

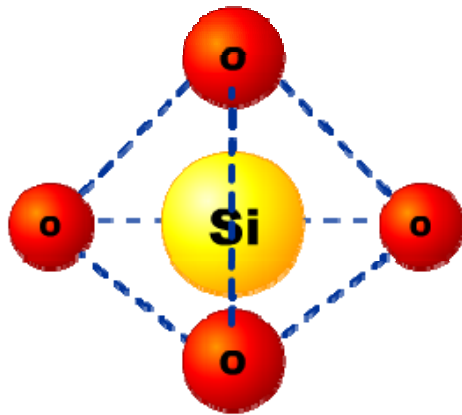
Your Day with Silica

SASSI

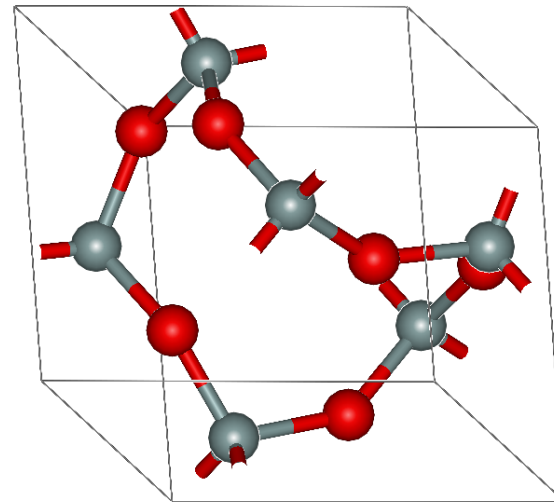
What is Silica?

Silica is also known as Silicon Dioxide (SiO_2)

- 46.6% Oxygen
- 28% Silicone



Silica Tetrahedron

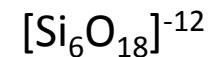
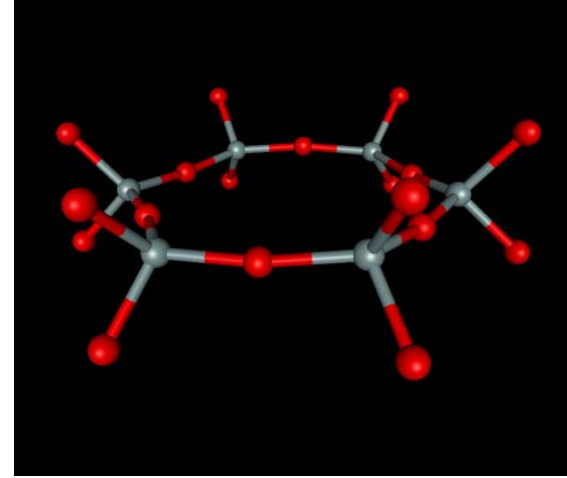
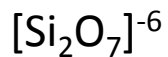
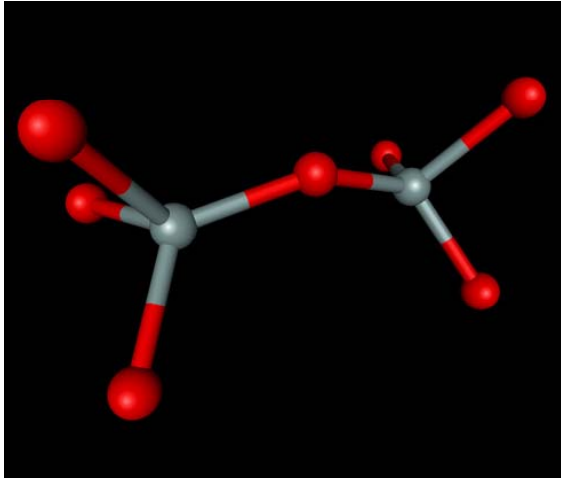


α -quartz

Silica is found in nature (sand or quartz) and is also manufactured in various forms (fused silica, silica gel, precipitated silica, colloidal silica and fumed silica)

What Is a Silicate?

A Silicate is a compound containing a silicon bearing anion. The charge is balanced by cations.



The silicon atom still occupies a tetrahedral environment but are joined as pairs or rings to form chains, double chains, sheets and three dimensional frameworks

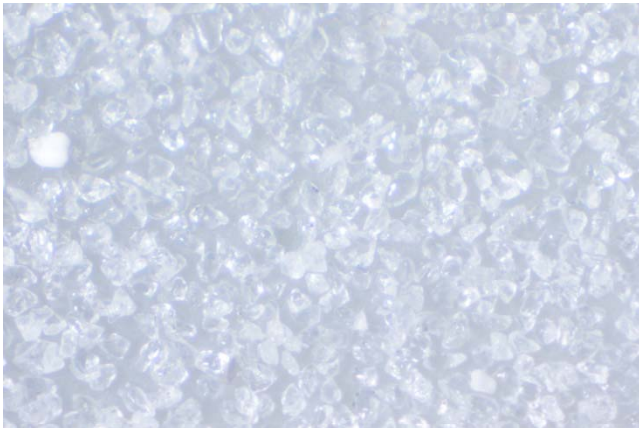
Beach Sand

Naturally Occurring Silicon Dioxide

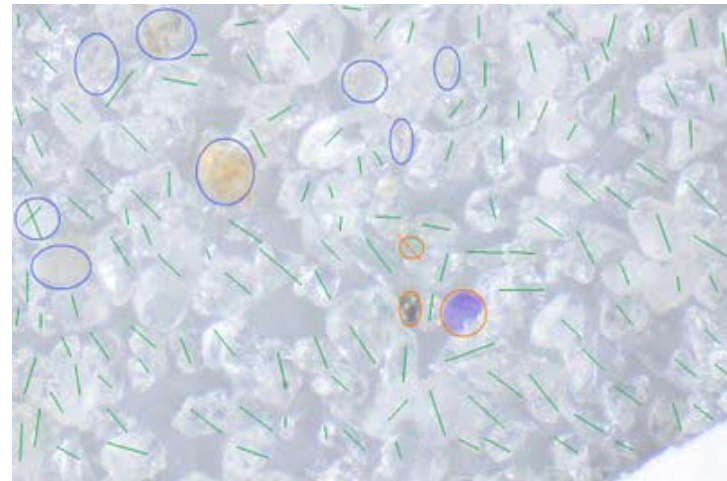


Cape Henlopen, DE

The most common constituent of sand is quartz grains. Siesta Beach has 99% quartz content!

