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Silica Nanoparticles with Functionalized Surface Chemistries for Improved UV Compatibility

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Topics Outline

- ❑ Utility of Silica Nanoparticles in Coating Systems
- ❑ Traditional Silica Use in Coating Systems
- ❑ Challenges of Silica Use in Coating Systems
- ❑ Monomer-specific Silica Nanoparticle Surface Treatment

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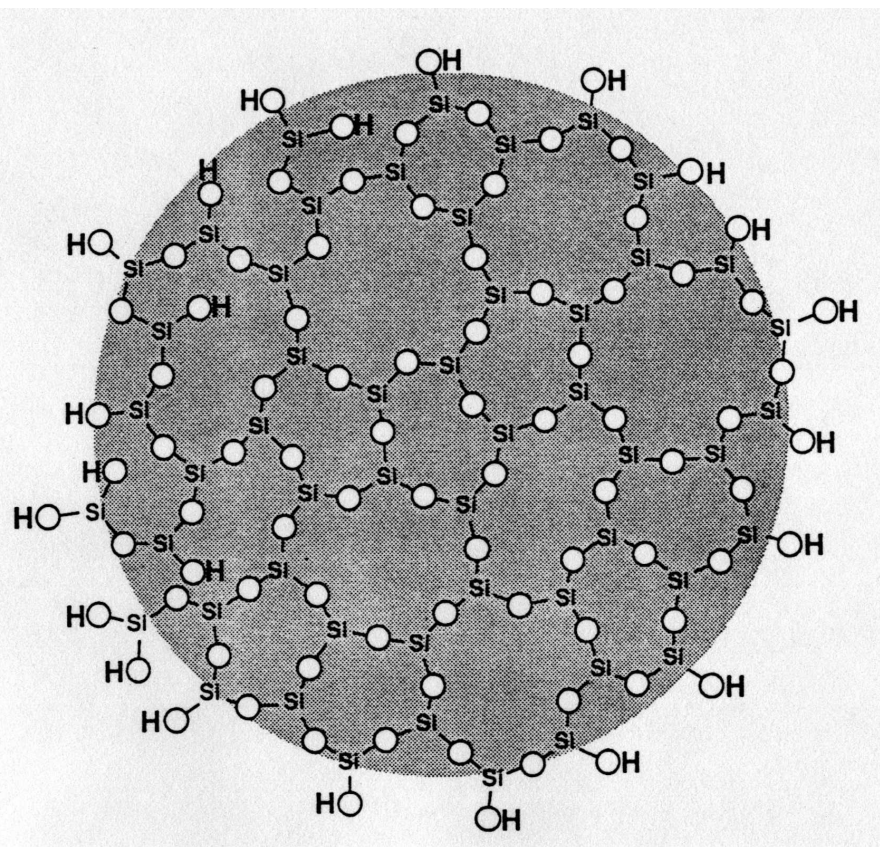
Usefulness of Silica Nanoparticles

What is a Silica Nanoparticle?

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What is a Silica Nanoparticle?

- ❑ Silicon dioxide (SiO_2)
- ❑ Generally spherical, but other shapes available
- ❑ Generally between 5 and 500 nanometers diameter
- ❑ Hydroxyl (OH) groups bonded to silicon atoms (silanols) dominate surface chemistry
- ❑ Anionic, negative zeta potential



