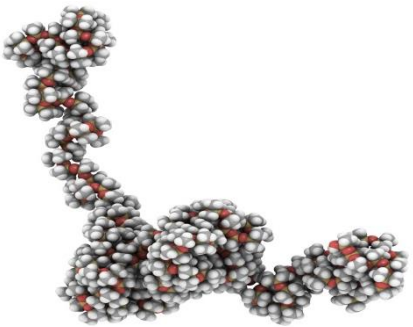
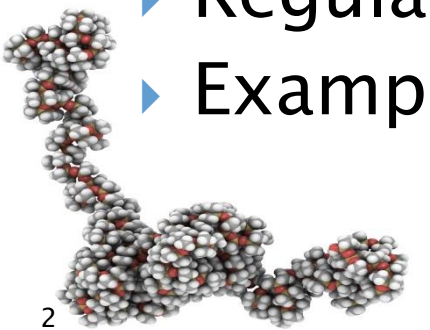
Regulation-Driven Product Development in The Silicone Industry

Siltech Corporation
Dave Wilson

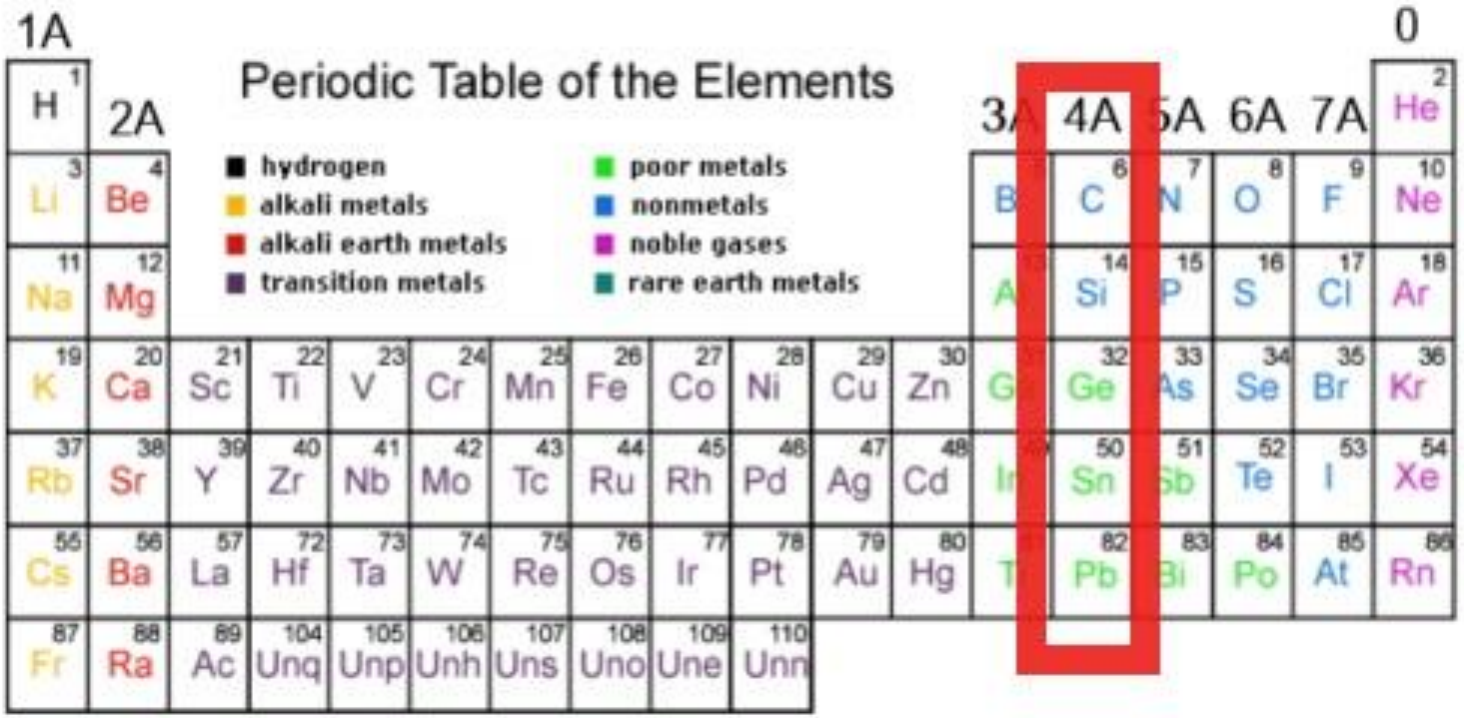


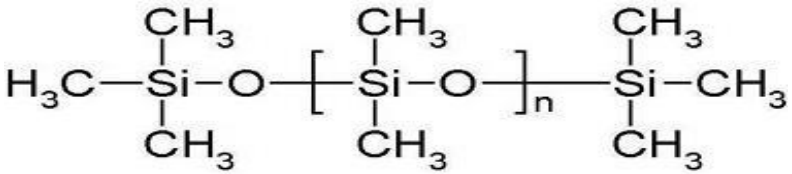
Siltech Corporation

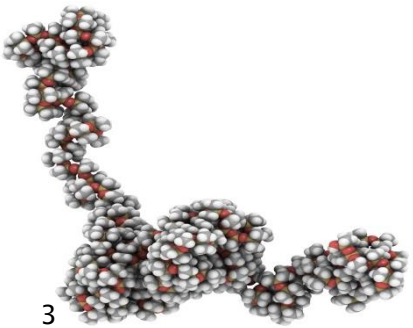
- Regulations are common drivers for innovation
- Examples in the silicone world follow



Silicon


Periodic Table of the Elements
hydrogen
alkali metals
alkali earth metals
transition metals
poor metals
nonmetals
noble gases
rare earth metals
1A
2A
3A
4A
5A
6A
7A
0
H
He
Li
Be
B
C
N
O
F
Ne
Na
Mg
Al
Si
P
S
Cl
Ar
K
Ca
Sc
Ti
V
Cr
Mn
Fe
Co
Ni
Cu
Zn
Ga
Ge
As
Se
Br
Kr
Rb
Sr
Y
Zr
Nb
Mo
Tc
Ru
Rh
Pd
Ag
Cd
In
Sn
Sb
Te
I
Xe
Cs
Ba
La
Hf
Ta
W
Re
Os
Ir
Pt
Au
Hg
Tl
Pb
Bi
Po
At
Rn
Fr
Ra
Ac
Unq
Unp
Unh
Uns
Uno
Une
Unn


CH3
H3C
Si
O
n



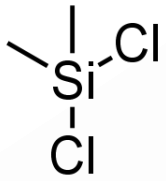
The Road from Silicon to Silicone

14
Si
28.0855

Elemental **Silicon**:
Abundant in the earth's crust predominately as oxide minerals; silica, sand, quartz, or gemstones.