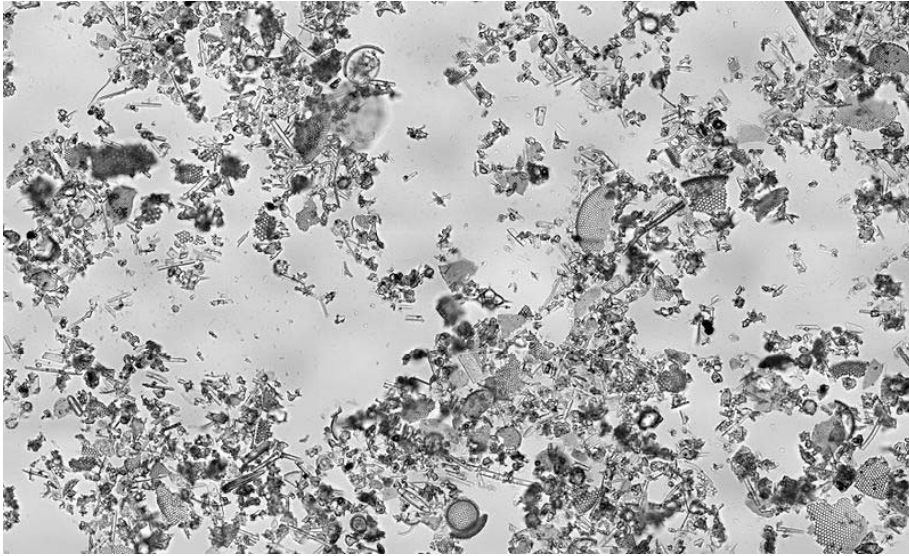


Siesta Beach, FL



Beach sand also contains heavy mineral grains along with bits of shells and coral.

Diatomaceous Earth



consists of 80-90% SiO_2

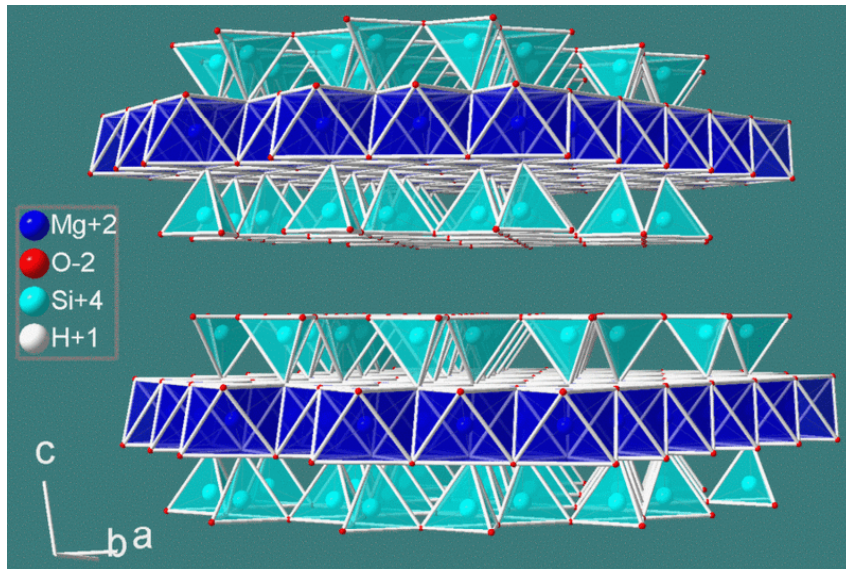
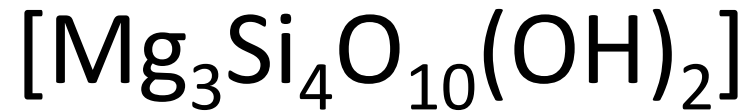
composed of diatoms
(hard-shelled algae)

used as filter media, cat litter,
plastics

individual diatom showing
intact cell wall



Talc is a Hydrated Magnesium Silicate



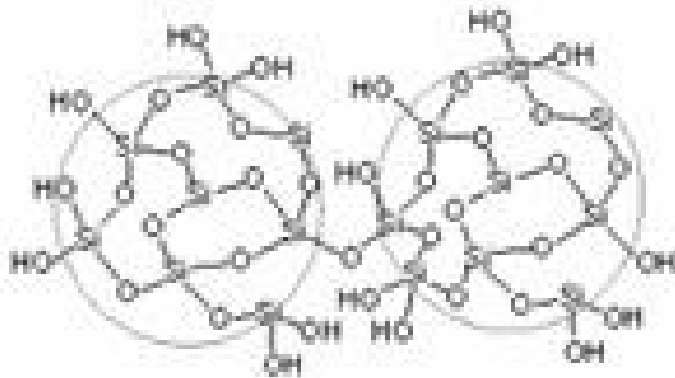
The structure of talc is composed of Si_2O_5 sheets with Mg sandwiched between the sheets

Common uses include cosmetics, paper (filler), ceramics, food



Talcum Powder

Amorphous versus Crystalline



Lack of Long Range Order
Amorphous



Long Range Order
Distinctive Faceted Crystals

Silica Gel as well as Precipitated, Fumed
and Colloidal Silica Are All Amorphous

What Have We Learned and Fun Facts

- The silicon atom likes to be surrounded by 4 oxygen atoms in a tetrahedral environment
- Silicon dioxide or Silica (SiO_2) has no negative charge and therefore has no need for counter ions (quartz)
- Silicates are composed of silicate anions whose charge is balanced by cations (minerals)
- Silicates are the building blocks of the earth's crust making up over 90% of the weight of the earth's crust
- Silicon dioxide occurs in nature (diatomaceous earth, rice hulls) as well as being industrially manufactured
- Industrially manufactured forms of silica are amorphous, not crystalline
- Those little packs in computer bags, apparel...that say "do not eat" are silica gel which acts as a desiccant

