Nanogel™ - Cabot’s Aerogel Technology
Cabot’s Core Businesses

**Carbon Black**
- 25% global share

**Major Competitors**
- Degussa
- Columbian

**Fumed Metal Oxides**
- 35% global share

**Major Competitors**
- Degussa
- Wacker

**Performance Materials**
- Ta, Nb, Barium Titanate,
  - Cesium formate

**Major Competitors**
- HC Starck (Bayer AG)
- Ningxia (China)
Carbon Black Aggregates
Carbon Black Division

Carbon Black

• Company founded on technology
• World largest supplier
• Flame based particle formation
• Surface Modified Grades also available

Primarily used as reinforcing filler

• Tire
• Elastomer composites
• Plastics, Pipe
• Printing Inks, Coatings
Fumed Silica Aggregates

Thermal conductivity: 12 to 16 mW/m·K
Light transmission: 20 to 80% at 2 cm
Particle density: 140 kg/m³
Bulk Density: 40-100 kg/ m³
Surface area: 700 m²/g
Porosity: > 90%
Particle size: 5µ - 5 mm
Surface Chemistry hydrophobic
Fumed Metal Oxides Division

Fumed Silica, Alumina, Titania, and Ceria

• 45 year old division
• World second biggest supplier
• Flame based particle formation
• Surface Modified Grades also available

Primary use as rheological additive

• Silicone/Sealant Reinforcement
• Chemical Mechanical Planarization (CMP)
• Adhesives & Coatings
• Toners and pharmaceuticals
Xerogels: Rigid and Porous Silica

A solution of silica (waterglass) is precipitated to form silica particles (the sol), flocculated into open network (the hydrogel), and dried (the xerogel).

Waterglass  Sol  Hydrogel  Xerogel

Xerogels crosslink on drying.
Why hydrogels compact when dried:

- Capillary forces compress the gel (surface tension and pore size).
- Free -[OH] groups cement the shrunken gel together.
The Drying Process
Brief History of Aerogels

**Discovery**
- 1930’s: Kistler discovers supercritical process
- Carbon dioxide: 50 C and 1500 psi
- Alcohol: 270 C and 1500 psi
- Since then over 1500 Aerogel patents have been awarded

**Prior Commercialization efforts**
- **Monsanto (Santocel) 1950’s through mid-1970’s**
  Failed due to high cost/safety issues of supercritical process
- **BASF, Armstrong, Airglass and Thermolux 1980’s - 1990’s:**
  Failed due to high cost of supercritical process
Supercritical Process:

Waterglass → Sol → Hydrogel → Supercritical Extraction → Aerogel
Why supercritical drying works:

• At the critical temperature and pressure, there is no boundary between gas and liquid.

• Without any interfacial tension, no compressive forces pull the walls together.
Typical Aerogel Properties

- **Surface chemistry:** hydrophobic
- **Particle size:** 5 µm to 5 mm
- **Particle shape:** round or granular
- **Particle density:** ≈140 kg/m³
- **Bulk density:**
  - ≈100 kg/m³ (5 mm)
  - ≈30 kg/m³ (5 µm)
- **Surface area:** 600 to 800 m²/g
- **Porosity:** > 90%
- **Thermal conductivity:** 0.018 W/(m K)
- **Refractive index:** ≈1.04
- **pH:** ≈5
- **Speed of Sound:**
  - 100 m/s versus
  - 340 m/s in air
Thermal and Acoustic Insulation

Gas Molecules in Open

Trapped Gas Molecules

Heat Source
Thermal Insulation!

Worlds best insulating solid
Acoustic Insulation: Loss in 2 3/4" Panel

Nanogel STC: 35, OITC: 26

- 50% Reduction in Loudness
- Nanogel

Frequency (Hz) vs. Sound Transmission loss (dB)
Loose fill insulation: translucent wall elements

FUNCTIONS:
- thermal insulation
- light transport
- light scattering
- transport of solar energy
- aesthetic appearance

AEROGEL REQUIREMENTS:
- light transmission >50% (2 cm)
- thermal conductivity 20 mW m\(^{-1}\) K\(^{-1}\)
- no impurities
- good appearance (blue)
- no dust
If the supercritical process is impractical, what else?

Waterglass → Sol → Hydrogel → ? → Aerogel

This is quintessential industrial R&D
Aerogel Processing: The Technology Shift

- HMDS / HCl
- Hydrogel
- Water / HCl
- Reaction of TMCS with surface
- Water / HCl
- HMDS / TMCS
- OSiR₃
- R₃SiO
- OH
- SiO₂
- Primary particles
- Cabot Corporation
State-of-the-Art Manufacturing Technology

Waterglass → Sol → Hydrogel → Silation → Aerogel

Silating Agent
The Nanogel™ Drying Process
Nanogel™ aerogels: applications of aerogel-containing composites in motorized vehicles

- Thin layer insulation for inside roof and floor of passenger compartment
- Insulation of the firewall of the passenger compartment
- Thermal and acoustic insulation for diesel engines
- Filling for heatshields in underbody area for insulation of the exhaust system
- Multi-functional interior and trunk (boot) insulation panels
- Space-saving insulation in narrow spaces (air conditioning ducts, fuel tank)
Nanogel™ Automotive Composite Concept

- Heat Source
- Sound Source
- Insulation Basecoat
- Reflective Topcoat
- Steel Panel
- Heavy Matte
Great Aerogel - How do you apply it?

Good composite thermal properties requires minimal use of binder.
Cabot Aerogel Binder Composite System

- Select a waterborn polymer.
- Spray to create foam!
- The two components have about the same volumes and densities.
- Add Cabot aerogel particles.
- Coat the surface and dry.
Aerogel-Binder Composite
SEM

formulation:
• aerogels and organic binder

application methods:
• co-spray
• foam spray (SEM image)
• foam extrusion

functions:
• thermal insulation
• acoustic insulation

patents:
• Cabot has many!
Manufacturing Facility

Location: Frankfurt, Germany
Industrie Park Hoechst

Capacity: 2.0 to 3.0 M lbs/year

Capabilities on Site:

- Nanogel® aerogel production
- Process development center
- Pilot plant
- Quality control laboratory
- Application development Laboratory
Nanogel™ Silica Aerogel

Product Lines and Markets

Loose Fill Insulation Products
- Natural daylighting elements
- Solar collectors
- Cryogenic tanks
- Pipe-in-pipe

Advanced Composite Insulation Systems
- Thermal & Acoustic
- Vacuum insulation panels
- Spray-on binder composites
- Composite Sandwich panels

Chemical Additives
- Silicone Rubber Reinforcement
- Matting Agents for Coatings
- Rheology control for Sealants/Adhesives/Coatings
- Agricultural pesticide carrier
Thank you!