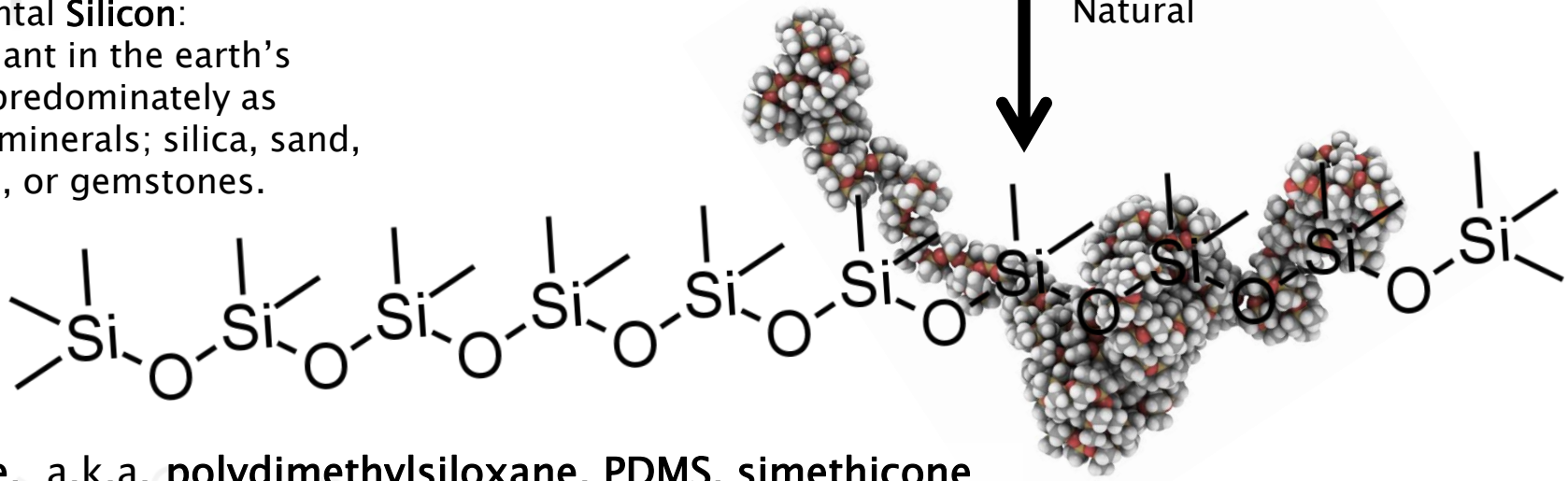
1) **Methanol**: A naturally occurring biochemical very common in nature. Generally made from Natural Gas.
2) **HCl**: a naturally occurring mineral acid

Catalysts:
From the Earth



A variety of **chlorosilanes**: man-made, highly reactive intermediates. These are only used by chemical companies.

Water:
Natural

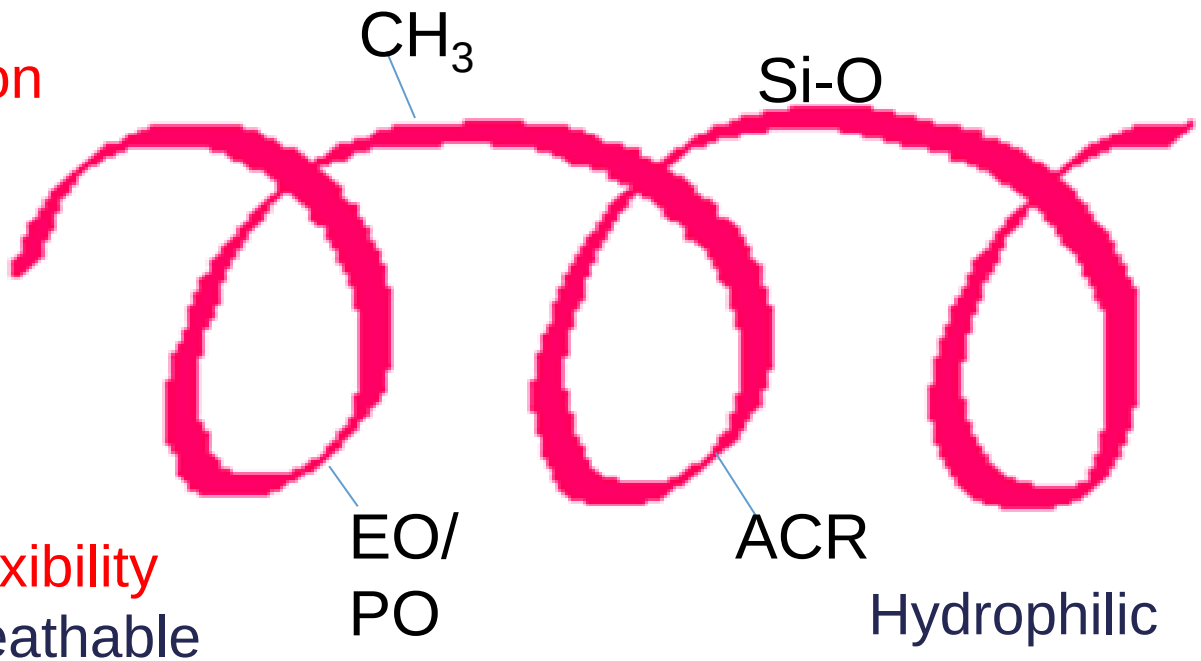


Silicone. a.k.a. **polydimethylsiloxane**, **PDMS**, **simethicone** or **dimethicone**. This man-made polymer is used in a very wide range of medical, food, personal care, household and industrial uses. It is among the most toxicologically studied and low toxicity polymers known to man.

Properties of Silicones

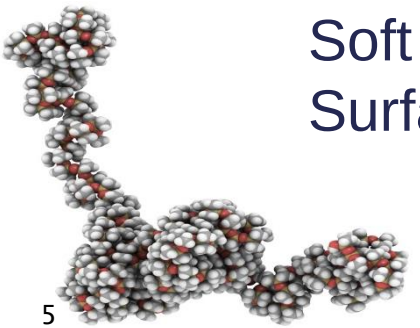
Thermal Stability
Chemical Resistance
Weather resistance

Hydrophobic
Release
Lubrication
and Slip



Flexibility
Breathable
Soft
Surface Active

Hydrophilic
Reactive
Gloss
Level and Wet



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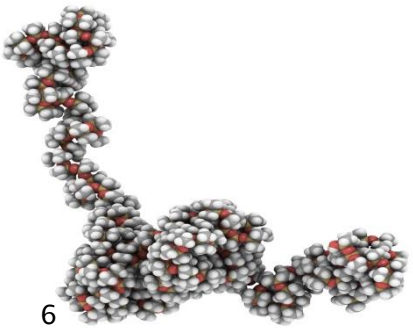
Regulatory Drivers in the Silicone Field