Let's Take A Closer Look At
Synthetic Amorphous Silica

Types Of Synthetic Amorphous Silicas

- Colloidal Silica
- Fumed Silica
- Silica Gel
- Precipitated Silica

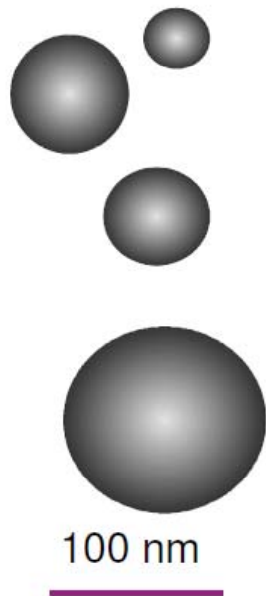
Synthetic Amorphous Silica Overview

- Precipitated, Colloidal and Silica Gel are referred to as “wet phase” silicas since they are borne in the water phase through acidulation of aqueous sodium silicate.
- Fumed or pyrogenic silica is made in a “flame process” by burning SiCl_4
- Colloidal Silica is sold only in dispersion form and consists of nanometer sized particles which are non-porous
- Precipitated silica, silica gel and fumed silica are aggregated products consisting of primary particles, aggregates and agglomerates
- Precipitated silica and silica gel and fumed silica are sold mainly as dry powders while fumed silica is sold as a dry powder or dispersion

Structure of Synthetic Amorphous Silica

Nano-object

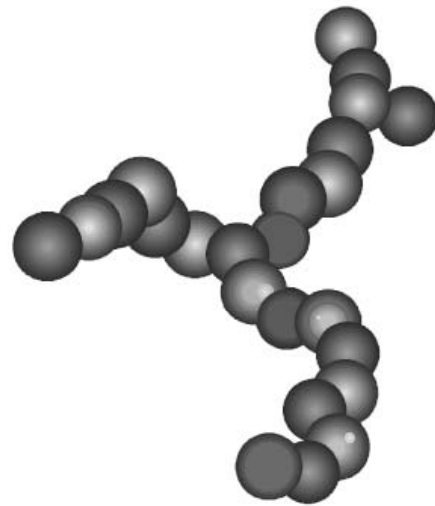
Nanoparticles



Nanostructured

Aggregate

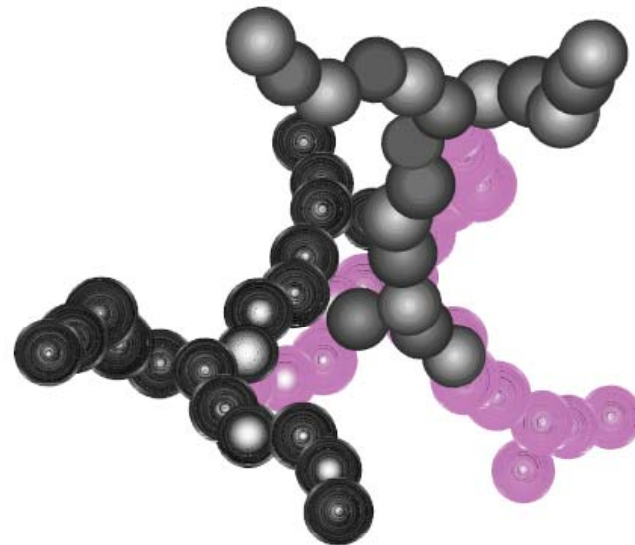
Chemically bonded



Fused, **chemically** bonded
primary particles

Agglomerates

Van der Waals forces

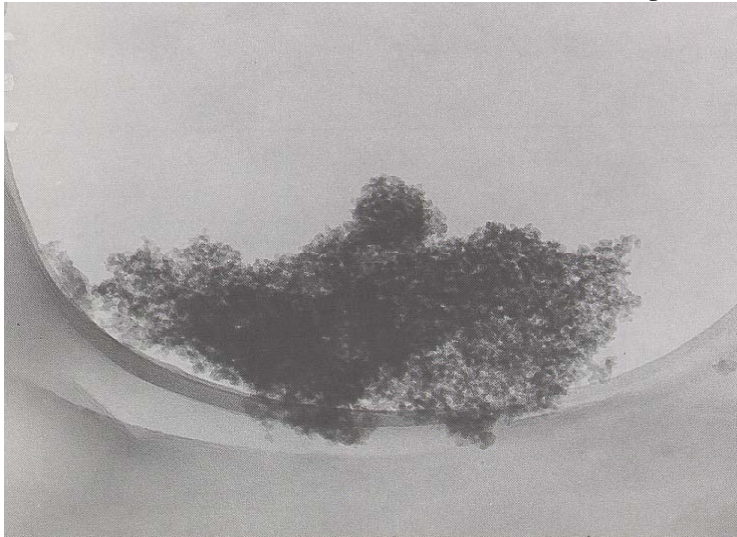


Particles or aggregates
stick together **via van der
Waals Forces**

Half life time of isolated 20 nm particles above $1 \text{ mg/m}^3 < 3,8 \text{ s}$

Preining (1998) The physical nature of very, very small particles and its impact on their behaviour. J. Aerosol Sci. 29, 481-495

