



Editors Note: This edition of the Silicone Spectator is presenting a general article on Silicone Chemistry written in 1999. While the paper was written a long while ago the contents are still topical today. We hope you enjoy.

Basic Silicone Chemistry – A Review

Anthony J. O'Lenick, Jr.
Siltech LLC
Dacula, Ga. 30019
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This review has been written with the objective of supplying a working knowledge of the chemistry of silicone compounds to the practicing chemist. It has been divided into two parts, the first dealing with basic chemistry of silicones, and the second dealing with silicone based surfactants.

Despite the fact that silicone compounds have been around for over fifty years, the chemistry of these materials remains elusive to the average formulating chemist. This is indeed unfortunate, since the chemistry of silicon atom and resulting silicone compounds is every bit as wide in scope and rich in content as the chemistry of the carbon atom and the resulting surfactant chemistry upon which it is based.

Whilst the chemistry upon which surfactants are commonly based has been around for almost exactly the same period as that of the basic silicone chemistry, it is only in the past decade that the ability to use silicone as a hydrophobic material in the preparation of surfactants has been common. The recent trend to combine silicone, fatty and polyoxyalkylene moieties in the same molecule has resulted in a plethora of new compounds with new properties.

Introduction

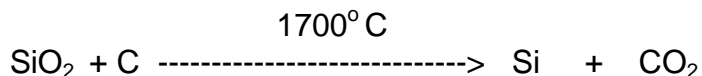
Silicon is the 14th element in the periodic table. Although it does not occur naturally in free form, in its combined form it accounts for about 25% of the earth's crust. Silicone compounds are unique materials both in terms of the chemistry and in their wide range of useful applications. Silicon in combination with organic compounds provides unique properties that function over a wide temperature, making the silicone based products less temperature sensitive than most organic surfactants. These properties can be attributed to the strength and flexibility of the Si-O bond, its partial ionic character and the low interactive forces between the non-polar methyl groups, characteristics that are directly related to the comparatively long Si-O and Si-C bonds. The length of the Si-O and Si-C bonds also allows an unusual freedom of rotation, which enables the molecules to adopt the lowest energy configuration at interfaces, providing a surface tension that is substantially lower than the organic polymers.

One of the most basic technical errors made by people referring to materials is confusing silicon with silicone. The former silicon is used to refer to the elemental material, (Si); the latter to refer to materials in which silicon is bonded to oxygen. Silicon is the most elemental raw material from which all silicone chemistry finds its roots. Since it is not at all common in the metallic form in nature, the first step in the chemistry is to produce silicon from quartz.

The term silicone is actually a misnomer. It was incorrectly thought that the early silicone polymers were silicon based ketones, hence the contraction silicone. Despite this error, the term is still widely used and accepted.

Silicon from Quartz

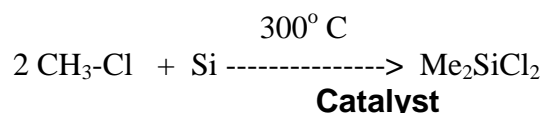
Silicon is obtained by the thermal reduction of quartz (SiO_2) with carbon. The reaction is conducted at very high temperatures and therefore is commonly carried out where there is abundant inexpensive power. The reaction is as follows:



The purity of the silicone is generally at least 99% pure. In addition, certain trace contaminants must also be controlled to obtain a material that is suitable for the preparation of silicone compounds. Since the silicon so produced is a solid metallic material, it is crushed into powder having a particle size of between 100 and 350 nm for reaction in the Rochow process. This process is named after Eugene G. Rochow, the father of silicone chemistry¹. Because of the complicated process technology, and high capital requirements to construct plants suitable to practice the chemistry, few companies actually carry out the Rochow process. Because the silicon is crushed prior to reaction in a fluidized bed, the companies practicing this technology are referred to as "silicon crushers". Because this is an elite group of companies, being referred to as one of the silicon crushers is considered an honor in the silicone world.

