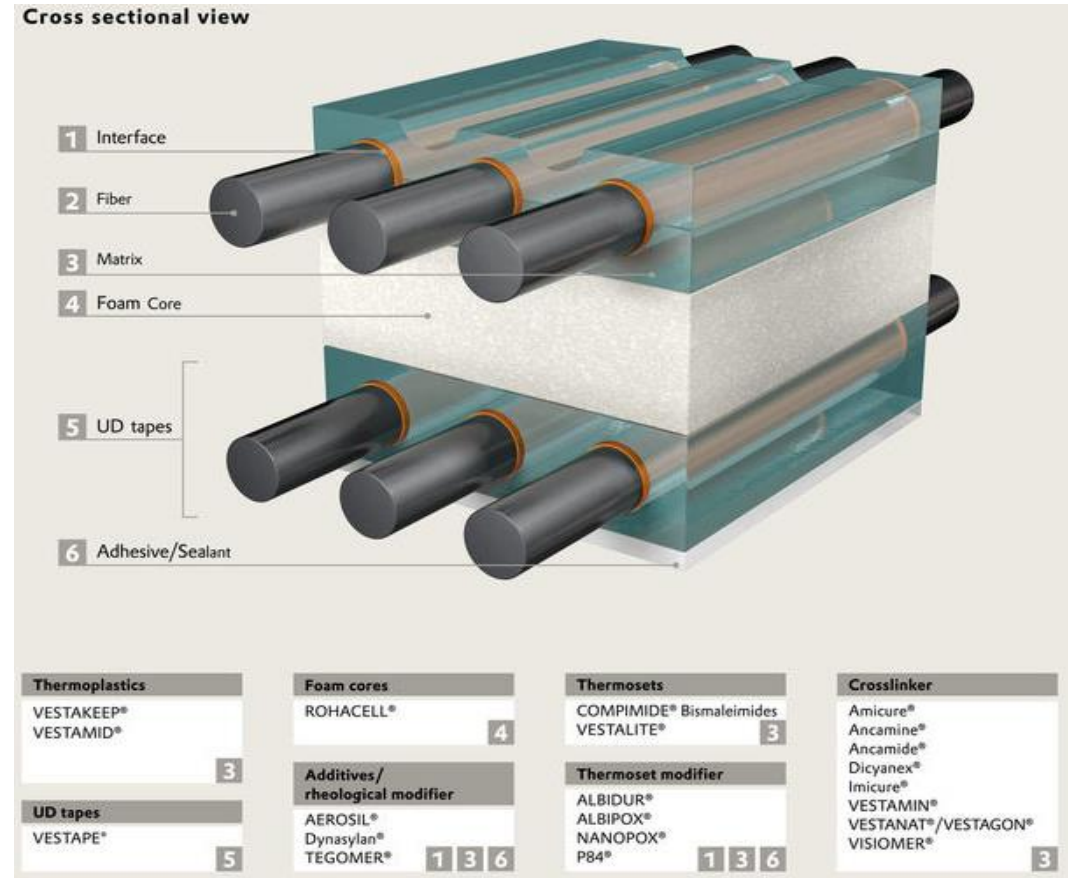
1. Evonik's Role in the Composites Industry
2. Silane Chemistry Introduction
3. Glass Fiber Production Process (Sizing)
4. Unique Aminosilane for Glass Fiber Sizing
5. Conclusion / Q&A



Evonik & the Composite Industry

Aerospace Automotive Construction Electronics Marine Medical Technology Oil & Gas Sports Wind Energy

- Additives/rheological modifiers
- Crosslinkers
- Foam cores
- Tapes
- Thermoplastics
- Resins for thermoplastic matrices
- Thermosets
- Thermoset modifiers