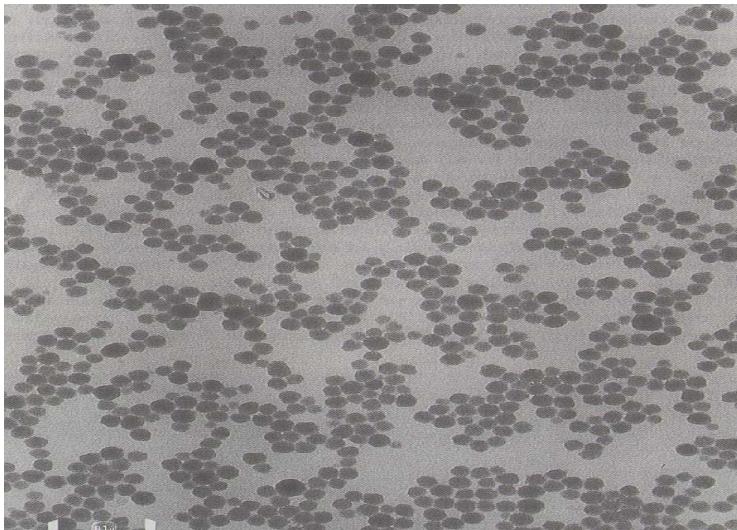
Pictures of Synthetic Amorphous Silica



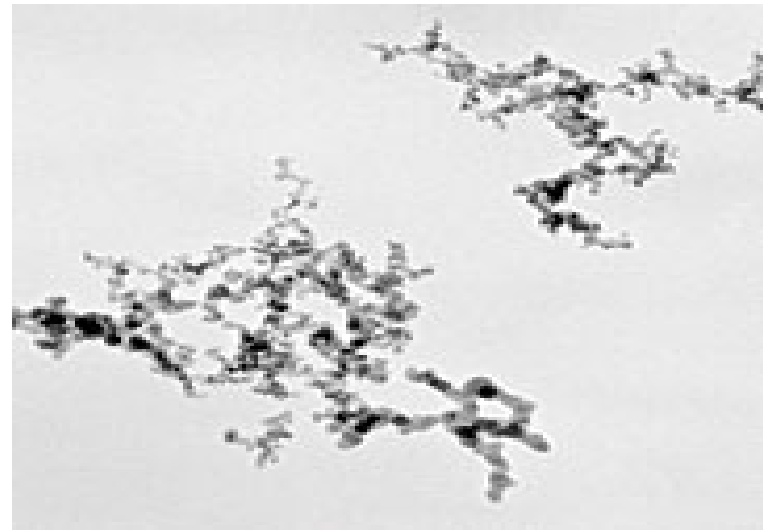
Silica Gel



Precipitated

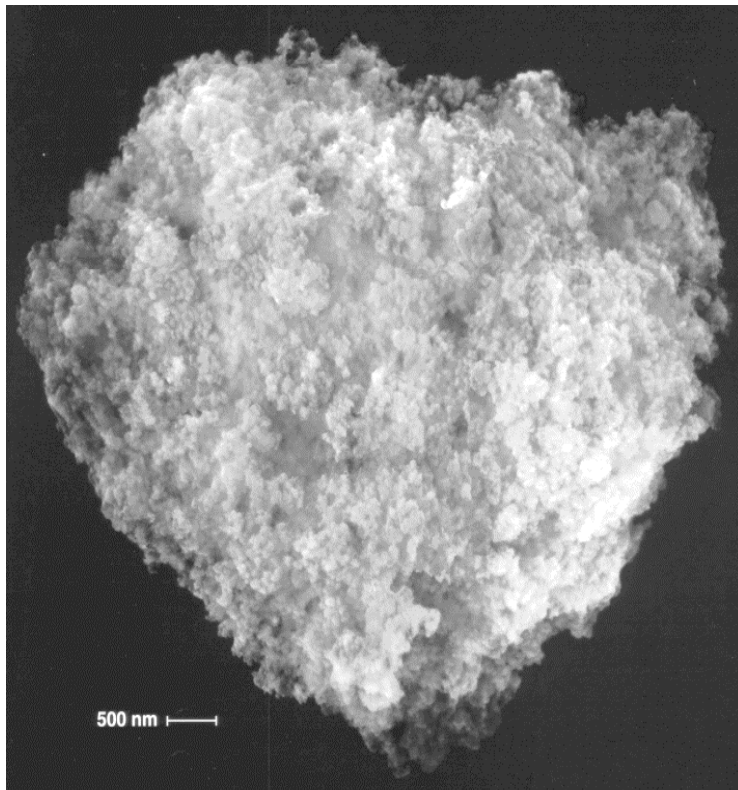


Colloidal

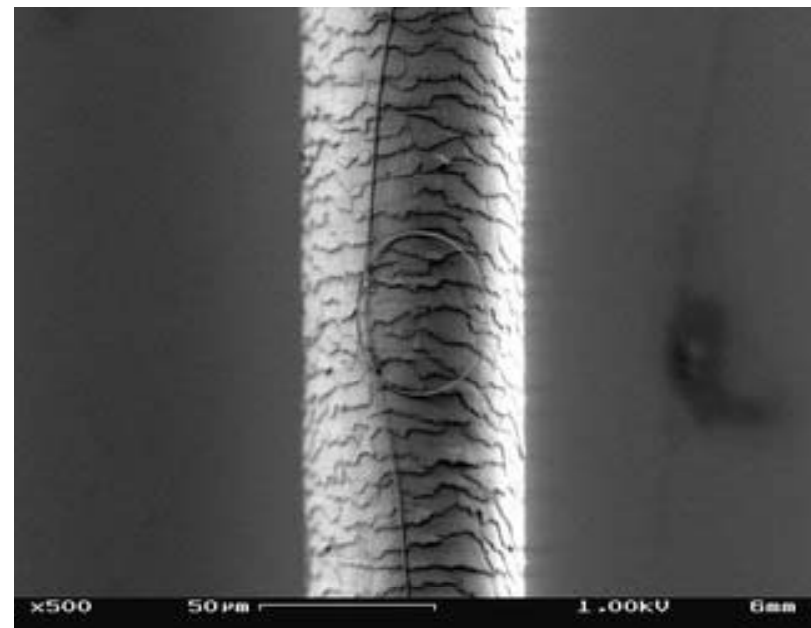


Fumed

Precipitated Silica Particle

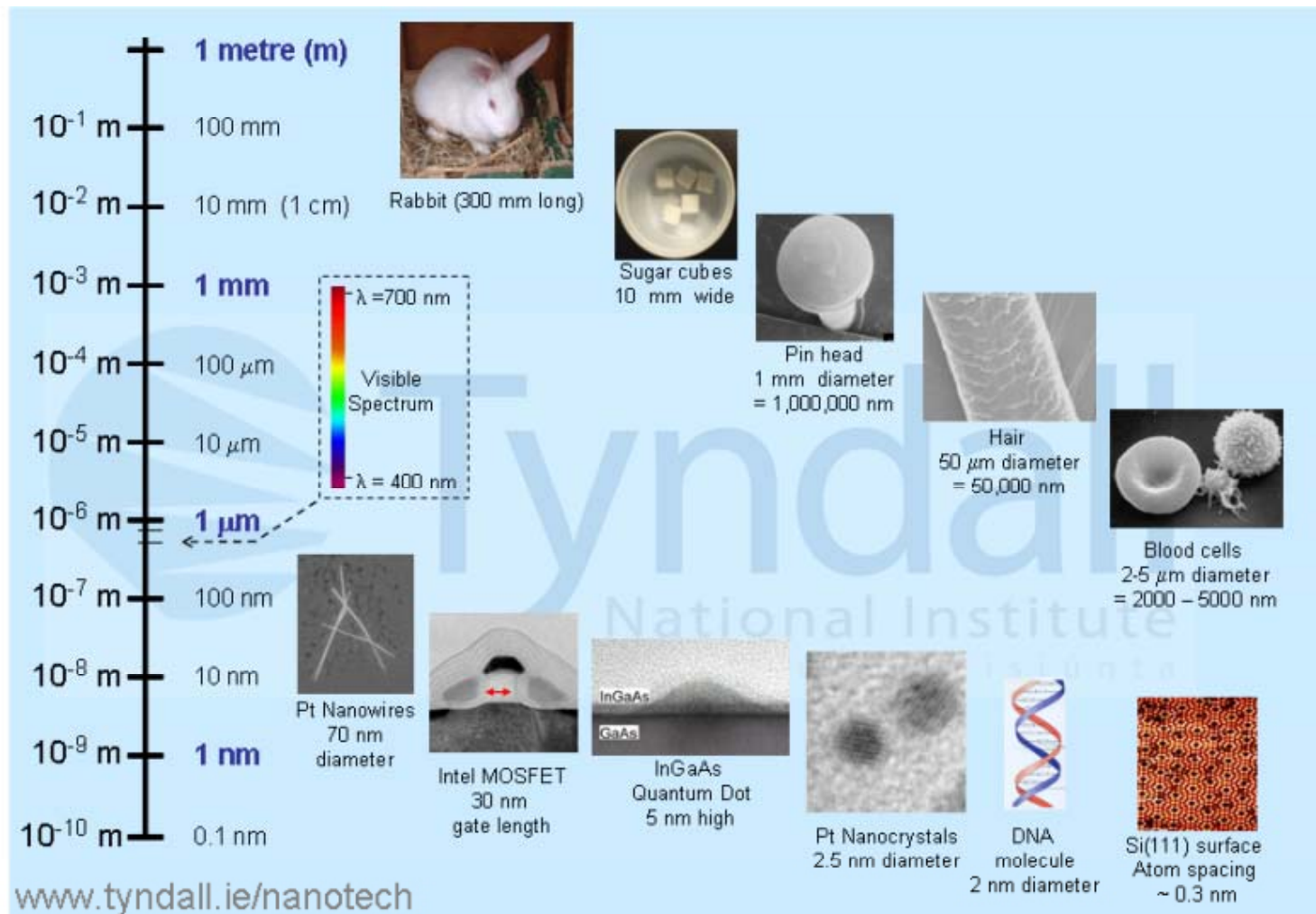


8 - 12 microns (μm)
8,000 – 12,000 nanometers (nm)



Diameter of a human hair
is 50 – 100 μm
or 50,000 – 100,000 nm

Fun Facts - Length Scales



Let's Start Our Day!

Toothpaste

Precipitated Silica and Silica Gels are widely used in toothpaste and serve two key functions:

- Abrasion – typically loaded at 8 – 20 % by weight
- Thickening – typically loaded at 3 – 8% by weight



Silica effectively and safely removes extrinsic stains from the tooth surface

Toothpaste



Due to its porosity, precipitated silica and silica gels function as effective thickeners in toothpaste

Why is toothpaste rheology important? (Rheology is the study of the flow of matter)

- monotonous extrusion of the paste through pressing the tube and non-extrusion or non-overflow of the paste without pressing the tube
- proper stand-up of the paste on the brush and non-penetration of the paste into the bristles of the brush
- physical stability during the term of storage and distribution until delivery to consumers – no syneresis (separation)

poor standup



Advantages of Silica Based Toothpastes

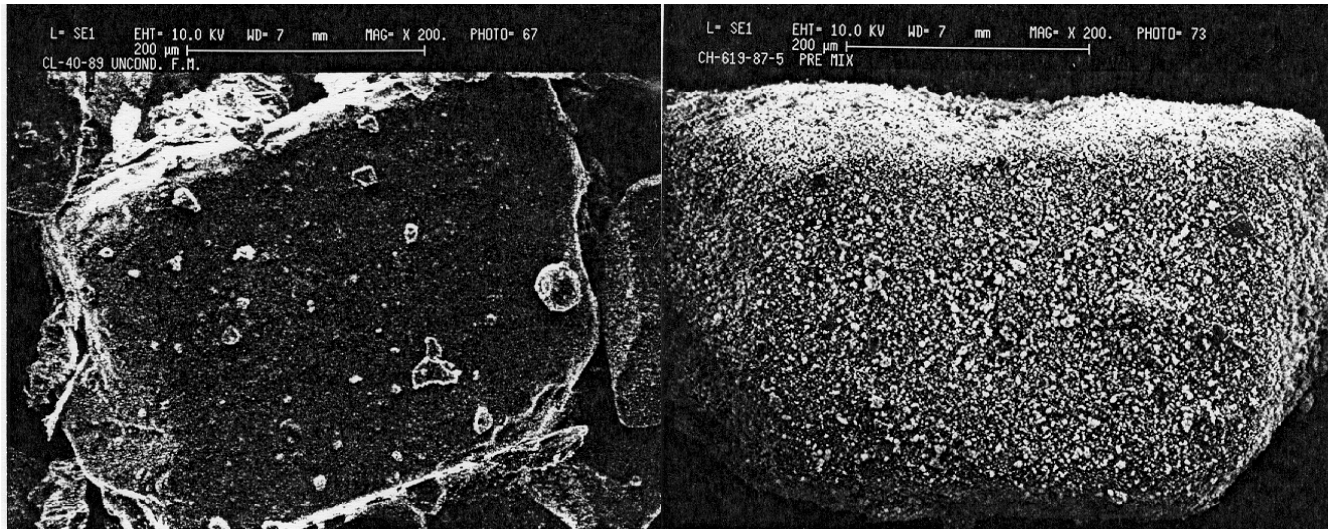