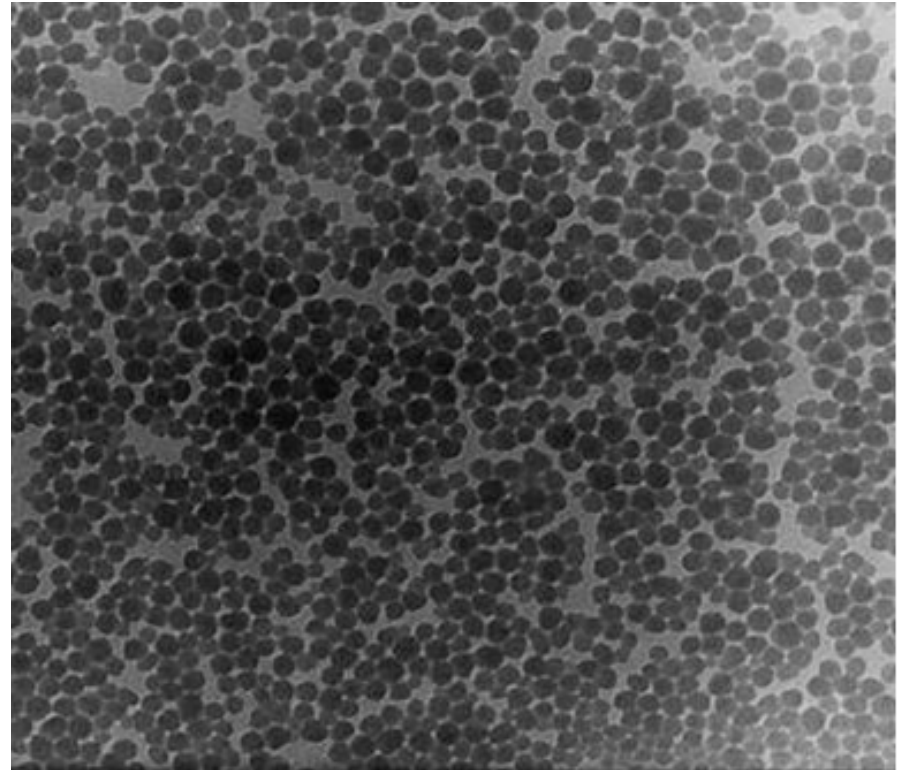


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Types of Commercial Silica Nanoparticles

- ❑ Powders of fumed or precipitated silica, or slurries from powders
- ❑ Aqueous solutions
- ❑ Organic solvent dispersions
- ❑ Monomer dispersions
- ❑ Additive dispersions



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Properties of Silica Sols

Property
of silica

Insulating

Low dielectric loss

Refractive Index 1.45 \Rightarrow Close to resin (1.5~1.6)

Low thermal expansion

High heat resistance

High hardness

Function
of sol

Higher dispersibility \Rightarrow Lower viscosity

Smaller particle \Rightarrow Higher transparency

SiOH
group
on
surface

Cross-link site, Reactivity

Bonding with Resin, Adhesion with Resin

Hydrophilicity, Moisture Absorbency

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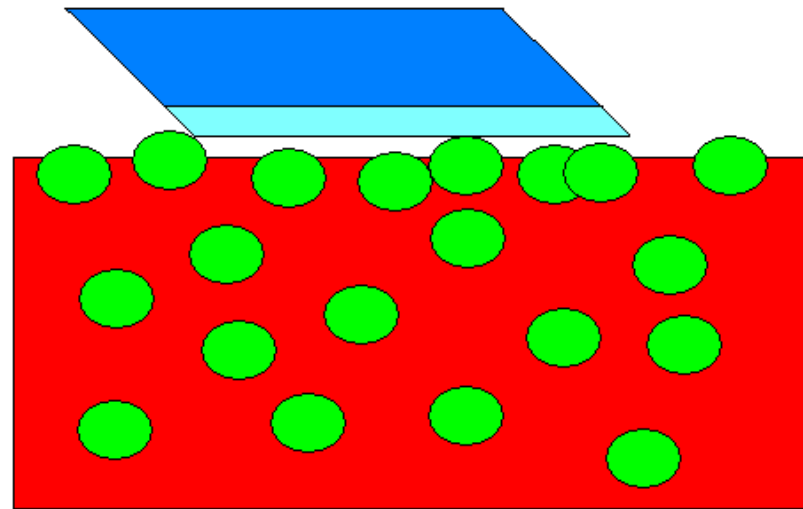


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Functionality of Silica Nanoparticles

- Scratch, Mar, and Abrasion Resistance
- Physical Property Modification
- Optical Transparency
- Colorless
- Nanocomposite Applications
- Others