1. Solvents and Volatiles
2. Fluorine
3. Emulsifiers
4. The Green Trend
5. Remaining Challenges



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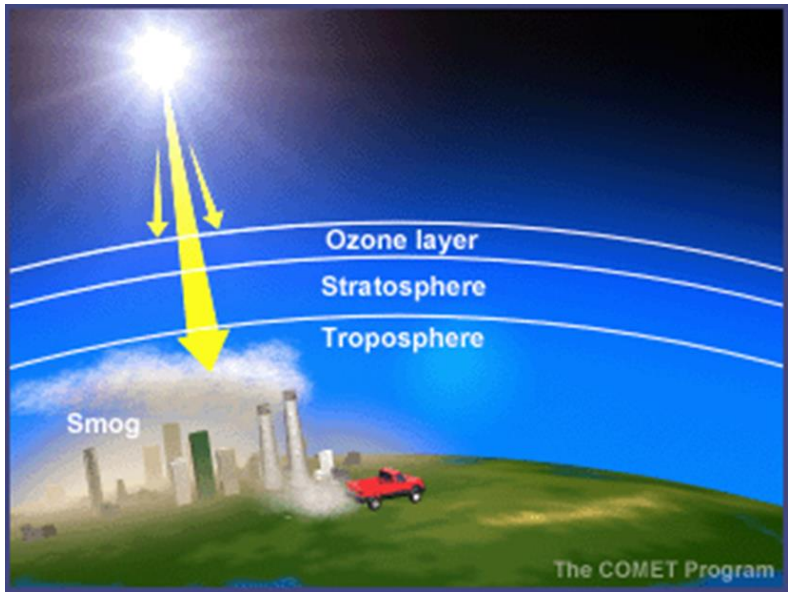
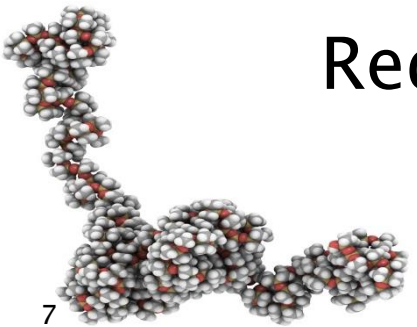
1. Solvents and Volatiles