In general, Silica offers the following advantages over other abrasives such as dicalciumphosphate and calcium carbonate:

- superior compatibility with active ingredients such as NaF, SnCl_2 , antimicrobials
- ability to formulate clear gels and translucent pastes like Close Up and Max Fresh
- high levels of cleaning (stain removal) and low levels of abrasion so dentine and enamel are not removed



Silica As Free Flow Agents For Food

Precipitated Silica and Silica Gels are widely used as free flow and anti-caking agents in foods like salt and non-dairy creamers (federal regulations allow up to 2% by weight)



Fine particle silica sticks to salt crystals preventing formation of salt bridges due to environmental humidity changes – prevents caking and maintains good flow

Silica in Non-Dairy Creamers

Precipitated Silica and Silica Gels are used in non dairy creamers:

- in the spray drying process during manufacture to prevent sidewall buildup in the dryer
- as a conditioning aid (post drying) to prevent humidity caking and maintain flow properties

Silica is also used as a free flow anti-caking aid in other foods such as:

- seasonings
- spices
- beverage mixes
- hydrolyzed vegetable powder
- cake mixes



Cosmetics and Personal Care

Precipitated and fumed silica improve the distribution of colored pigments in lipstick. Once applied, the silica prevents the pigments from bleeding into the fine lines of the lips.