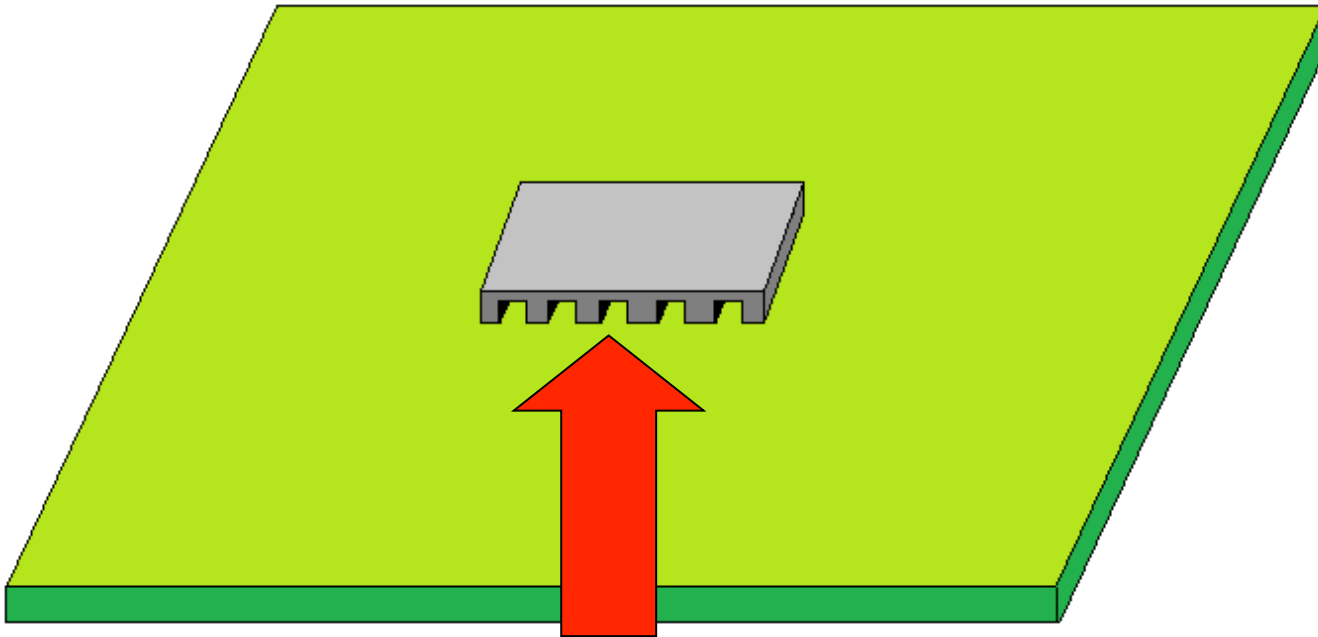


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Silica in Epoxy

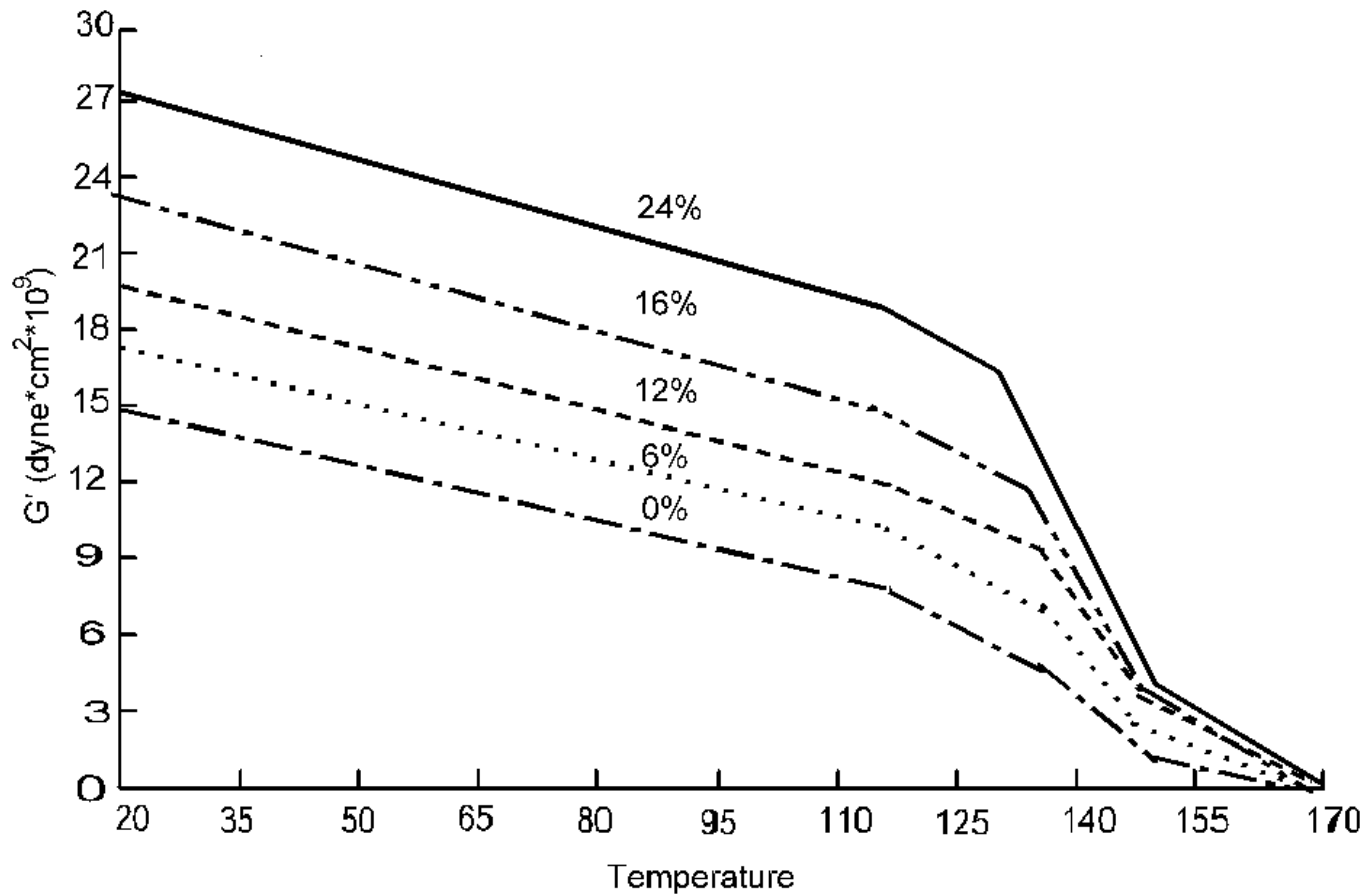


Silica Nanoparticles are used in underfill adhesive for flip chips

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Silica in Epoxy



Relationship between silica content (percent by volume) and modulus with temperature in epoxy

Source: Husman, J. (2004, April 15). *Nanomaterials at 3M: Coupling Nanotechnology to Business Opportunities*. Presentation at PennState Materials Day, University Park, PA

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Traditional Colloidal Silica Uses

- Silica sol (silica dispersed in organic solvent) mixed into resin for increased functionality
- Binder for Catalyst Substrates
- Polishing Slurries, CMP additive
- Adhesives
- Precision Investment Casting
- Inkjet
- Architectural Coatings
- Films/Foils
- Anti-Blocking for Plastics

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Common Difficulties

- ❑ Silica dispersion - Solvent issues
- ❑ Coating properties affected
- ❑ Silica-Resin incompatibility
- ❑ pH-related issues for Matrix or Sol