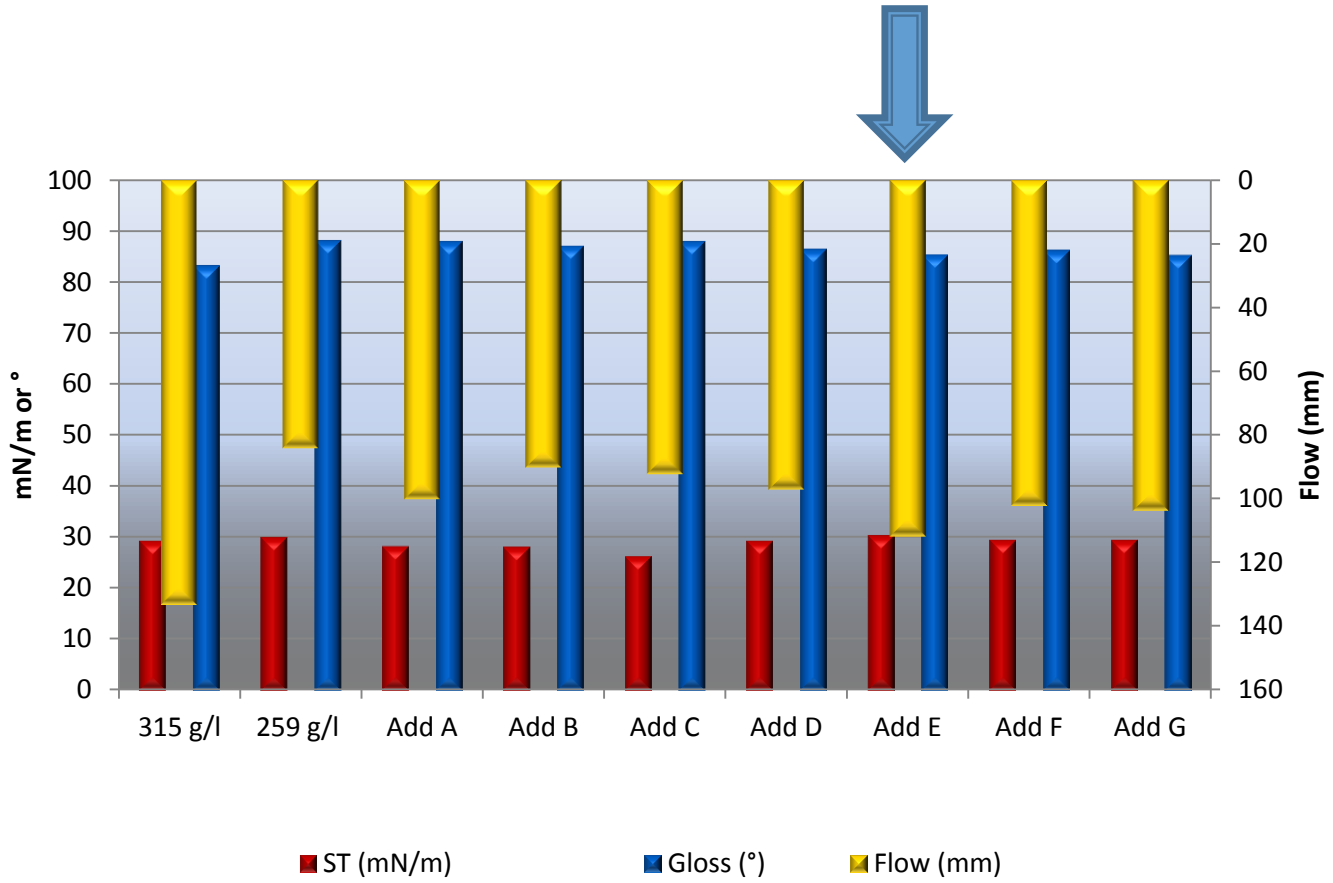


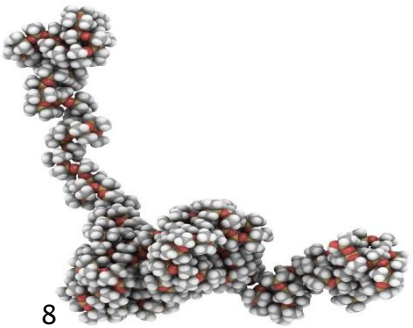
Reduce Volatiles and Eliminate Solvents

Reduce Volatile Siloxanes and Eliminate Silicone Solvents



Reduce Organic Solvent





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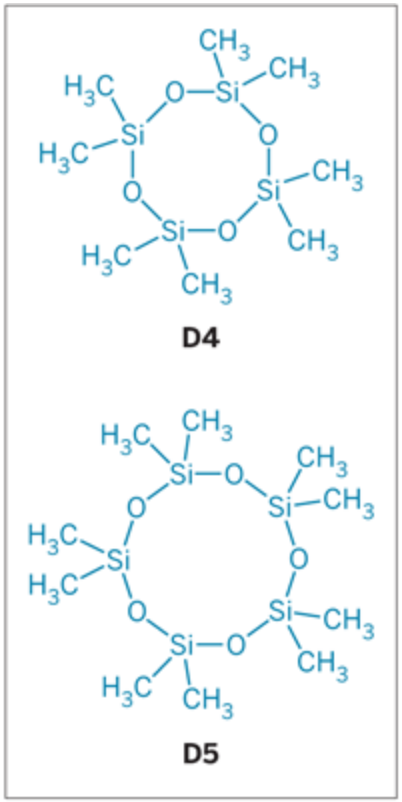
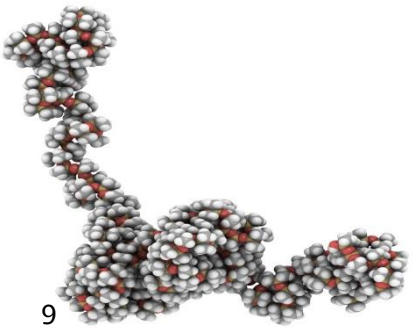
Volatile Cyclic Siloxanes

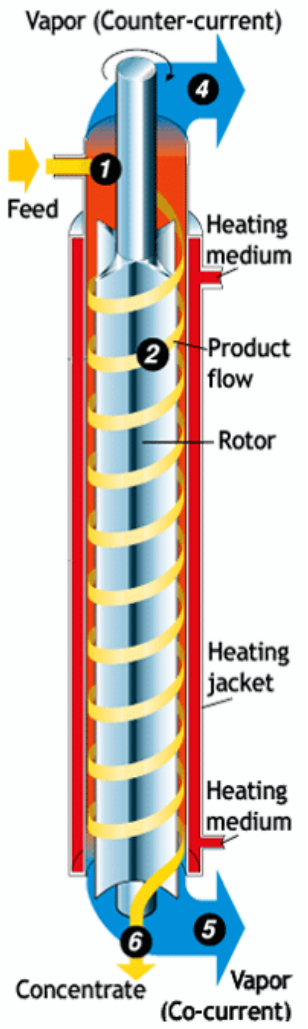
- Silicones are non-HAPs
- Extensive toxicological testing related to breast implants
- Some early results led to concern over volatile silicones D_4/D_5
- Personal Care
- Canada and Norway

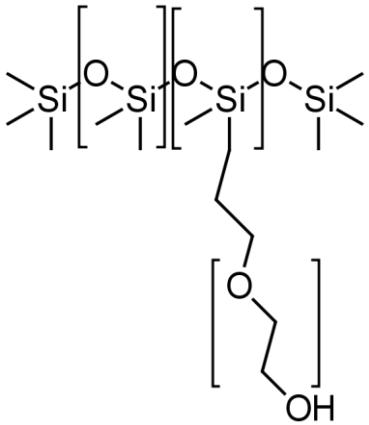




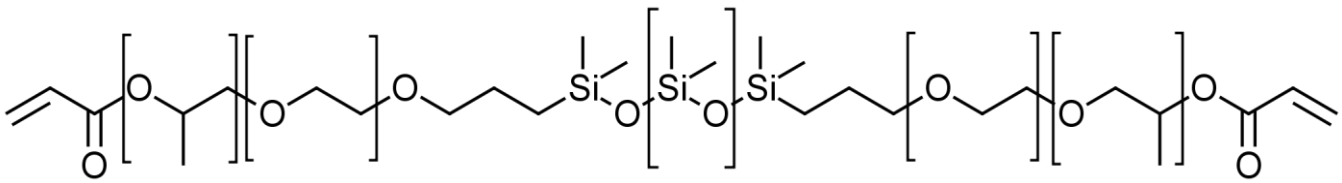
Volatile Cyclic Siloxanes

WFE

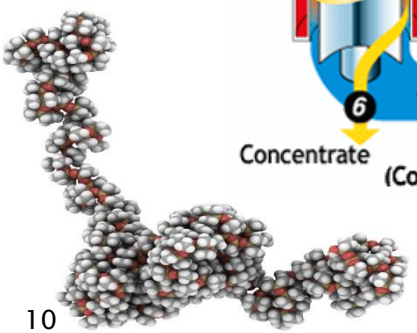




SPEs



Di-acrylates



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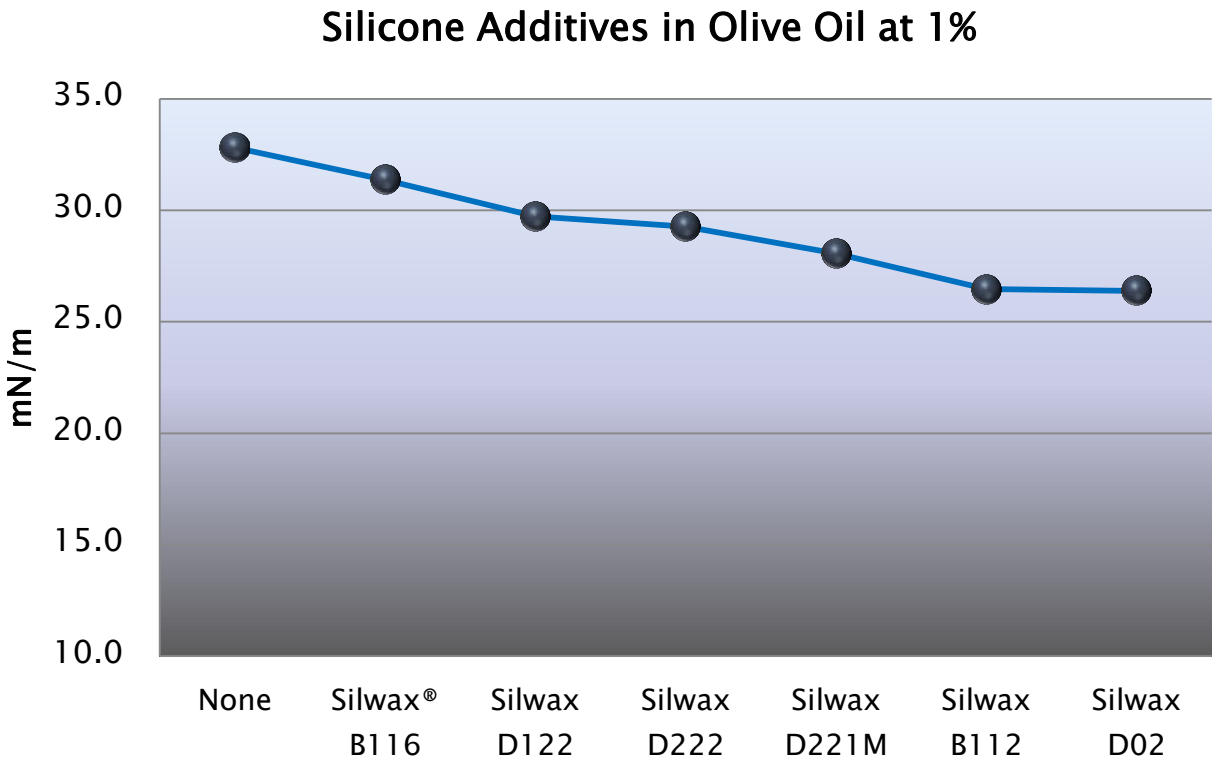
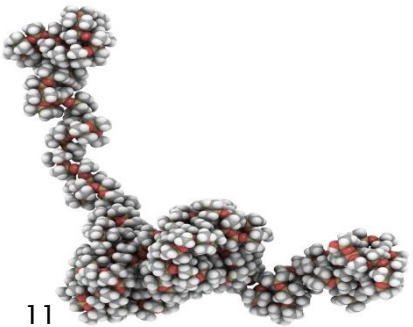
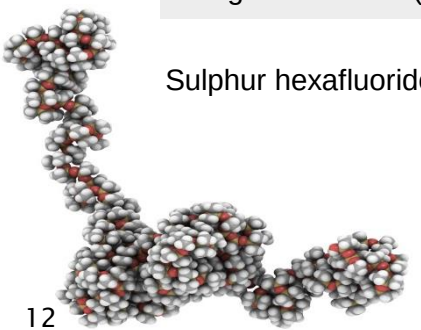
Eliminate Silicone Solvent