Fumed silica prevents pigments from settling and serves as a rheology modifier to improve application properties



Precipitated and fumed silica act as suspension stabilizers to prevent the agglomeration of active ingredients (aluminum and zirconium salts) helping to keep them effective and long lasting

Newsprint

During the production process in the paper mill, precipitated silica and silicates are used to increase the coefficient of friction of newsprint improving the efficiency of the winding process



Precipitated silica and silicates improve:

- brightness:
- opacity
- show-through
- strike-through
- color printability

Going to Work or School

Separators for Lead Acid Car Batteries

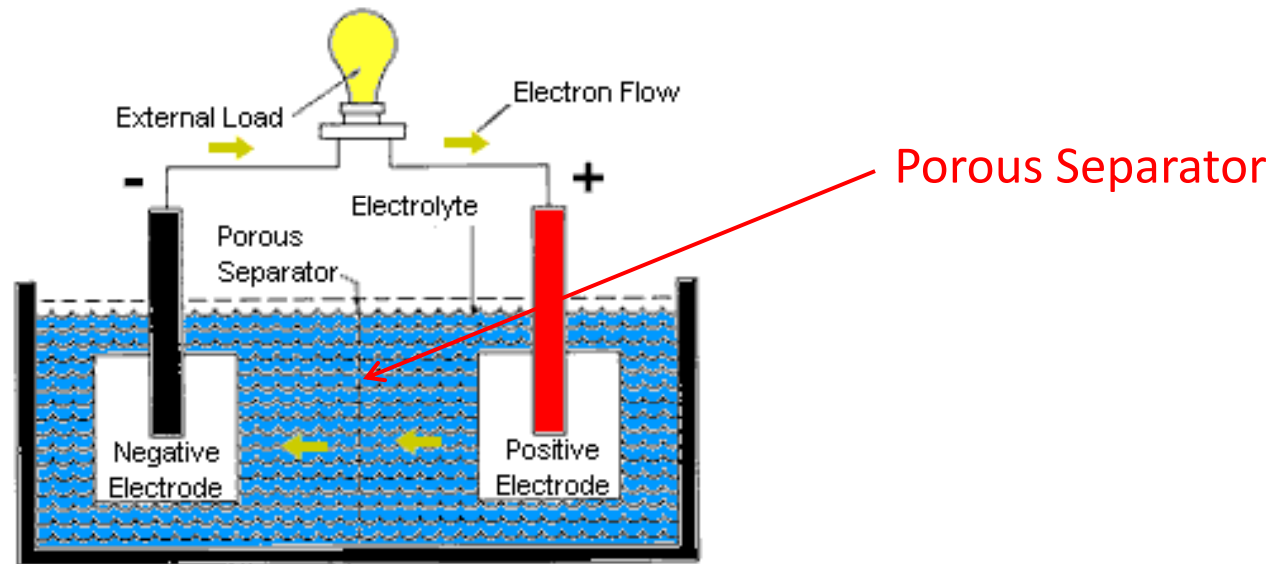


Figure 1 - Components of a Battery Cell
(Discharge Circuit)

- **Keep positive and negative electrodes physically apart preventing flow of any electronic current directly between them**
- **Need optimum flow of ionic current** - the reaction requires the migration of (H^+ , O^- , H_2O) through the separator. The separator must be sufficiently **porous** to allow migrations while minimizing the internal electrical resistance

Precipitated Silica Provides Porosity



Typical Polyethylene Separator Formulation

Component	% wt	Functionality
<i>Precipitated SiO₂</i>	~ 60	Imparts porosity, low electrical resistance
UHMW PE	~ 20	5-9 mio AMU; mechanical performance, puncture strength, chemical stability
Mineral Process Oil	~15	High aromatic content, separator processing and oxidative stability
Carbon Black	< 1%	color
Antioxidants	< 1%	Oxidative stability

Green Tires

Are green tires really green?

Green tires are called green because they offer higher fuel efficiency due to lowering of the tire's rolling resistance.



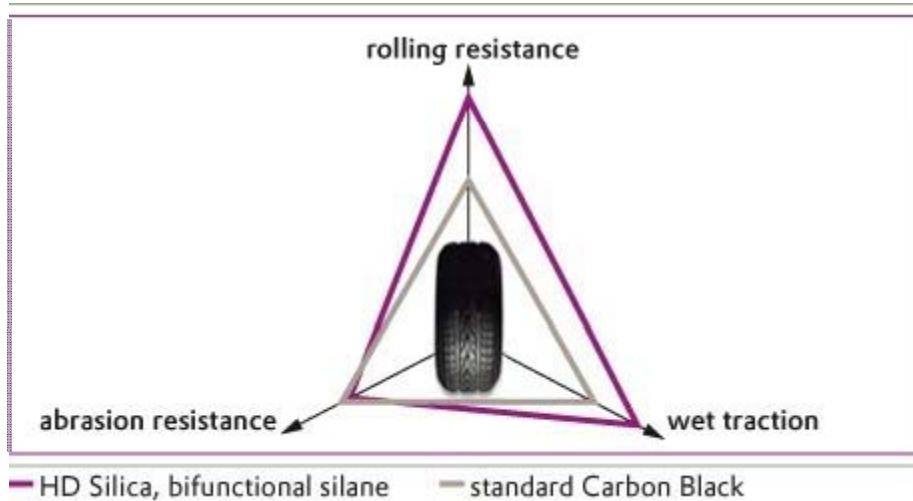
Some interesting facts:

- Overcoming the rolling resistance that tires encounter when they roll accounts for 20% of the fuel used in the average car
- Rolling resistance is responsible for 4% of worldwide CO₂ emissions from fossil fuels

Green Tires Are Good For The Environment!