Rochow Process - Chlorosilanes from Silicon

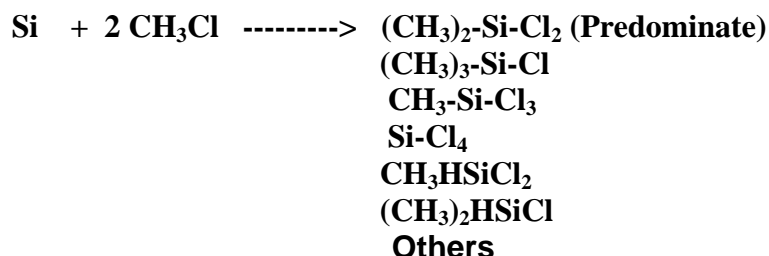
The next step in the preparation of silicone compounds is the reaction of suitable silicon to make products from which silicones may be derived. The Rochow process is the most commercially important reaction in the preparation of silicone compounds. In it methyl chloride is reacted with solid silicon metal, in the presence of copper catalysts and certain promoters to produce a mixture of chlorosilanes. Simplistically, the overall reaction is as follows:



However, a complex mixture of products is actually achieved.

Rochow Process

(SYNTHESIS OF CHLOROSILANES)



The predominant material obtained is dimethyldichlorosilane (approx. 80% by weight). The next most abundant compounds in order of concentration are methyltrichlorosilane (approximately 12% by weight), followed by trimethylchlorosilane (approximately 4%) and methylhydrogendichlorosilane (approximately 3% by weight.). This composition information is very important since it drives the economics of the silicone business. Since every pound of chlorosilanes produced results in the distribution of products described, one must balance allocation of costs of each material in proportion to the amount produced and the demand for each. In order to operate this business profitably one must sell every pound of product produced. This by definition makes this a commodity business. Specialty producers on the other hand make what they can sell and do not have to balance by-product and co-product streams. Since many silicone surfactants are based upon methylhydrogendichlorosilane, a relatively minor component of the silane stream, the cost of these materials is high, relative to silicone fluids, based upon dimethyldichlorosilane.

The reaction to make chlorosilanes is quite complex and is carried out at a temperature of about 300°C, under pressures typically of 3 bars. The reaction mass needs to be heated in order to obtain reaction, but once the reaction temperature is reached, the reaction becomes exothermic, and consequently requires very stringent temperature control. The reaction is carried out in a fluidized bed reactor and occurs in a solid / gaseous reaction. In order to maximize the reaction efficiency, the solid silicon must be low in other metallic components. The fine residue that is extracted from the process is dependant upon the quality of the silicon going into the process but is generally made up of Cu, Fe, Al, and Ca. Consequently, silicon having low concentrations of these elements is desired for the process.

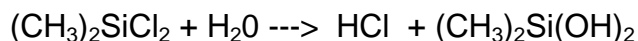
Silicone from Chlorosilanes

Hydrolyzate

The preparation of silicone compounds from chlorosilanes is an important synthetic pathway. The most important process to achieve this transformation is the so-called hydrolysis process. In the hydrolysis process the chlorosilanes compounds produced in the Rochow process are reacted with water converting them into a mixture of linear, and cyclic compounds. The exact composition of the Rochow products, the conditions of pH, concentration of water and temperature of hydrolysis determines the exact composition of the hydrolysis produced.

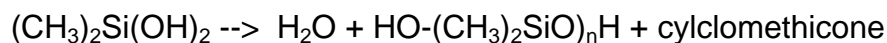
Since the Rochow process produces primarily dimethyldichlorosilane, the reaction of that component with water is shown below;

Hydrolysis of chlorosilane to produce HCl and siloxanediol



This step results in the formation of hydrochloric acid and a siloxanediol. The corrosive nature of the HCl has to be carefully considered and handled in the plant to avoid corrosion of the equipment.

Dehydration of siloxanediol to cyclomethicone and silanols

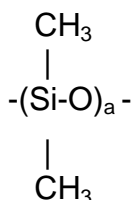


This process results in two types of compounds that are used by the cosmetic chemist. They are silanol (dimethiconol) and cyclomethicone. The former is used in hair gloss compounds and the latter is commonly used in antiperspirant compositions.