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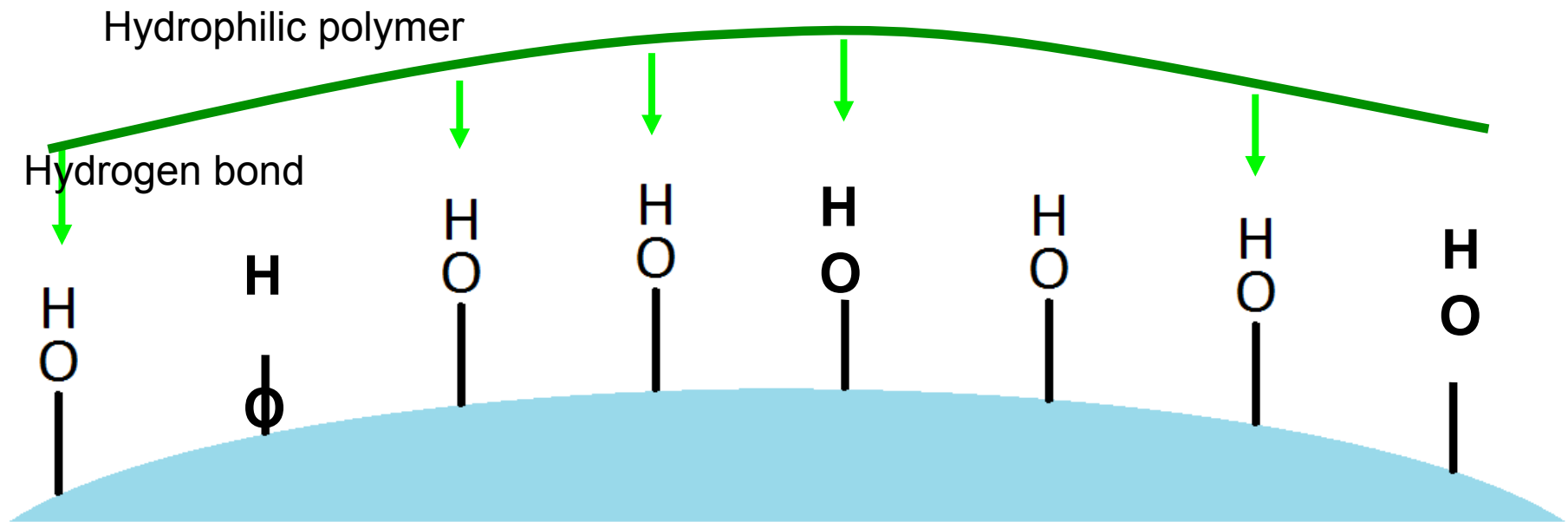
Monomer-specific Silica Nanoparticle Treatment

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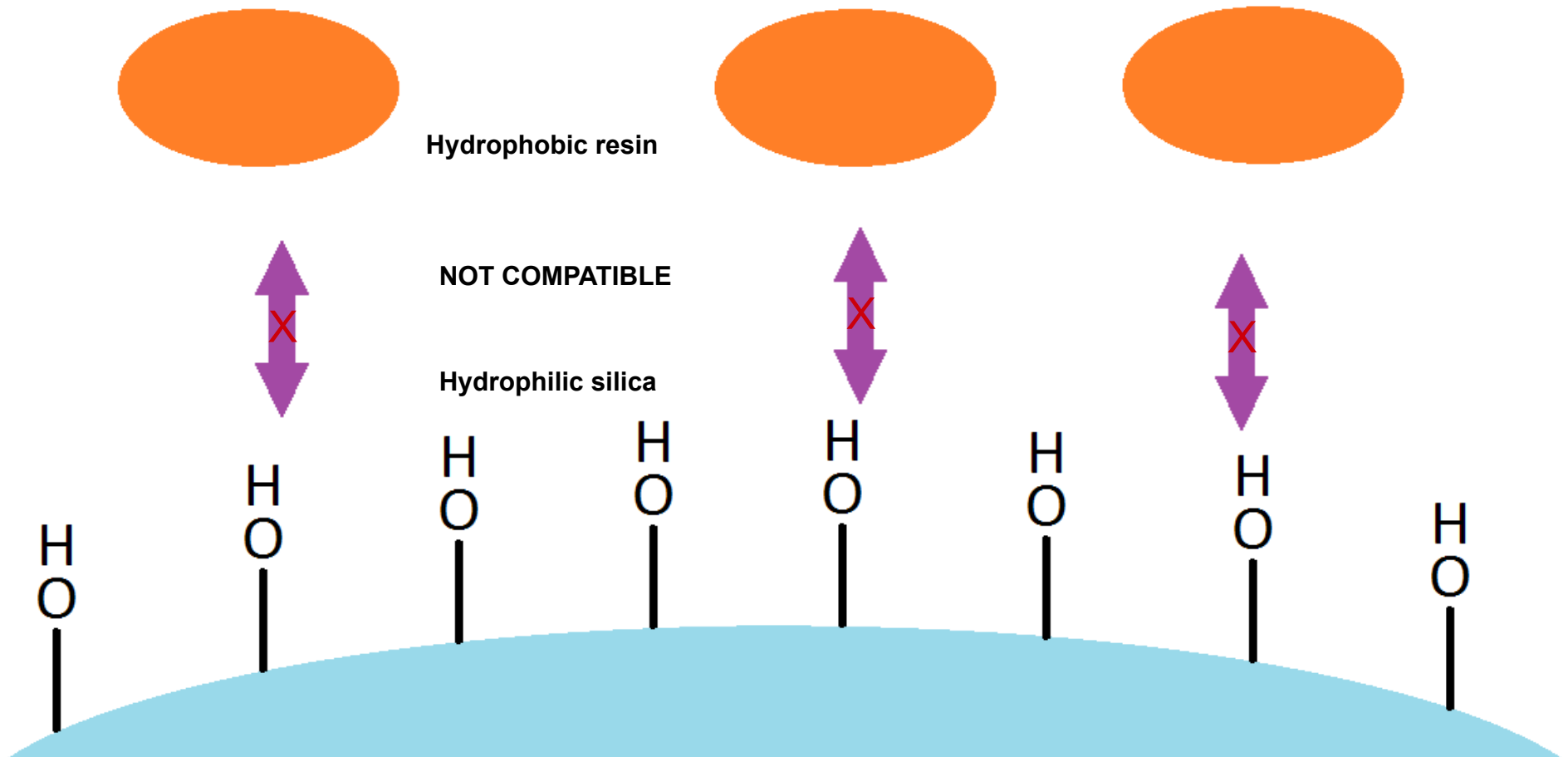
Untreated Silica