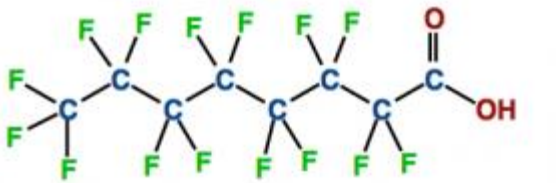


2. Fluorine

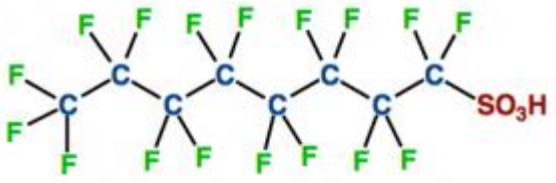
F-gases			
Gas	**Use**	**Lifetime in atmosphere (half-life)**	**Global warming potential**
CFC-11	Early refrigerant (banned)	45 years	4,680x CO2
CFC-12	Car air conditioning (banned)	100 years	10,720x
CFC-113	Refrigerant, propellant (banned)	85 years	6,030x
HCFC-22	Refrigerant, propellant	1780 years	12x
HFC-23	Microchip etching, fire suppressant, by-product of HCFC-22 production	270 years	14,310x
HFC-134a	Fridges, car air conditioning	14 years	1,410x
HFO-1234yf	Replacement for HFC-134a	11 days	4x
Tetrafluoromethane (CF4)	Biproduct of aluminium smelting	50,000 years	5,820x
Hexafluoroethane (C2F6)	Biproduct of aluminium smelting	10,000 years	12,010x
Nitrogen trifluoride (NF3)	Etching silicon	740 years	17,200x
Sulphur hexafluoride (SF6)	Anti-sparking in electricity substations, magnesium production	3,200 years	22,800x



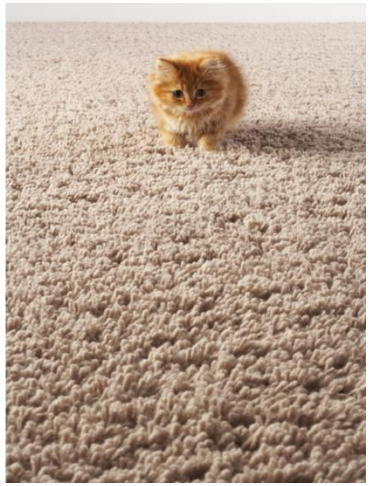
Fluoropolymers



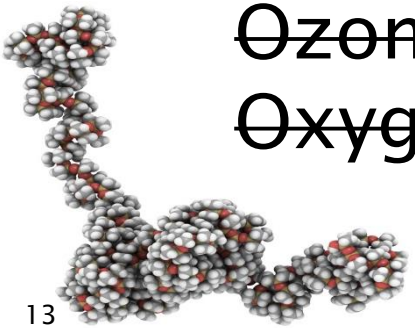
PFOA - perfluorooctanoic acid



PFOS - perfluorooctanesulfonic acid



~~Bacteria~~
~~Ozone~~
~~Oxygen~~



- Reduce length of fluorine chain
- Substitute fluorocarbons with fluorosilicones

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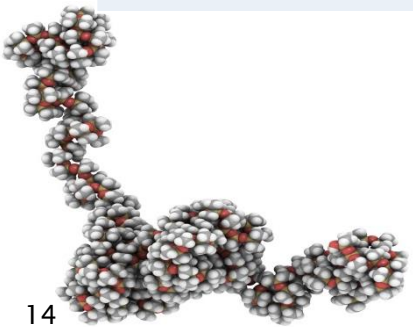
Comparison of Selected Properties of Silicone and Fluoropolymers

Silicone	Fluoropolymer
✓ Low surface energy	✓ Very low surface energy
✓ Very good thermal flexibility	✓ Marginal thermal flexibility
✓ Good chemical resistance	✓ Very good chemical resistance
✓ Marginal oil resistance–swelling	✓ Very good oil resistance
✓ Very good water resistance	✓ Good water resistance
✓ Marginal abrasion resistance	✓ Low abrasion resistance
✓ High cost	✓ Very high cost
✓ Effective at low use levels	✓ Effective at low use levels