Cyclomethicone

Cyclomethicone is distilled from the mixture. The predominate cyclomethicone produced

is D4, with lesser amounts of D5 and D3.



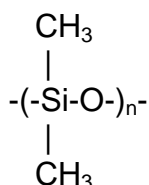
D4 a is 4

D5 a is 5.

The ratio of D4 to D5 in the above reaction is generally 85% D4 to 15% D5. The cyclomethicone mixture distills off the hydrolysis process as an azeotrope. This common azeotrope is the least expensive cyclomethicone composition produced. Since separation of the two from each other requires distillation, the pure D4 is more expensive than the azeotrope and the D5 is still more expensive.

Cyclomethicone Products

Cyclomethicone refers to a series of cyclic a silicone compounds. The structure of which is:



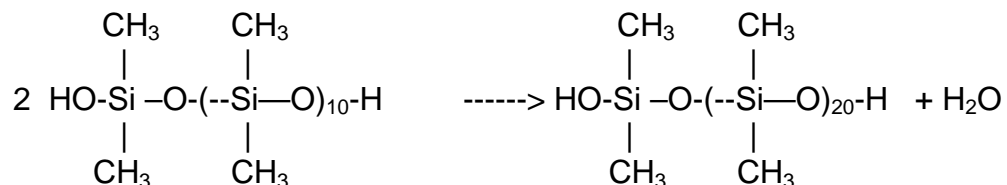
Wherein n is an integer ranging from 3 to 30. It is interesting that the terms "volatile silicone" and "cyclomethicone" are sometimes confused. This is because lower cyclomethicone compounds (n is 3-6) are volatile compounds used in applications like antiperspirants and as cleaning solvents for electronic parts like circuit boards. It is important to realize that all cyclomethicone compounds are not volatile (for example n=30), and likewise all volatile silicones are not cyclic (for example MM). The term cyclomethicone refers to a structure; the term cyclomethicone refers to a physical property.

Cyclomethicone is available in a variety of compositions. Pure D3, D4, and D5 are

available as well as a more common lower cost 85% D4 / 15% D5 composition. This becomes important for skin feel and solubility in many solvents. Volatile, cyclomethicone compounds are much more organic soluble than silicone fluids that are higher molecular weight and are linear.

Silanol Compounds

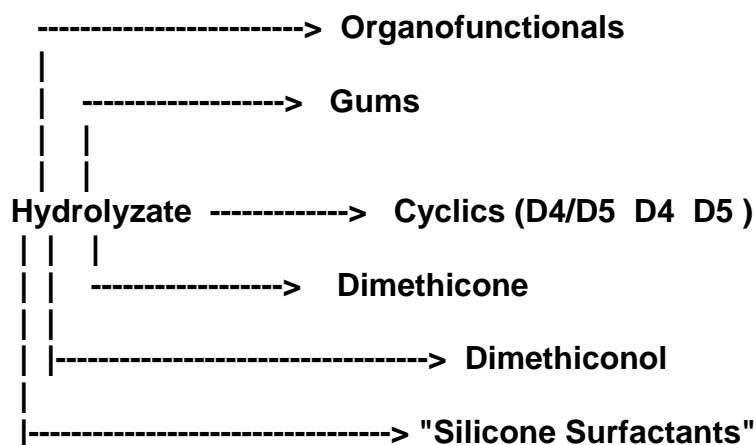
Silanol compounds are also called dimethiconols². These compounds have terminal Si-OH groups present on the molecule. The Si-OH group is reactive toward many organic reactions and is in many regards analogous to the carbanol group CH₂-OH. There is one major exception. The silanol groups can homopolymerize under many conditions to produce water and a higher molecular weight silanol. The reaction is as follows:



Despite the fact that these materials can homopolymerize under certain conditions, these materials find utilization in a variety of applications, most notable waxes, textiles, and personal care applications.

Silanol compounds are available in a range of viscosity from 5,000 to 50,000 cst. These materials by virtue of their hydroxyl reactive groups are raw materials for a sealant, paints and more recently a series of silanol based esters.