Benefits of Using Organofunctional Silanes in Glass Fiber Sizing Formulations

Increased Mechanical Strength



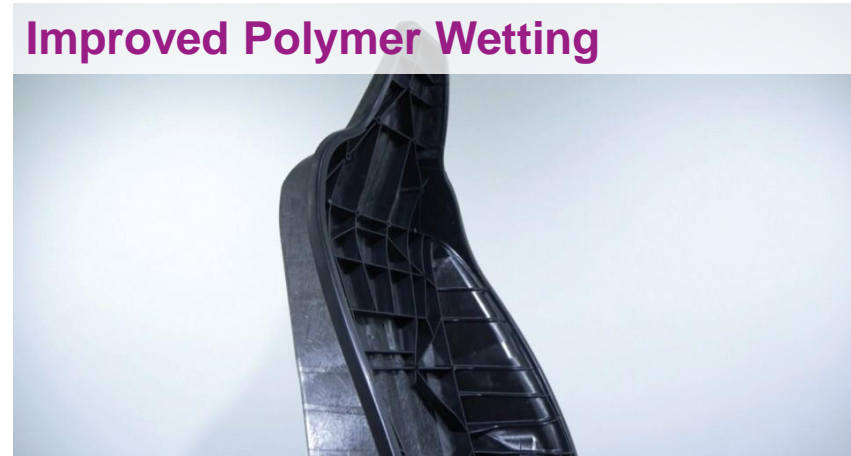
Easier Processing



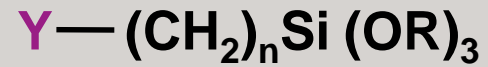
Enhanced Coupling to Polymer Matrix



Improved Polymer Wetting



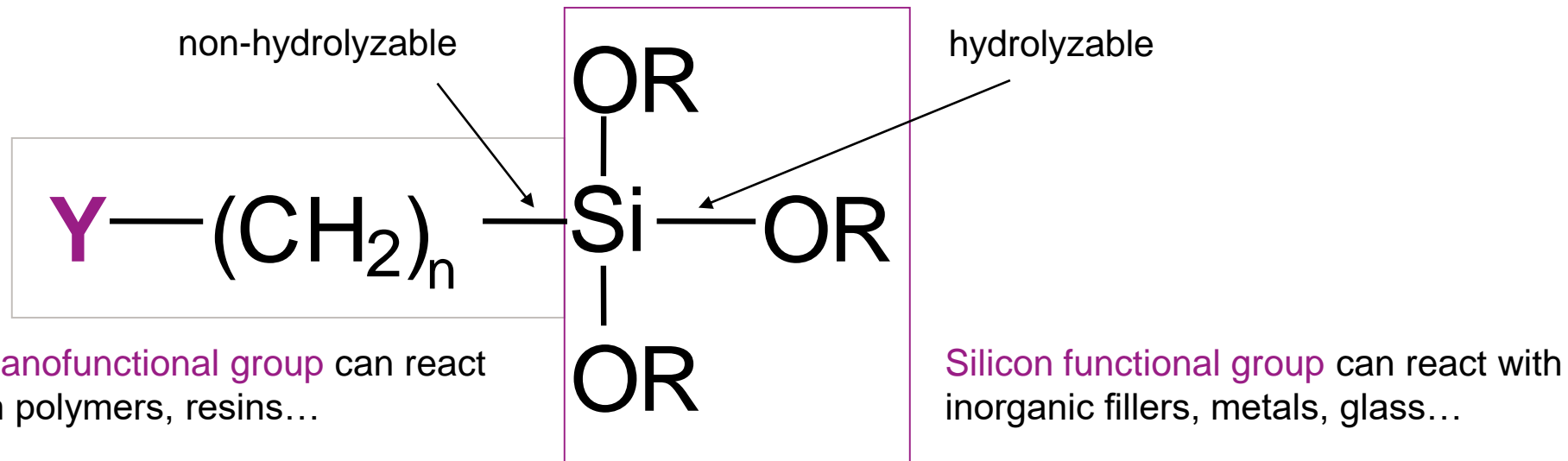
Organofunctional Silanes are Bifunctional Molecules



n = 0, 3

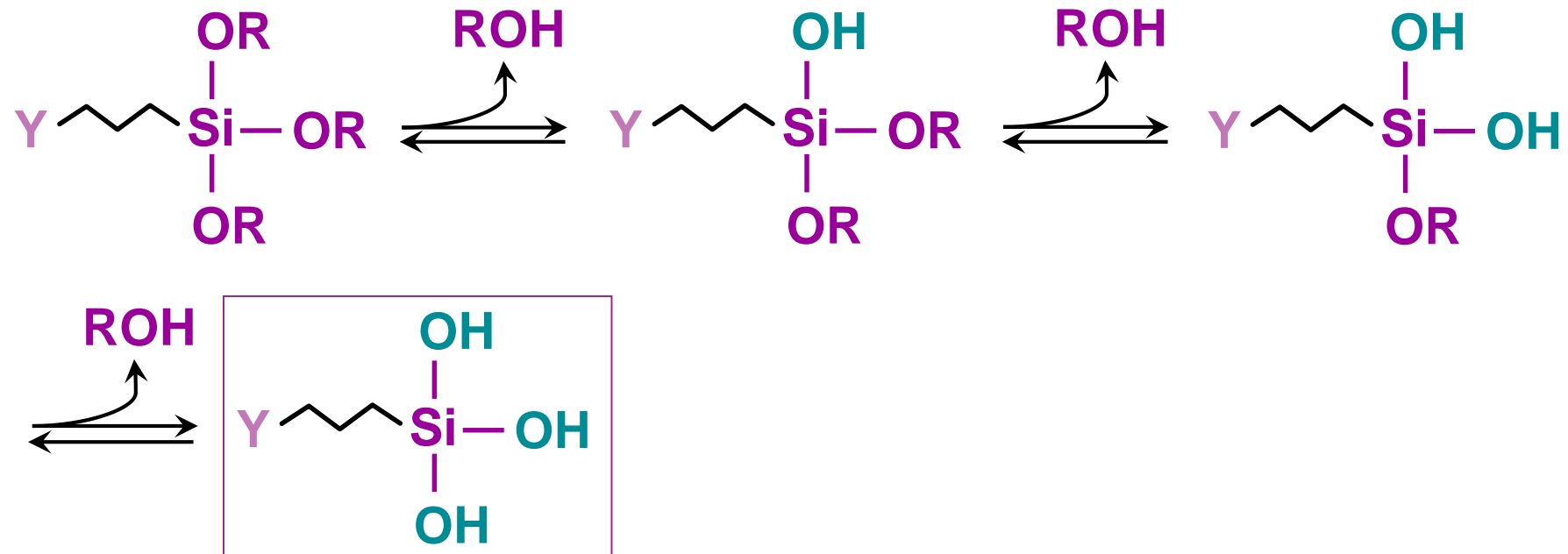
R = CH₃, C₂H₅, (CH₂)₂OCH₃

Y = Organofunctional group



Hydrolysis of Silanes

In the presence of excess water...