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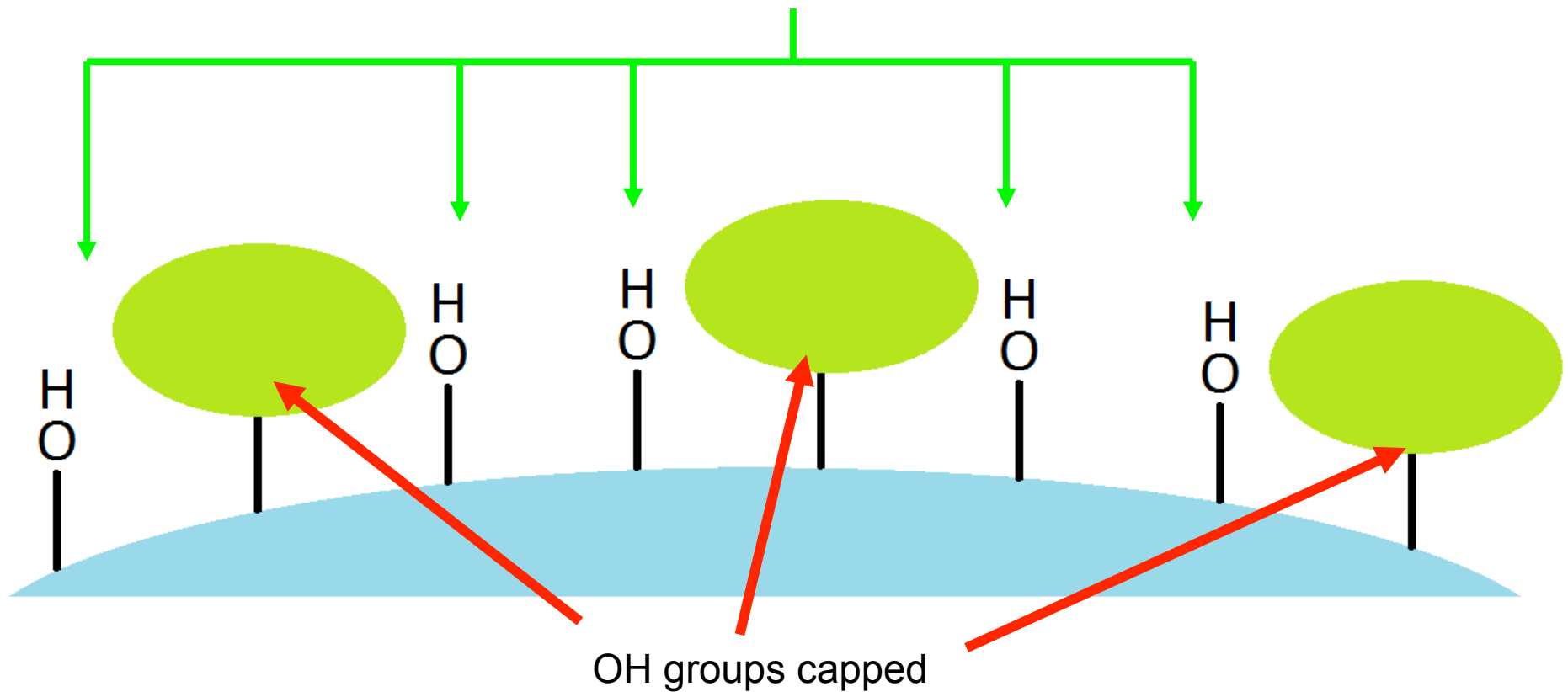
Untreated Silica