SILICONE DERIVATIVES FROM HYDROLYZATE

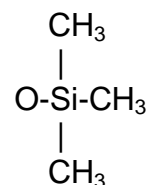


Silicone Terminology

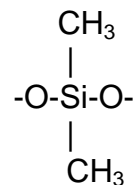
Silicone Backbone Nomenclature

In order to better understand the polymer chemistry, a shorthand has been developed that is more enlightening to the chemist than the name dimethicone copolyol. Developed by Alfred Stock³ in 1916. The nomenclature is based upon the type of groups present in the molecule.

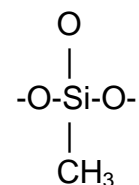
“M unit” is monosubstituted (one oxygen atom on silicon)



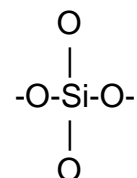
“D unit” is disubstituted (two oxygen atoms on silicon)



“T unit” is trisubstituted (three oxygen atoms on silicon)



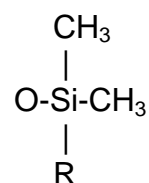
“Q unit” is tetrasubstituted (four oxygen atoms on silicon)



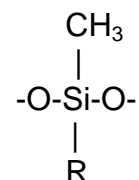
If organofunctional groups other than carbon are introduced, the group is given a “*“

Is added to its designation.

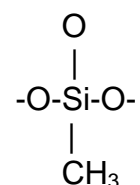
“M* unit” is monosubstituted (one oxygen atom on silicon)



“D* unit” is disubstituted (two oxygen atoms on silicon)
with organofunctionality



“T* unit” is trisubstituted (three oxygen atoms on silicon)
with organofunctionality



There is no “Q* unit” since there is no possibility of functional groups.

One of the most important is that the number of (*) substituents in the polymer can be higher in comb compounds than in terminal structures. The reason is that the number of substituents in the terminal compounds can be no more than 2 (one at each end). The number of functionalized groups in a comb compound can be much larger than 2.

The other major difference is one of economics. The terminal compounds are more expensive than the comb compounds having the same molecular weight. This is a direct consequence of the fact that the raw material for making the terminal products M^*M^* is not abundant in the Rochow Process and is therefore expensive.

There has been an interest in developing a product that is a monosubstituted terminal compound. That is one that has a methyl group on one end and an organo functional group on the other. In fact MM^* is available. However, as you recall the preparation of the silicone polymer is based on equilibration chemistry, even though MM^* is used as a raw material, the resulting polymer is a mixture of 2 parts monosubstituted monomethyl-terminal polymer, 1 part fluid (dimethyl terminated) and 1 part difunctional compound having no methyl terminal group. Since the fluid is not water soluble, a silicone fluid is always present in the reaction mixture.

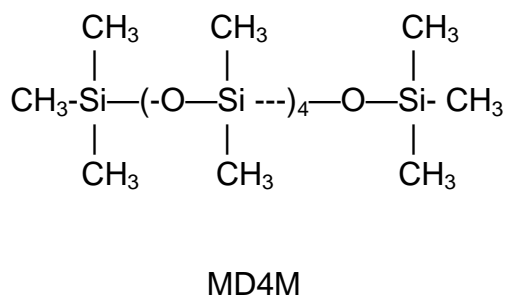
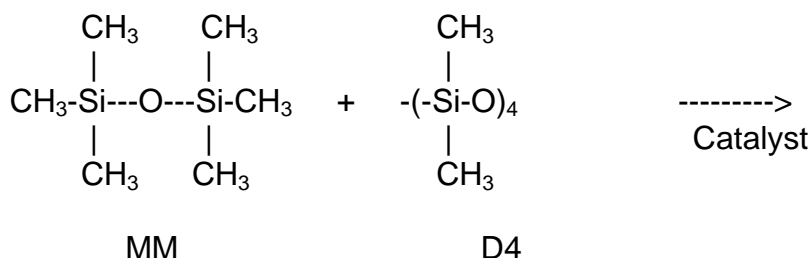
This observation leads to another important concept. In order not to make fluid in a polymer equilibration reaction, there must be a certain number of water soluble functional groups in a comb structure relative to D units as not to produce fluid. Our laboratory has evaluated the minimum number of D units to D^* units needed to make a product that is substantially free of fluid. This was determined by the ability to make a water-soluble product. This observation explains why there are not an unlimited number of products in this class offered commercially.