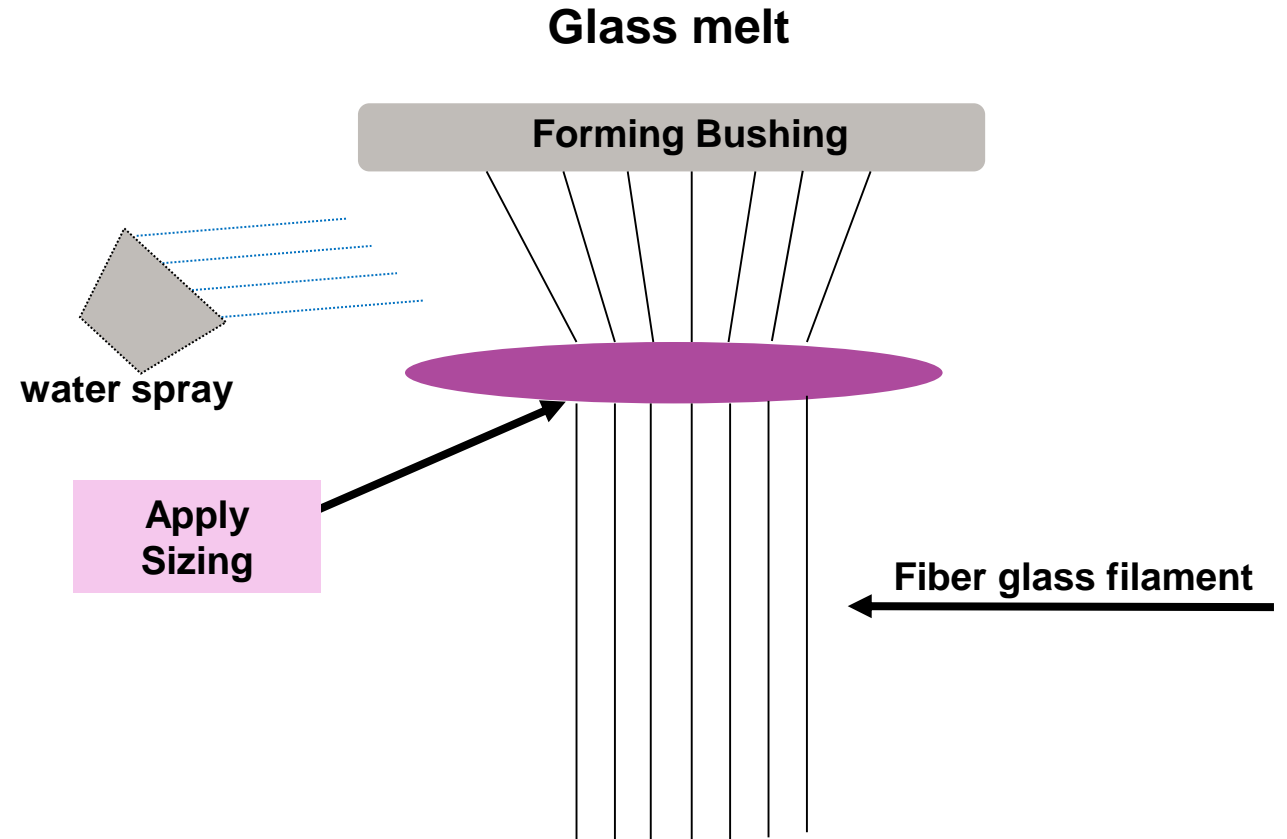


OR = "Silicon-functional" group | Y = "Organofunctional" group

Glass Fiber Manufacturing Process & Sizing

Effect of Silanes in Sizing

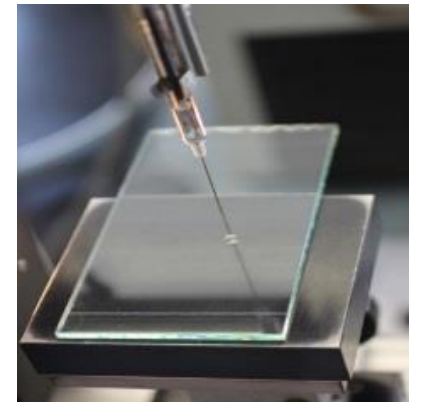
- Improvement of adhesion between glass fiber and organic resin
- Mechanical and chemical protection of the glass fiber (healing of micro cracks)
- Reduction of moisture sensitivity
- Improvement of properties (i.e. temp and electrical)
- Improvement of fiber processability like reduction of fiber break, less dust formation, better chopability



Optimization of Surface Properties on Glass Fibers

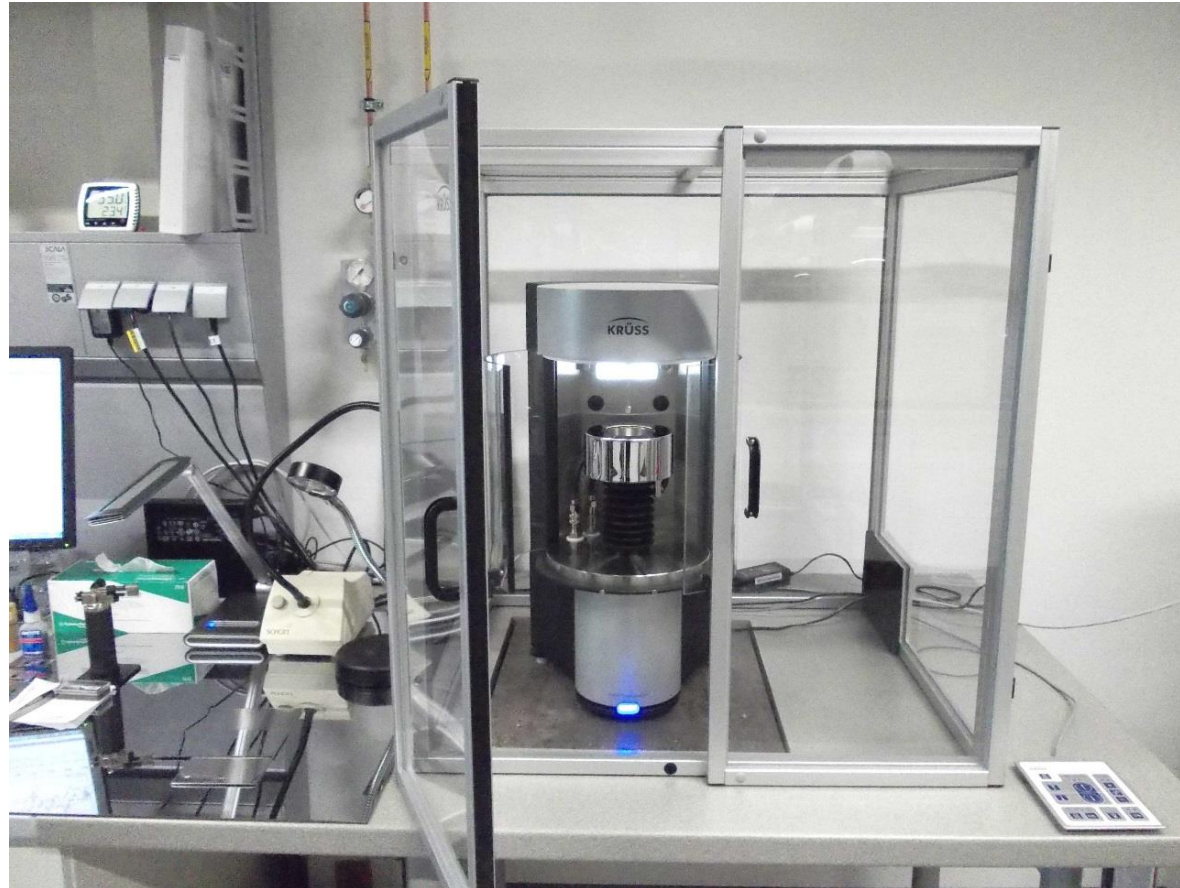
Evonik now has capabilities to perform droplet shape analysis and single fiber tensiometry