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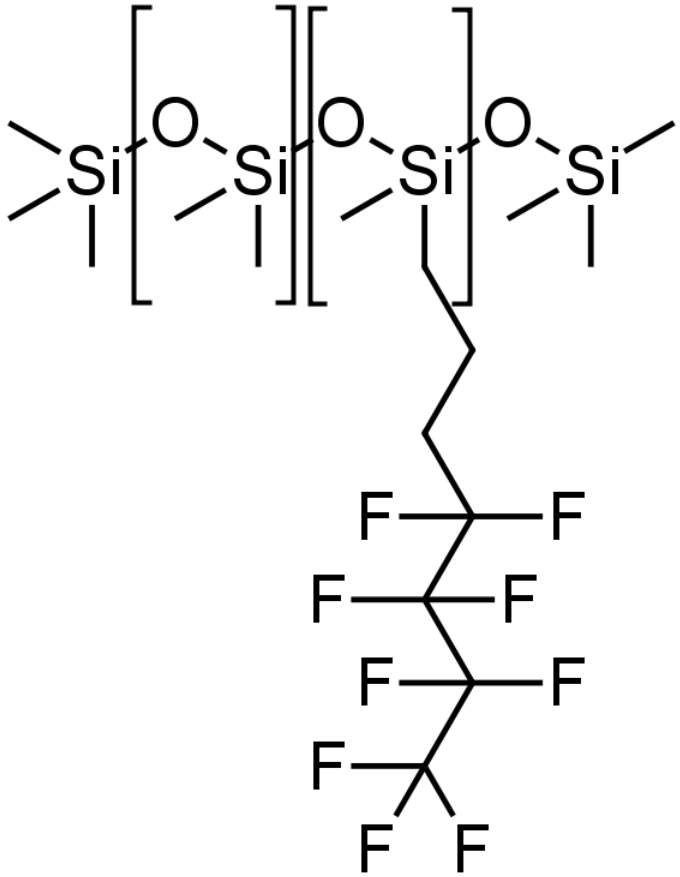
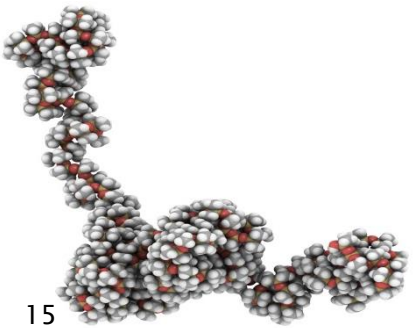
Fluorosilicones





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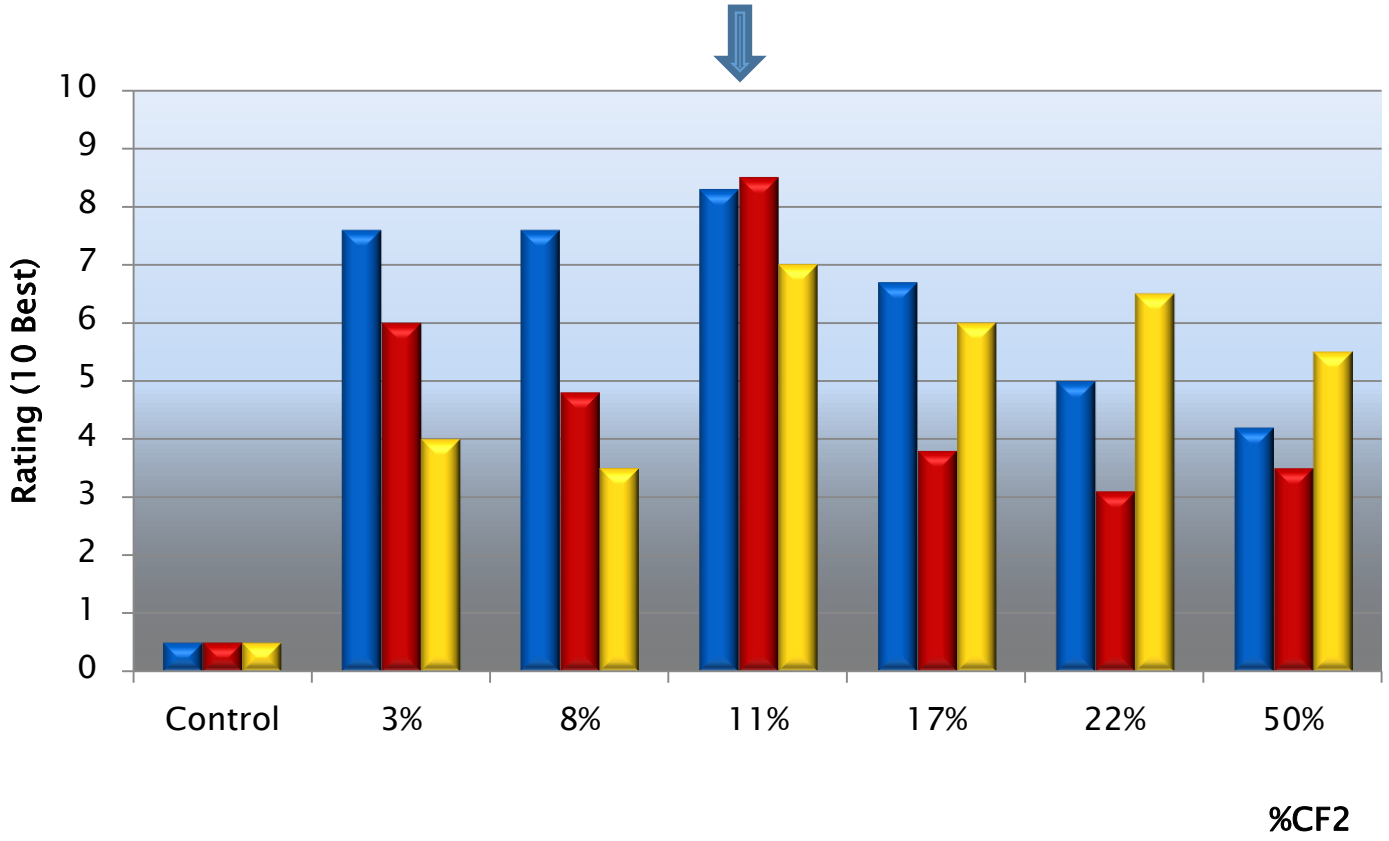
Substitution of Fluorocarbons



Reduce total F +

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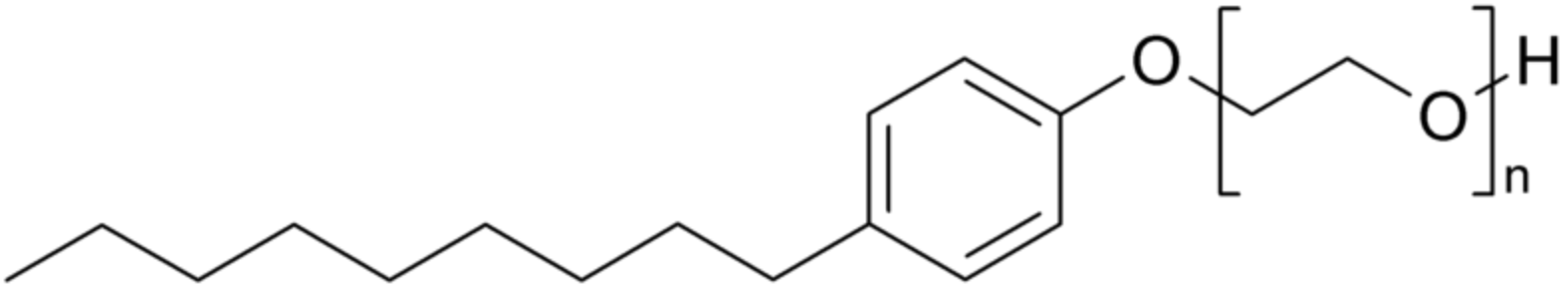
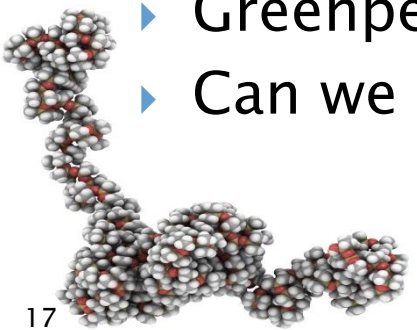
3. Emulsifiers (APEO- and EO-free surfactants)



- Mostly Nonyl
- Lipophilic and Hydrophilic
- Good emulsifying and dispersing properties
- Not toxic in themselves but degradation products are cited
- Greenpeace DETOX
- Can we have APEO- and EO-free too?