Silicone Fluids⁴

Synthesis

Silicone fluids are synthesized by the equilibration reaction of MM and cyclomethicone.

Typical of the synthesis of fluids is the following reaction in which one MM is reacted with one D4 compound to make MD₄M, a simple silicone fluid.



The reaction may be run with either acid or base catalyst. Typically, a catalyst might be sulfuric acid at 2% by weight and the reaction conducted for 12 hours at room temperature. The resulting product is a mixture of about 10% free cyclic and 90% linear fluid. If the catalyst is now neutralized and the cyclic stripped off a stable fluid results. If the catalyst is not neutralized during strip, the fluid will degrade back to MM and D4.

The equilibration process is critical not only to produce stable silicone fluids, but as a process to introduce functional groups into the polymer. This will be discussed in more detail in the section on hydrosilylation, a process used to make organofunctional silicone compounds.

It is also quite interesting to note that a "finished silicone fluid" may be placed in contact with D4 and catalyst and re-equilibrated to make a higher viscosity fluid. Conversely, a "finished

silicone fluid" may be re-equilibrated with MM and catalyst to get a lower viscosity fluid. Finally, silicone rubber may be decomposed into MM, and D4 via stripping of the product in the presence of catalyst. This property of silicone polymers makes them decidedly different from organic compounds.

Properties

Silicone fluids, also called silicone oils, or simple silicone are sold by their viscosity and range from 0.65 cs to 1,000,000 cs. If the product is not made by blending two different viscosity fluids the viscosity is related to molecular weight. The viscosity allows for an approximate calculation of the value of "n" in the formula below⁵.

Viscosity 25 C (Centistokes)	Approximate Molecular Weight	Approximate "n" Value
5	800	9
50	3,780	53
100	6,000	85
200	9,430	127
350	13,650	185
500	17,350	230
1,000	28,000	375
10,000	67,700	910
60,000	116,500	1,570
100,000	139,050	1,875

Silicone may be adhered to substrate, including fiber, fabric, metal surface, hair and skin by virtue of one or more of the following mechanisms:

(a) Hydrophobicity - When oil is placed into water, it disrupts the hydrogen bonding between the water molecules in the water solution. This disruption is accomplished only when the energy of mixing is sufficient to break the hydrogen bonds. When the mixing is stopped the oil is forced out of the water by the re-formation of the hydrogen bonds between water molecules. This phenomenon can be used to deliver oil to a surface. Silicone fluids are delivered this way.

Improved properties are obtained by using molecules that have additional mechanisms that include:

(b) Ionic Interactions - The charge on the molecule will also have an effect upon the delivery of the oil to the hair or skin. For example, if the oil has a cationic charge on the molecule, it will form ionic bonds with substrates that contain negative surface charges. The two opposite charges together forms a so-called pair bond.

(c) General Adhesion - If an oil is delivered to the skin or hair penetrates and then polymerizes, there will be an interlocking network of polymer developed. Although not bonded directly to the substrate, this polymer network will adhere to the substrate.

(d) Specific Adhesion - If an oil is delivered to the skin or hair penetrates and then reacts with groups on the hair or skin, there will be a chemical bond between the polymer and the substrate. This is the strongest and most permanent of the adhesion mechanisms.

Silicone fluids react almost exclusively by mechanism (a). To the extent the other mechanisms may be introduced, the more strongly and efficiently the conditioner can be delivered to substrate. Organo-functional silicone seek in large part to capitalize on these additional mechanisms to provide through and efficient conditioning for hair and skin.