- Surface Homogeneity
- Fiber Surface energy
- Polarity content on glass fiber surface
- Surface properties of specific glass compositions
- Wetting properties of sizing formulations on glass & resins



Single Fiber Tensiometer K 100 SF

Used to measure the surface tension (liquid) and evaluate the free surface energy of glass fibers

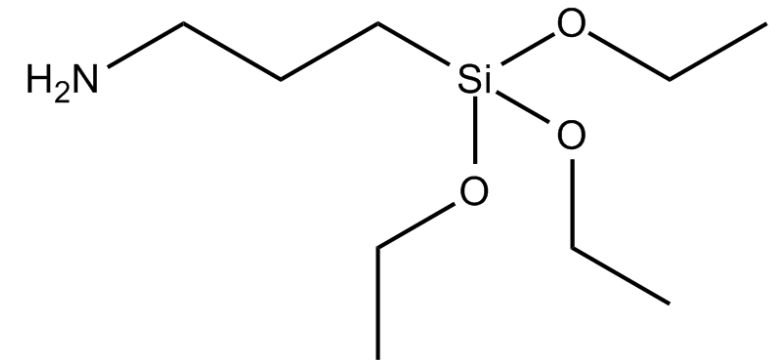


Development of New & Unique Aminosilane for Glass Fiber Reinforced Polypropylene Composites

Desired Properties

- Excellent wetting of the sizing to the glass fiber
- No additional wetting additives needed for the sizing formulation
- Improved wetting of the polymer to the unique silane-sized fiber

Unique Aminosilane = VPS 1208



**Aminopropyltriethoxysilane
(Dynasylan® AMEO)**

This aminosilane is commonly used in glass fiber sizings and will be compared against this new unique aminosilane

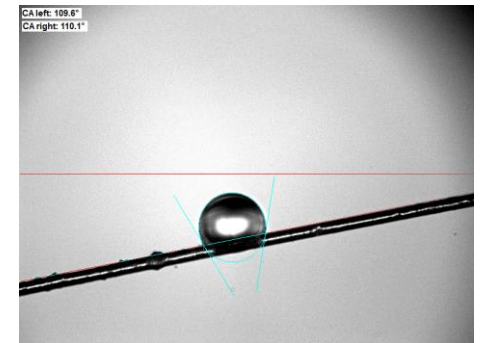
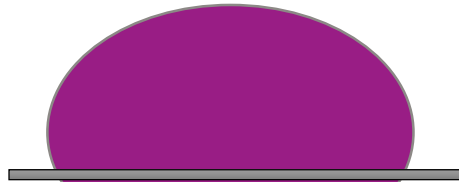
Achieving Excellent Surface Wetting through Surface Energy Analysis

Excellent surface wetting can be achieved if:
surface tension of the sizing < surface energy of the glass fiber

Surface tension of the sizing is << than the surface energy of the fiber



Surface tension of the sizing is >> than the surface energy of the fiber

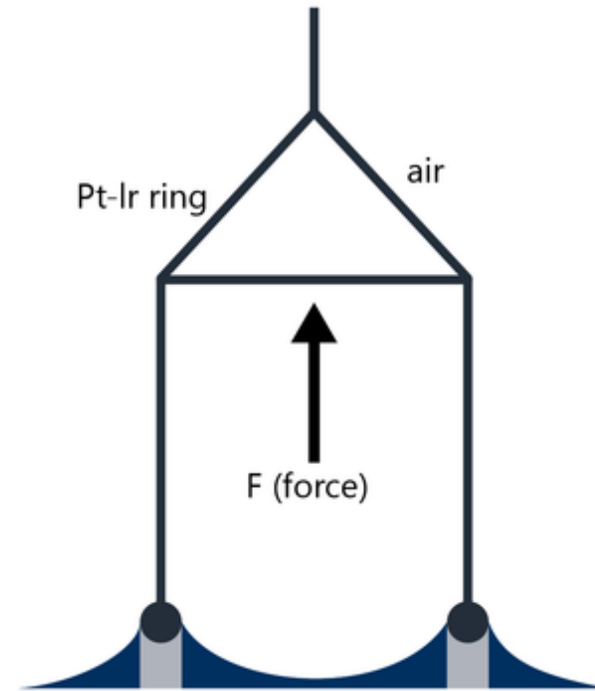


Surface Tension Measurement via Fiber Tensiometer – Du Noüy Ring Method

Principle of the method:

The measured force referred to the wetted length¹ acting on a ring as a result of the tension of the withdrawn liquid lamella when moving the ring from one phase to another.