Treated Silica

Adjacent OH groups sterically hindered

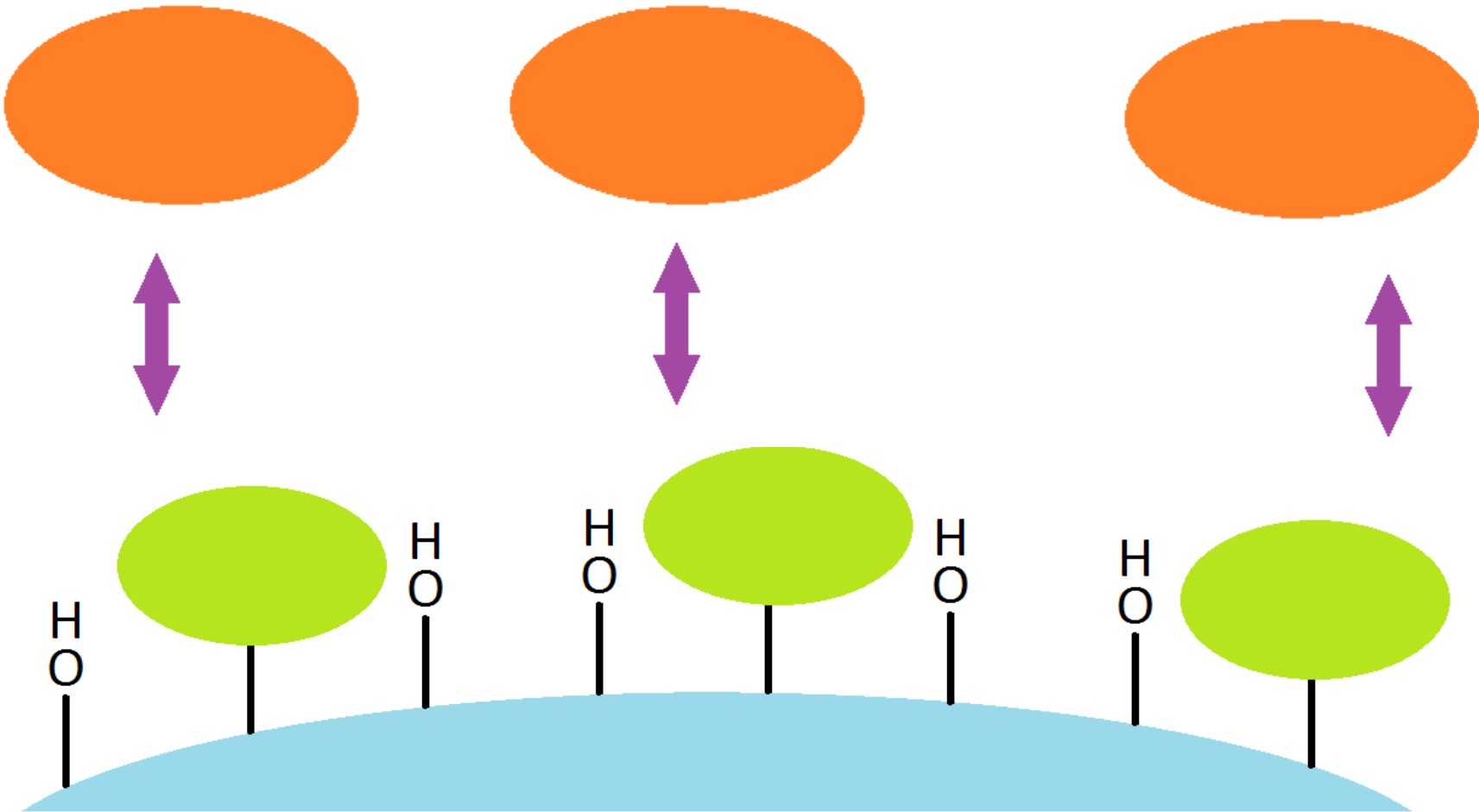




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Resin-Silica Compatibility



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New Monomer-Specific Products

MEK-AC

- ❑ 30% or 40% silica in methyl ethyl ketone
- ❑ 10-15, 40-50, 70-100 nanometer diameter choices
- ❑ Treated with silane coupling agent with acrylate-compatible functionality
- ❑ Compatibility with most acrylates/methacrylates
- ❑ May enhance scratch and mar resistance above conventional silica

MEK-EC

- ❑ 30% silica in methyl ethyl ketone
- ❑ 10-15 nanometer diameter
- ❑ Compatibility with epoxies

MIBK-SD and SD-L

- ❑ 30% silica in methyl isobutyl ketone
- ❑ 10-15, 40-50 nanometer diameter choices

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Ketone grades

Grades	MEK-ST	MEK-ST -L	MEK-ST -ZL	MEK-ST -UP	MEK-EC -2102	MEK-EC -2104	MEK-AC -2202	MEK-AC -4101	MEK-AC -5101	MIBK-ST	MIBK-SD	MIBK-SD -L
Solvent	Methyl Ethyl Ketone									Methyl Isobutyl Ketone		
SiO ₂ (%)	30	30	30	20	30	30	40	30	30	30	30	30
Particle size(nm)	10 -15	40 -50	70 -100	9 -15 (chain)	10 -15	10 -15	10 -15	40 -50	70 -100	10 -15	10 -15	40 -50



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MEK-AC, MEK-EC Grades MIBK Grades