Silicone Emulsions

Silicone emulsions are used in both hair and skin care products. The preparation of stable emulsions results in a silicone oil in a micelle, having a fine particle size. The preparation of the emulsion requires the use selection of the proper emulsifier pair and more commonly the use of a homogenizer to obtain a stable emulsion.

When silicone is delivered from a micelle, the energetics of delivery to the substrate is complicated by: (a) the presence of emulsifiers, (b) the type of emulsifiers, and (c) the

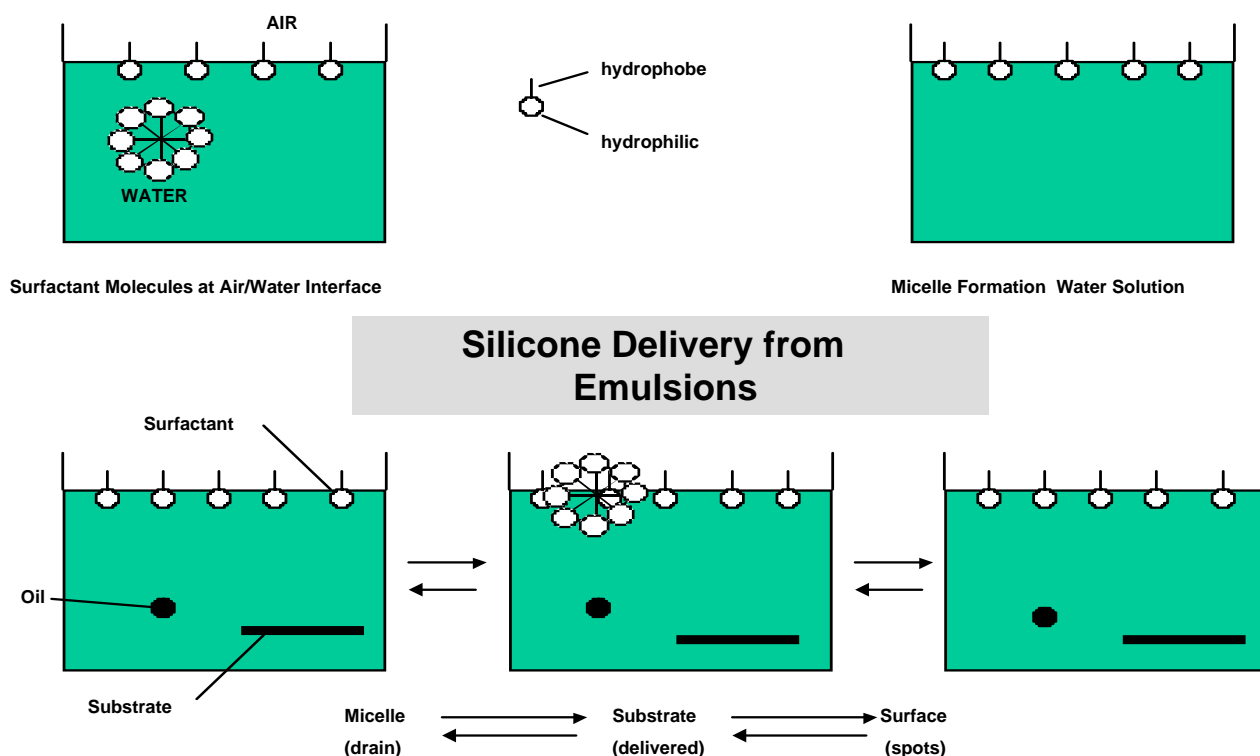
particle size of the silicone. All must be optimized for best performance of the emulsion in the formulation.

Many of the complications of using emulsions for the delivery of silicone to substrates relate to the fact that the silicone is delivered out of a micelle. When surface-active agents are added to water, the first observable effect is that the surface tension at the air water interface drops. As one continues to add surfactant, the critical micelle concentration is reached. At this point micelles are formed. There is an equilibrium between surfactant in the micelle and the surfactant the interface reducing the surface tension. Additionally, the surfactants used have detergency properties. When an emulsion is applied to the skin or hair, the silicone oil is delivered to the substrate that has been wet out by the surfactant at the air water interface. The emulsion breaks and the oil is deposited. However, the surfactant having emulsification properties re-emulsifies some of the oil. The net result is that silicone ends up both on the substrate, in the wash water. This complex equilibrium results in inefficiency when one uses emulsions.