¹The wetted length L of the ring is the sum of the inner and outer circumference

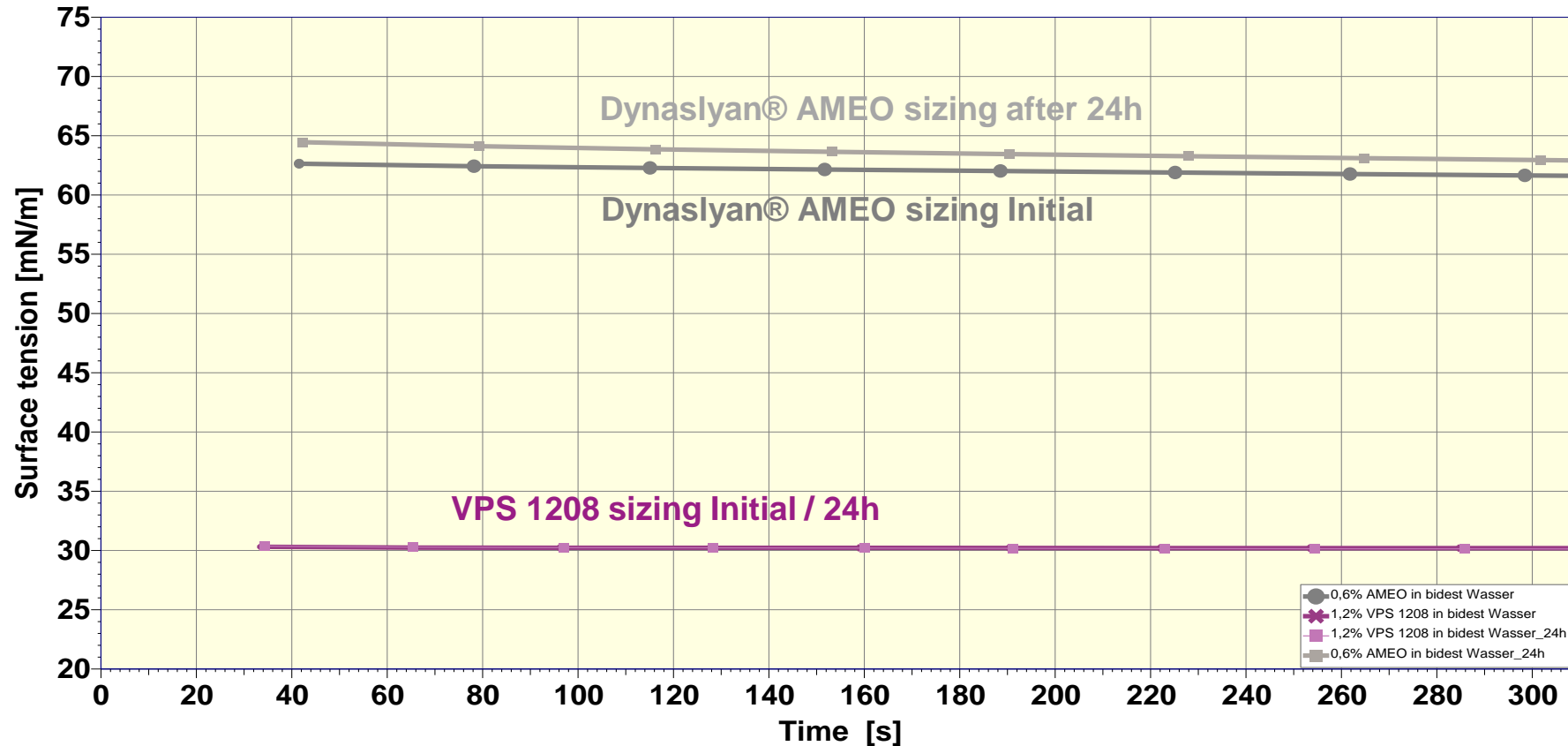


$$\sigma = \frac{F}{L \cdot \cos\theta}$$

Schematic diagram of the Du Noüy ring method

Surface Tension Comparison between VPS 1208 and Dynasylan® AMEO

Surface tension of VPS 1208 sizing is significantly better than Dynasylan® AMEO



All data generated with the single fiber tensiometer

Improved Wetting Properties of VPS 1208 Sizing Compared to Dynasylan® AMEO

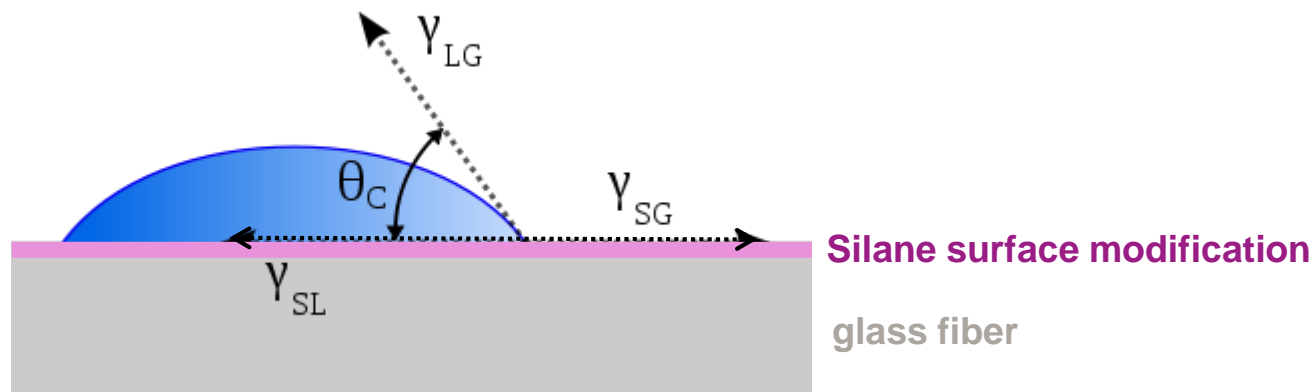
Surface tension of the VPS 1208 sizing is << than the surface energy of the fiber

	Surface tension [mN/m]	Free surface energy [mN/m]
E-Glass fiber unsized		48.3
VPS 1208 sizing	30.2	
Dynasylan® AMEO sizing	61.7	
Water	70.7	

All data generated with the single fiber tensiometer

Single Fiber Tensiometer for Free Energy Evaluation of the Glass Fiber Surface

- Contact angle measurement with **deionized water & diiodomethane**
- Calculation of the free surface energy based on Young's equation
- Contact angle depends on surface energy of the modified glass ...surface and the surface tension of the liquid.