Surface modified Grades

Grade	MEK- EC-2102	MEK- EC-2104	MEK- AC-2202	MEK- AC-4101	MEK- AC-5101	MIBK-SD	MIBK-SD- L
Dispersant	Methyl Ethyl Ketone	Methyl Ethyl Ketone	Methyl Ethyl Ketone	Methyl Ethyl Ketone	Methyl Ethyl Ketone	Methyl Isobutyl Ketone	Methyl Isobutyl Ketone
SiO ₂ (%)	30	30	40	30	30	30	30
Particle size (nm) [BET]	10 - 15	10 - 15	10 - 15	40 - 50	70 - 100	10 - 15	40 - 50
Compatibility	Epoxy resins		Epoxy resins, Acrylic resins			Acrylic resins	



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Surface-treated Silica Performance: ST vs EC

Sample		A	B
Epoxy Type	Bisphenol-A Diglycidyl Ether JER 828 (Mitsubishi)	Incompatible	Compatible
	Hydrogenated Bisphenol-A Diglycidyl Ether YX-8000 (Mitsubishi)	Incompatible	Compatible
	Alicyclic Epoxide CE 2021P (Daicel)	Incompatible	Compatible

A: Silica dispersed in methyl ethyl ketone (30% SiO₂ by weight) with standard silica surface treatment for compatibility with MEK

B: Silica dispersed in methyl ethyl ketone (30% SiO₂ by weight) with silica specially surface-treated for compatibility with epoxy resins (MEK-EC Grade)

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Thank You!

Questions?

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