Precipitated Silica In Green Tires

The Magic Triangle of Tire Technology



Traditionally, using carbon black as a reinforcement filler, improvement to rolling resistance comes at the expense of wet-road grip and durability.

Replacement of carbon black with precipitated silica and silanes allows tire makers to obtain lower rolling resistance, good tread wear and wet traction

At Work or School

Presentations - Ink Jet Paper Coatings

Precipitated silica and silica gels (3 – 16 μm) are used in coatings for matte ink jet paper. Their ability to absorb liquid and their unique structure enables:

- the rapid diffusion of liquid inks into the coating layer for fast drying
- high optical print densities – high contrast and bright color tones
- dot circularity with sharp edges – minimal bleeding



Matte Presentation Paper

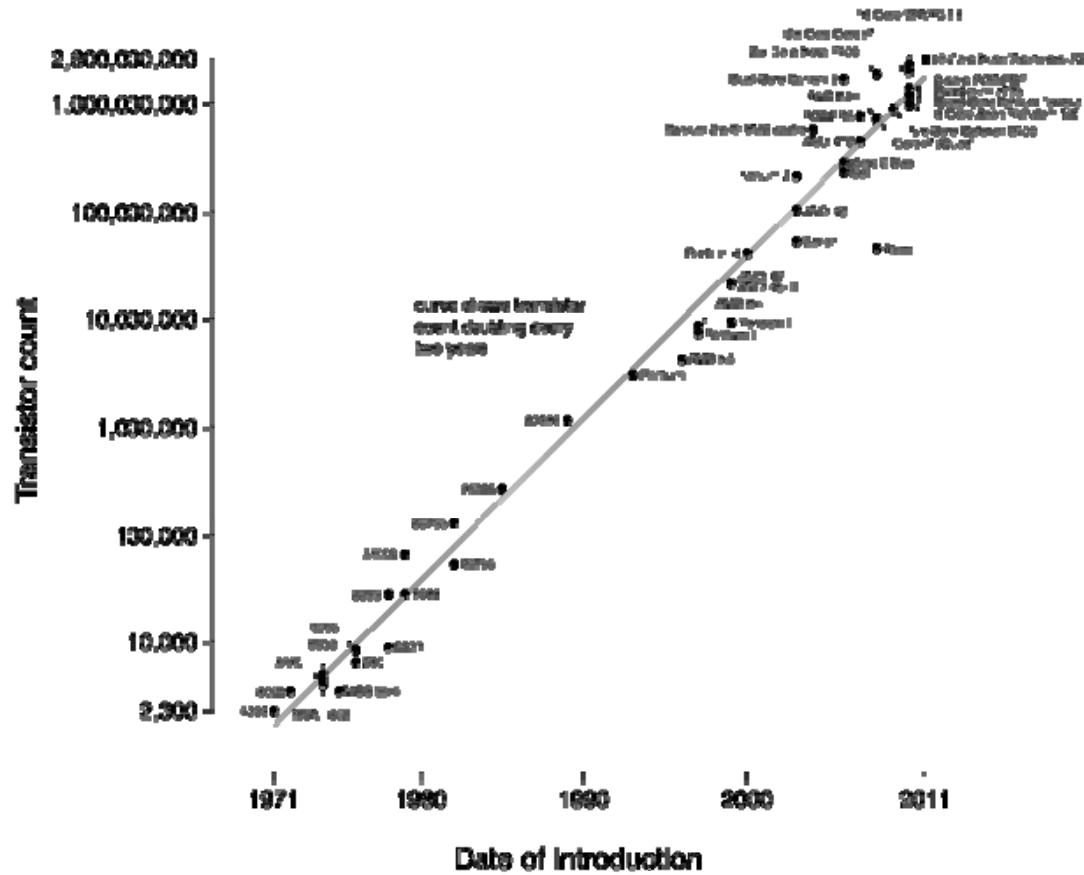
Fumed silica (0.2 – 0.3 μm) and colloidal sized silica gels (< 1 μm) are used in glossy photo ink jet paper.



Photo Glossy Paper

In your Computer Microprocessor

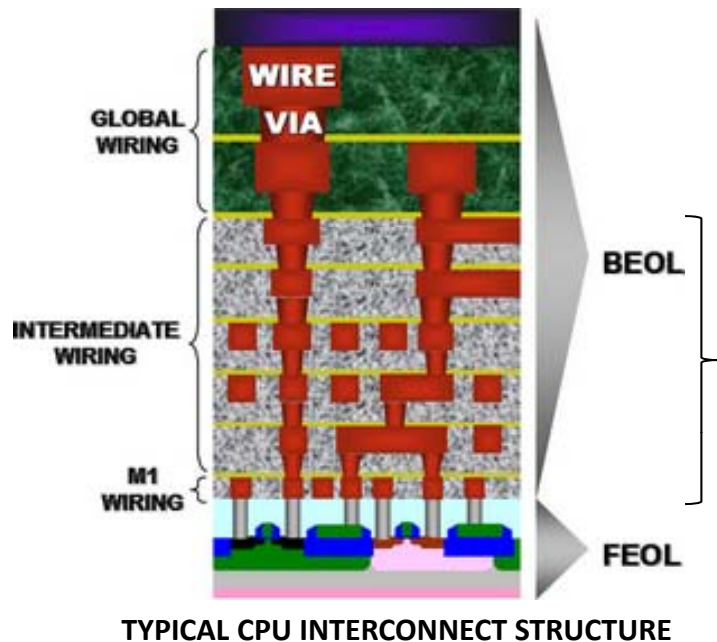
Microprocessor Transistor Counts 1971-2011 & Moore's Law



Moore's Law - the number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every two years – increased processing speed, memory, capacity