In addition emulsions have some inherent shear instability, and freeze thaw instability. Finally, there are limitations as to the type of additional surfactant that can be added to an emulsion containing system. If the HLB of the formulation is shifted too much, the emulsion will break. Care must be exercised in preparing emulsion-based systems. Happily however, with the proper selection of emulsion and the proper formulation techniques, silicone emulsions can be used in the creation of many emulsions useful in a plethora of applications results. These applications include uses as mold release agents, automotive tire gloss compounds, textile softeners, overspray in web offset printing and antifoam compounds.

Dimethicone and dimethiconol emulsions are used commonly in many industrial and personal care applications. All emulsion products comprise (a) water typically at least 40%, (b) silicone (typically 55%) and the remainder surfactant to make an emulsion. The fact that the silicone is contained in an emulsion by necessity requires that the delivery be from a micelle. Since there is an equilibrium that exists between the silicone on the substrate, like fabric, fiber,

metal, rubber, hair or skin, and the silicone in the emulsion, much of the silicone ends up in the wash water. Not only is this very costly and an inefficient use of expensive raw materials, but there are real environmental concerns since the wash water ends up in the sewer. In order to overcome this limitation, silicone surfactants have been developed that provide non-micellar delivery to the substrate. Silicone surfactants will be covered in a subsequent review article.



Silicone Antifoam Compounds

A. Background⁶

By virtue of their structure, surfactants perform several functions in aqueous solution. Often however, there are processes in which one uses a surfactant for a desired property and does not want the other properties inherent in the surfactant. For example, one may want detergency in a without foam. Modifications of the surfactant molecule offer minimal relief. Consequently,

antifoam compounds are added to many processes.

Antifoam agents are divided into three classes (a) those compounds used in industrial applications (b) those compounds used in applications sanctioned under 21 C.F.R. 173.105, 173.340, or 173.300 and (c) those compounds which have been modified to meet specific performance requirements.

Since most silicone compounds are water insoluble, they simply float on water as oily liquids. This attribute of water insolubility of many silicone compounds makes them useful as antifoam compounds. The term **antifoam** is generally used to denote a compound with the ability to prevent foam from forming. In contrast, the term **defoamer** is generally used to denote a material, which will knock down existing foam. Finally, a **depareating agent** will break up entrained foam. While some types of compounds are better when used in antifoaming applications and some compounds are better when used in defoaming applications, most compounds have properties that make them useful in both applications.

Mechanism of Antifoam

Regardless of the process, there are two mechanisms by which antifoam compounds work. The first is destroying interfacial films, and the other is by impairing foam stability. The former is the more commonly used and the more effective in most applications. A layer of antifoam, by virtue of its insolubility, ends up in between the bubble and where it contacts the water. This dislodges the bubble and breaks it.

Silicone fluids per se have both antifoam and defoaming attributes, they can be modified

by reaction with silica to make significantly more efficient antifoam compounds. Silicone-based antifoam compounds for uses in detergents are composed of two major components: silicone fluid and hydrophobic silica. The fluid polymer acts as a carrier to deliver the silica particles to the foam air-water interface, where film rupture then occurs.

Very efficient antifoam compounds can be prepared by the reaction of silanol compounds with silica. The so-called in-situ hydrophobized silica makes very efficient antifoam compound.

Silicone fluid is clear, colorless; insoluble in aqueous media; has a very low surface tension of 22 dynes/cm; spreads spontaneously in most aqueous solutions; is chemically inert and difficult to emulsify. The hydrophobic particulate silica is extremely effective at breaking bubbles by disrupting the contact point between the foam and water.