YOUNG's equation:
$$\sigma_s = \sigma_{sl} + \sigma_l \cdot \cos(\theta)$$

- contact angle θ
- surface tension of the liquid σ_l
- interfacial tension σ_{sl} between liquid & solid
- surface free energy σ_s of the solid

Free Surface Energy Evaluation of an Unsized Glass Fiber

Contact angle measurement results with water and diiodomethane

	Contact angle [°]
water	55.1
diiodmethane	76.6



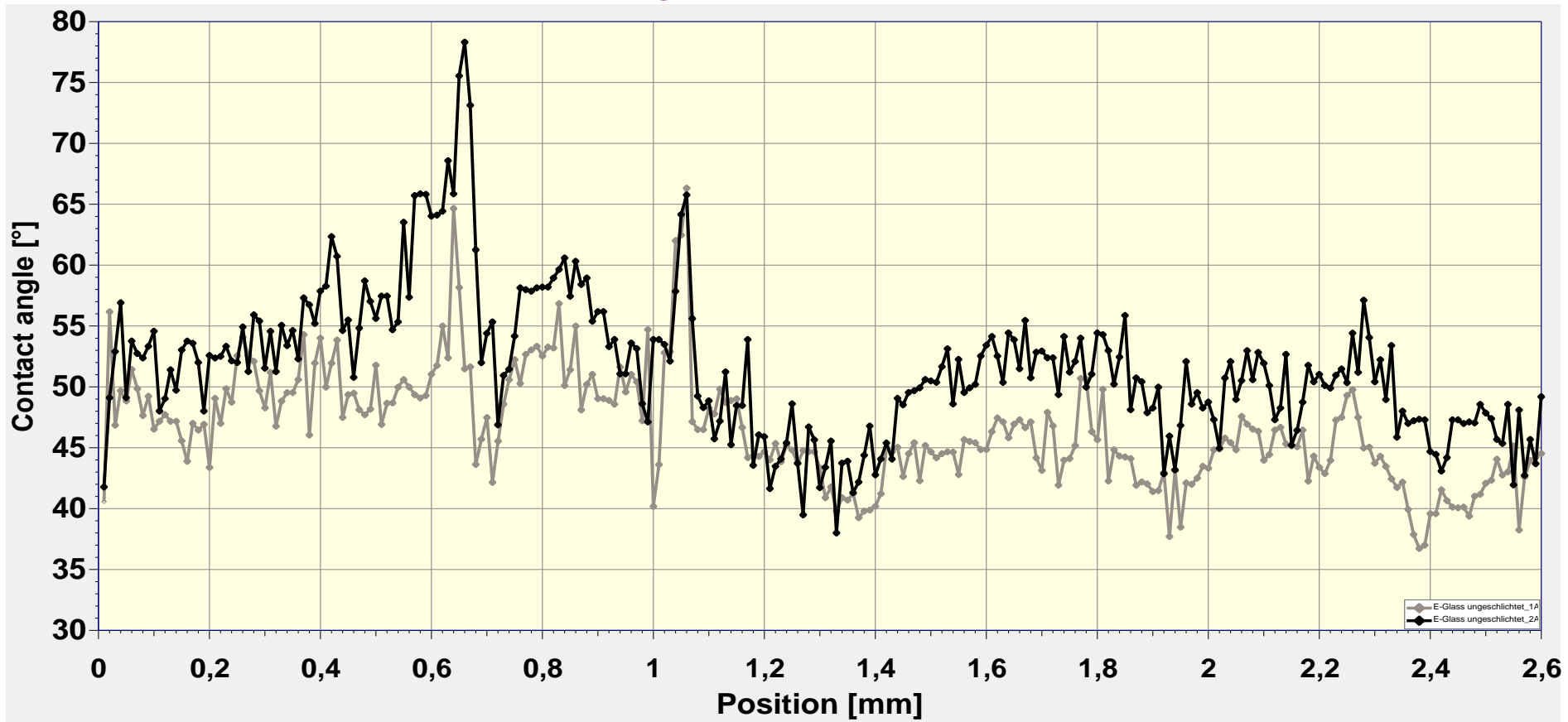
Free Surface energy [mN/m]	Polar [mN/m]	Dispers [mN/m]
48.3	43.8	4.5

All data generated with the single fiber tensiometer

Free Surface Energy Evaluation of an Unsized Glass Fiber

Variation in amplitude due to the microstructure on glass fiber surface

Contact angle measurement with water

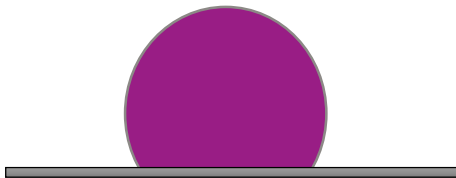


Improvement of Wetting Properties for Non-polar Polymer to Sized Glass Fiber

To achieve good surface wetting of non-polar polypropylene: reduce hydrophilicity of glass fiber surface