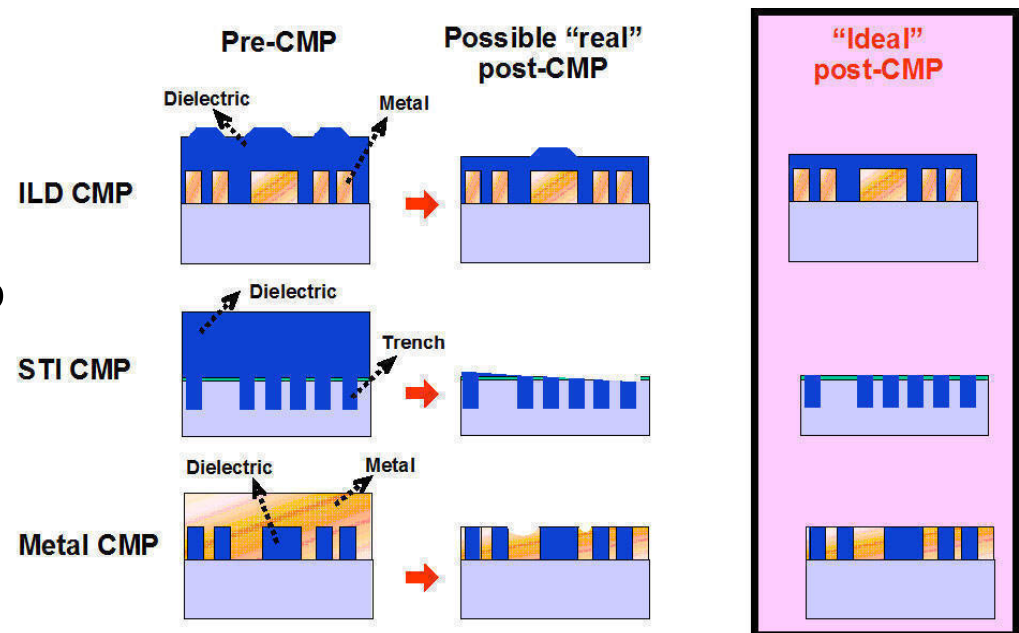


Chemical Mechanical Planarization

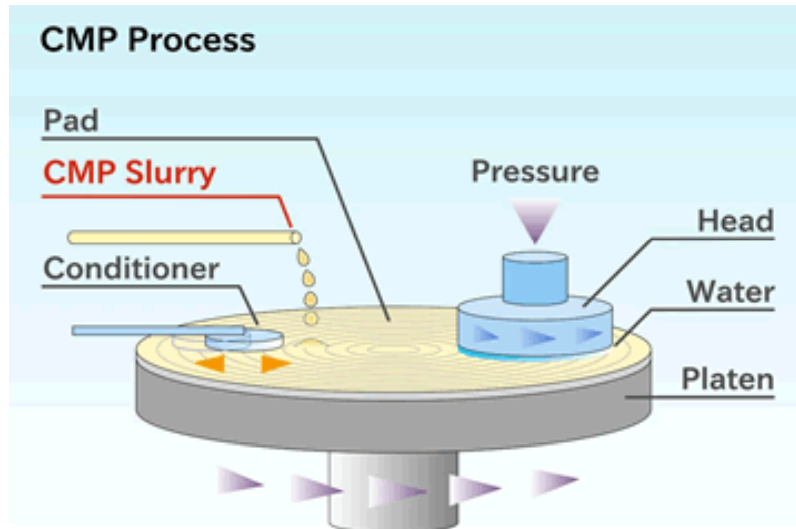


Multiple layers of Cu wiring and dielectric (insulation) connect the transistors

Each layer needs to be smooth prior to constructing the next wiring layer to minimize shorts and defects



CMP Slurries Contain Silica As Abrasive



Chemical Mechanical Polishing or planarization is a process of smoothing surfaces with the combination of chemical and ***mechanical*** forces

- Chemical reaction facilitates the formation of surface layers which are reactively softer than original one
- Mechanical removal of these surface layers by abrasion with slurry/pad
- Removal rate of higher point is faster thereby resulting in polishing

Both fumed silica ($0.2 - 0.3 \mu\text{m}$) and colloidal silica ($0.05 - 0.08 \mu\text{m}$) are used extensively as the abrasive component in CMP slurries

Lunch or Dinner Anyone?

Silica and Silicates Increase the Life of Oil Used For Retail and Industrial Frying

Specially engineered Silicates and Silica products increase the life of oil and improve the food quality and shelf life of fried food by adsorbing oil degradation products:

- total polar compounds
- free fatty acids
- soaps



Also, nuts, chicken, taquitos, corn dogs, veggie burgers.....

Oil Usage In a Mixed Use Fast Food Fryer						
Oil Quality	Triglycerides (%)	Polar Degradation Products (%)	Polymers (%)	Free Fatty Acids (%)	Oxidized Fatty Acids (%)	Soaps (ppm)
New Oil	> 96	< 4	0.5	0.02	0.01	0 - 7
Optimum	80	20	12	3.0	0.7	65
Degraded	75	25	25	8.0	2.0	>200

Silica and Silicates Can Extend The Useful Life of Frying Oil



Old Frying Oil

Old Frying Oil
Treated with Silicate

Old Frying Oil
Treated with Silica

Old Frying Oil

Reduction in Beer Haze Using Silica Gel

Beer contains proteins (polypeptides) and tannins (polyphenols) which react during shelf storage to develop colloidal complexes. The result is an increase in turbidity known as “chill haze”. Analysis of isolated beer haze deposits show that the largest fraction of haze material is protein (40-75%) where polyphenols make up a smaller component (~17%).

Use of hydrophilic silica gels as a filtration media allows only the hydrophilic proteins to be adsorbed and removed while leaving the hydrophobic proteins in the beer which stabilize foam. These hydrophobic compounds form thin films that surround the CO₂ gas bubbles and slow the rate at which they burst.



Clear Beverage, Good Foam, Excellent Shelf Life

Summary

- Silica and silicates are found naturally in the earth as well as in plants - quartz, talc, diatomaceous earth
- Important industrial forms of silica are amorphous and comprise, precipitated silica, silica gel, fumed silica and colloidal silica
- Synthetic Amorphous Silica is an important industrial inorganic chemical and is used in many applications:
 - Toothpaste
 - Food (salt, creamers, fried products, beer)
 - Personal Care Products
 - Newspaper and Specialty Papers (Inkjet/Thermal)
 - Automobiles (batteries, tires)
 - Semiconductor Processing
 - Other applications not discussed today: paints and coatings, defoamers.....

Thank You!