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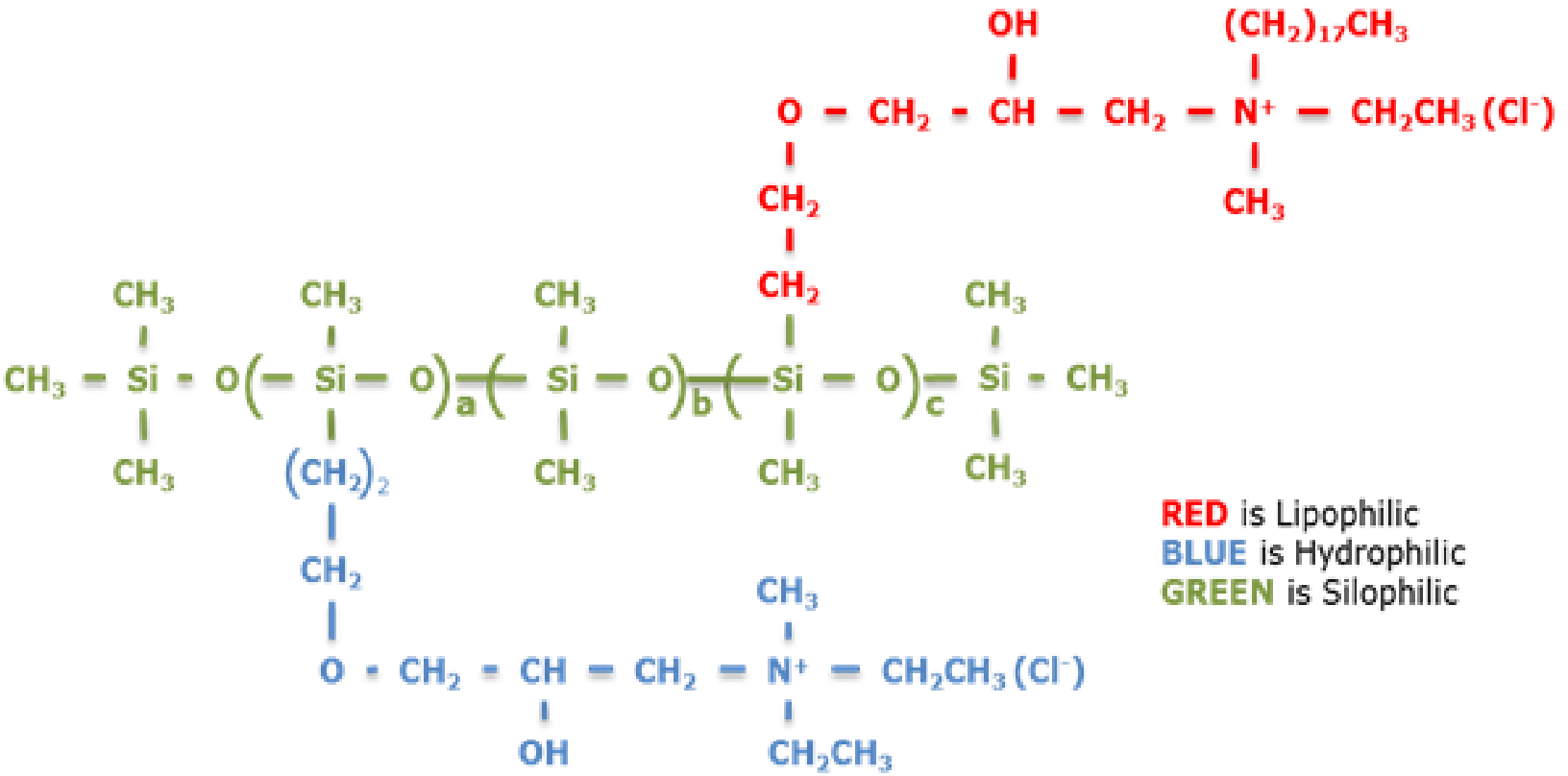
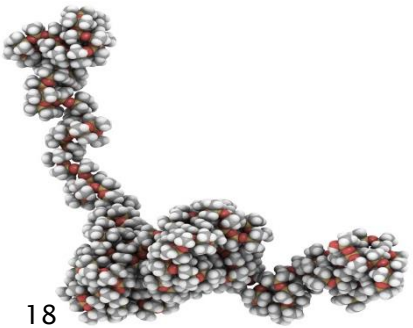
Silquat J2-xB series