Hydrophobic surface with low polar content

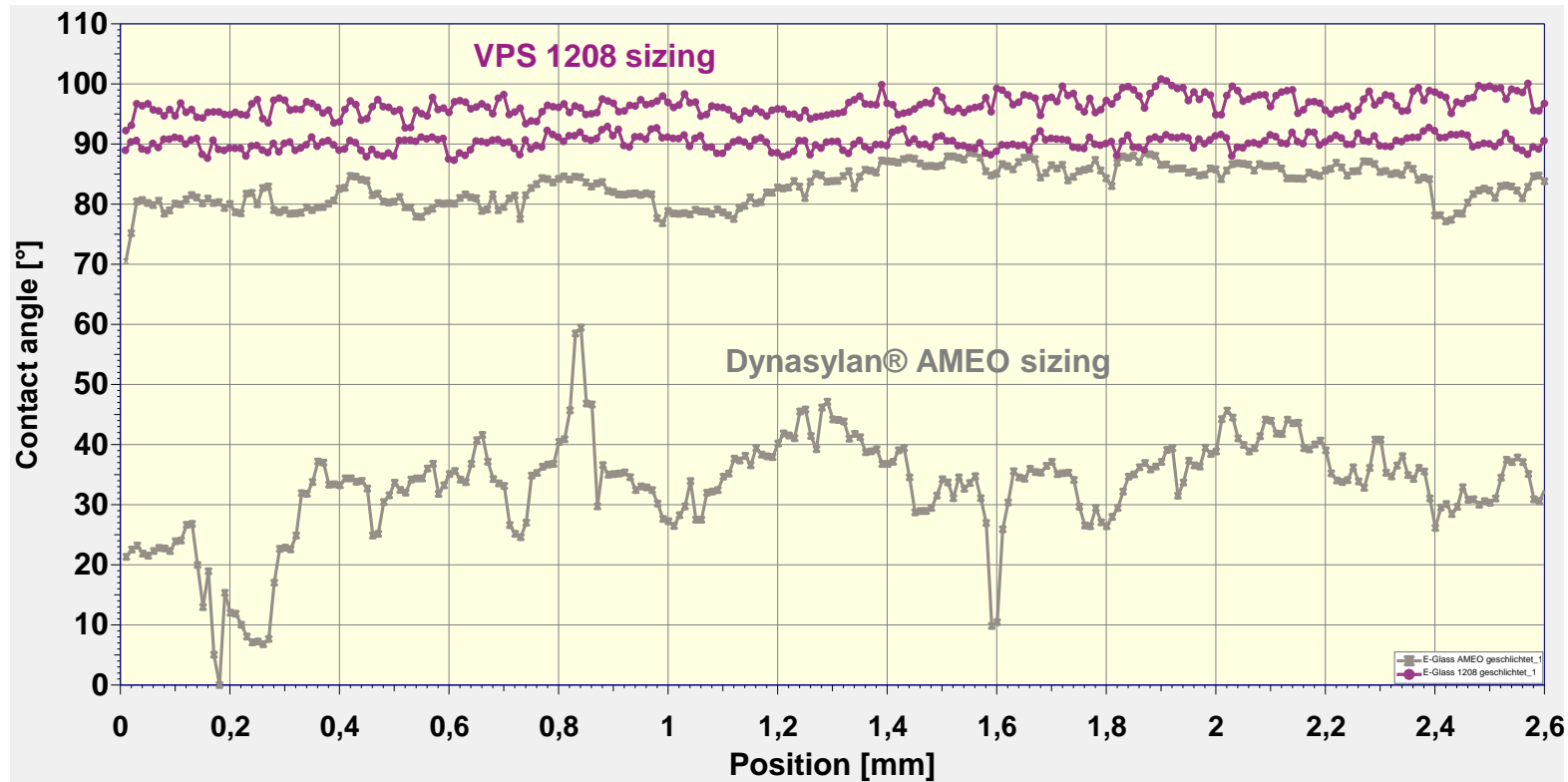


Hydrophilic surface with high polar content

VPS 1208-sized Glass Fiber Comparison to Dynasylan® AMEO-sized Glass Fiber

- **VPS 1208**-sized glass fiber measurements reveal smoother surface ...than Dynasylan® AMEO-sized glass fiber (less variation in amplitude)

Contact angle measurement with water



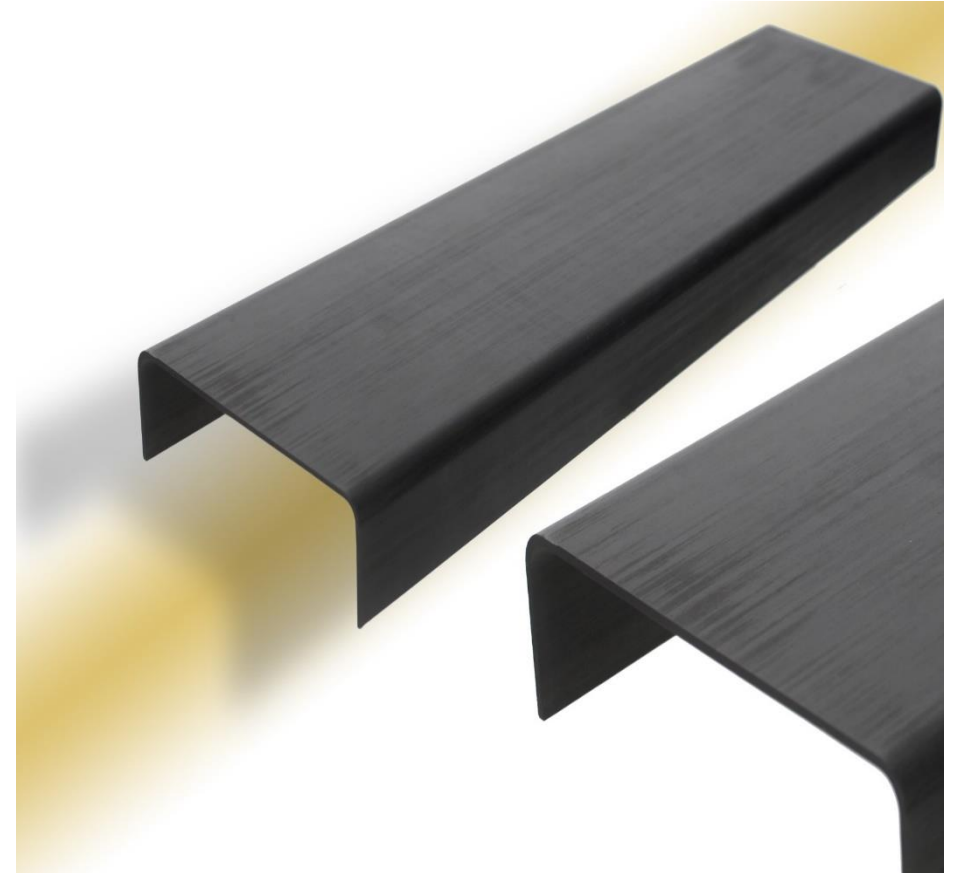
VPS 1208-sized Glass Fiber to Polypropylene Matrix (Wetting)

- Significant reduction of free surface energy with the VPS 1208-sized glass fiber
- Less polar content on the VPS 1208-sized glass fiber surface leads to ...improved wetting properties of the non-polar polypropylene polymer

Type of Glass Fiber	Polar content [mN/m]
Unsize Glass Fiber	43.8
Dynasylan® AMEO-sized Glass Fiber	14.9
VPS 1208-sized Glass Fiber	8.5
Polypropylene	0.0

Conclusions

- Unique aminosilane **VPS 1208** developed for polypropylene composite application
- Improved wetting of the sizing to the glass fiber
- No additional wetting additives for the sizing formulation
- Improved wetting of the polymer to the **VPS 1208**-sized fiber
- More homogenous fiber surface



For Further Assistance

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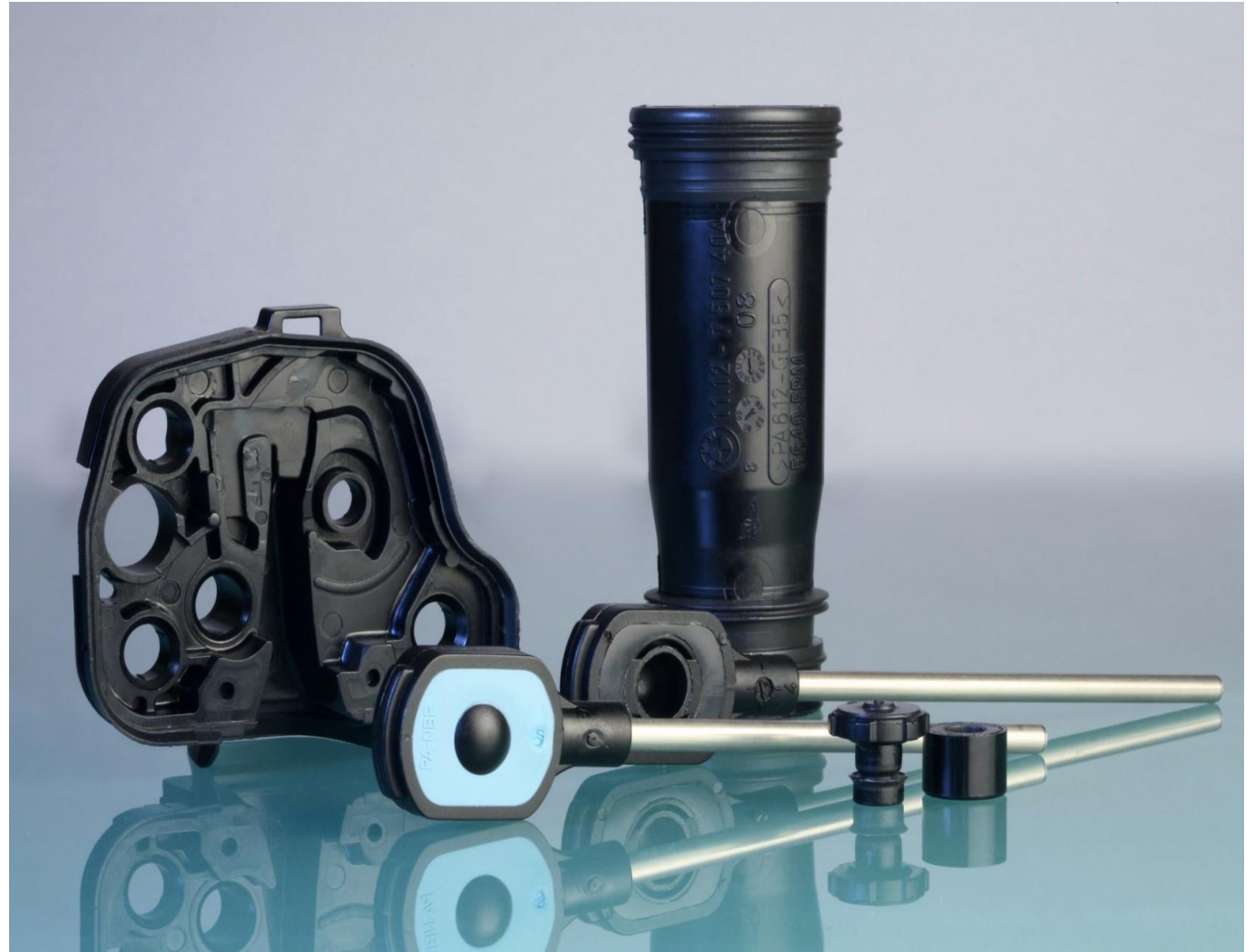
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