RED is Lipophilic
BLUE is Hydrophilic
GREEN is Silophilic



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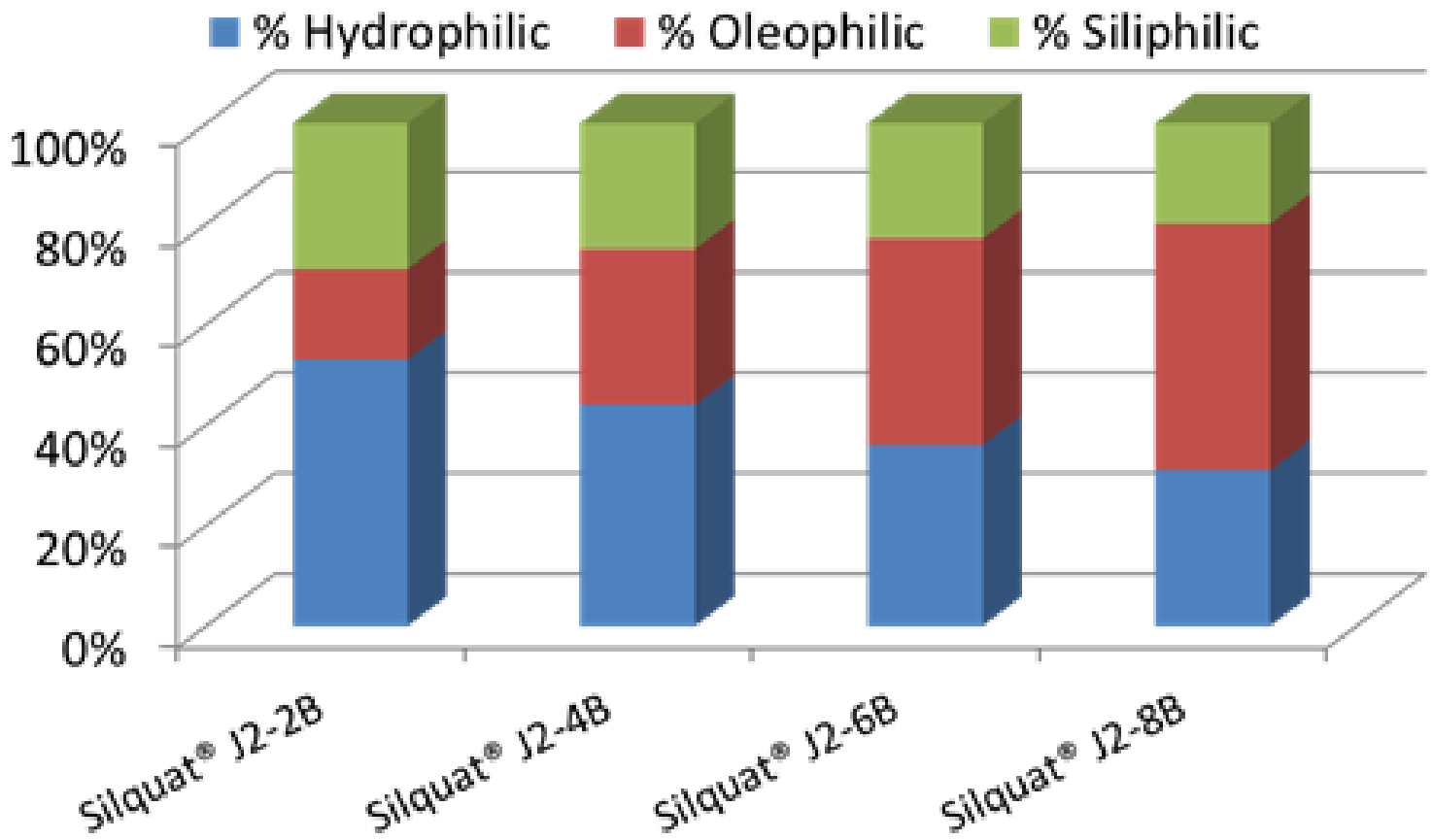
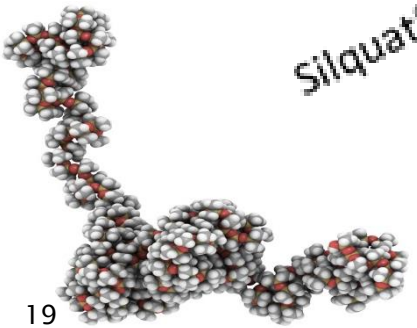
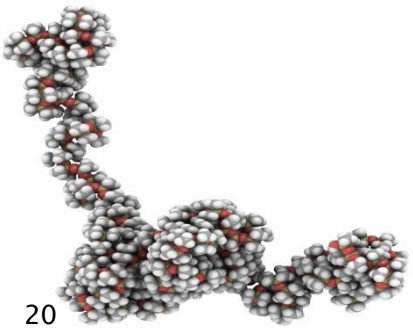
Silquat J2-xB series





4. The Green Trend

- “Green” has come to mean non-petroleum, preferably naturally, derived.
- Silicone itself is derived from silica – the main component of the earth’s crust.
- There is a market need for more natural products.
- A variety of products based on castor oils, peanut, sunflower and essential oils can be made.



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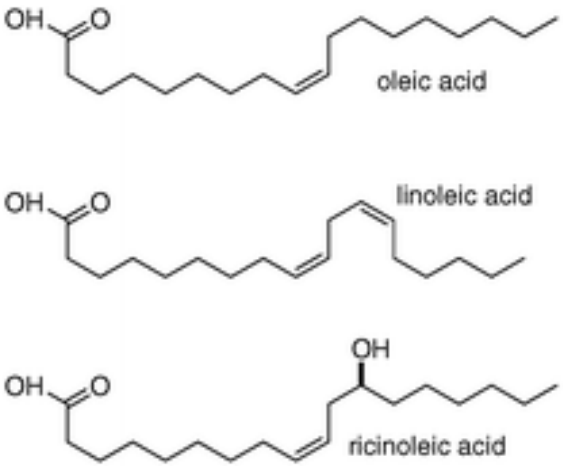
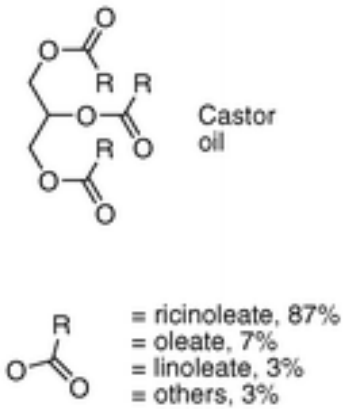
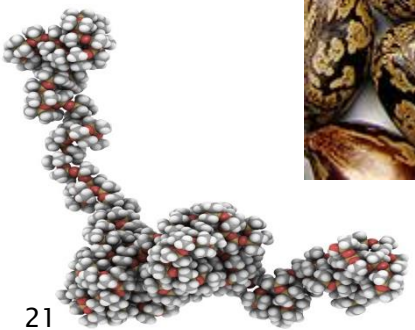
Castor Oil Silicones

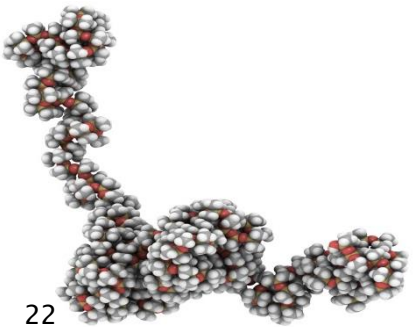






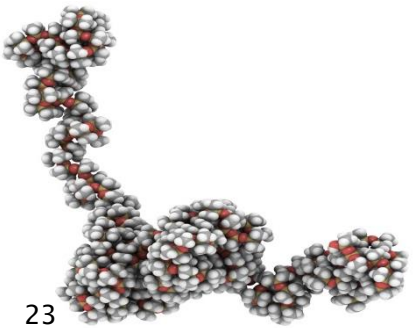
Castor Oil Silicones

1.74% additive in SB/PU	Gloss	Static COF	Kinetic COF	Marker Resist.	Mar Resist.	Coating Appearance
Silmer ACR Di 50	92.2	0.405	0.384	7.500	7.5	Mild waves
Silmer OH Di 50	97.2	0.680	0.745	7.000	7.6	Mild waves
Silube CO Di 45	96.3	1.019	0.945	9.000	8.2	Smooth



Natural oils can be siliconised

Remaining Challenges in Coatings



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Conclusion

- Regulations can foster innovation and result in better and safer chemicals
- We welcome partnerships