The performance of silicone-based antifoam compounds is independent of water hardness. They are effective at very low addition levels in all types of surfactant systems normally present in detergent formulations and are effective across a wide range of use conditions. Furthermore, silicones cause no yellowing on fabric. Thus silicone-based antifoam compounds have a number of benefits over soap-based foam control systems.

100% active silicone-based antifoam compounds are normally referred to as silicone antifoam **compounds**. If the silicone antifoam is in water it is referred to as antifoam **emulsions**. Mixtures of silicone antifoam compounds with non-aqueous dispersion or delivery

systems also exist, to aid their dispersion in aqueous media.

The term emulsion applied to aqueous silicone antifoam is a misnomer. The compositions are actually thickened dispersions. Addition of water will cause them to separate into two layers. If the water is added the dispersion needs to be re-thickened with polyacrylate or a similar thickener.

Industrial Processes

Many industrial processes utilize aqueous solutions and suspensions that include surface-active agents (surfactants). Surfactants produce foam that is detrimental to the efficient conduct of many process. Simple antifoam agents if employed to control foam during these processes but may lead to insoluble material deposition upon process equipment, requiring costly and inconvenient clean up and down time. The insoluble material used for de-foaming may actually deposit upon the surface of the substrate being processed. If this occurs, the substrate will be of inferior quality and may have to be reprocessed to remove insoluble material. Many specially formulated products, designed for specific processes have been developed and are used commercially. In fact, the vast majority of antifoam applications do not use simple antifoam compounds. They rely in fact upon formulated products, sold by companies that supervise the use of the product and in many instances guarantee results.

Some processes that use formulated antifoam compounds specifically designed for the process in which they are utilized include;

Paper Process

In the paper industry the Kraft process is one of the most frequently used alkaline pulping processes. It is valuable in that spent chemicals may be recycled and reused thus decreasing

processing costs. A large disadvantage of this process is the occurrence of foam during the pulp screening and washing procedures.

The Kraft process as taught in U.S. Patent 3,215,635 to Liebling is generally described as being performed by first cooking the wood chips in digesters and then drawing off the spent chemicals for reuse. The resulting pulp fibers are then washed free in brown stock washers of a large amount of residual chemicals. These washers are a series of vats usually three or four in number which alternatively dilute the pulp with water and thicken it by picking it up on large rotary screens. From the brown stock washers, the pulp travels to the screen room where it is again diluted with water and put through vibrating screens that accept the now completely delignified fibers and reject the clumps of unpulped fibers, knots and other foreign material. Foam problems are severe in the screen room since the diluted pulp is subjected to violent agitation by the screens. The water removed from the pulp after the screening operations is referred to as the dilute black liquor and, for the sake of economy, is normally used as the dilution water for the third and fourth stage of the brown stock washers. The dilute black liquor is a foaming material, containing from about 0.001% to 0.1% by weight of solids and has a pH of about 12. The foaming of the dilute black liquor increases with the increase of the resin content of the wood used in this process.

Antifoam formulations are generally used in most alkaline pulp mills during the screening operations so that a more efficient screening is accomplished and to prevent the pulp thickeners, utilized after the screening operations, from becoming clogged with entrapped air. When water dispersible antifoam compounds are used during the screening operation, the control of foam and entrained air in the screening operation contributes to the washing efficiency of the pulp during the alkaline pulping process. This is accomplished by the fact that the screening efficiency of the pulp is increased allowing ease of flow of the pulp throughout the thickeners and subsequent washers.

Paper De-inking

Paper de-inking process uses detergents which can cause considerable undesired foam when performing the desired removal of ink.⁷ The de-inking agents are used in solution in substantially aqueous media. The temperature of the de-inking solution may vary anywhere from room temperature, e.g., 40 - 70 ° F, up to about 200 ° F. Best results are achieved with the de-inking solutions are alkaline in pH. It therefore is desirable that an alkali be included. Although any suitable alkali or alkaline earth metal hydroxide or salt may be employed, the alkali metal hydroxides and salts, such as sodium hydroxide, potassium hydroxide, soda ash and the like are preferred. Enough of the alkali should be added to maintain the pH of the de-inking solution between about 7.0 and 11.5, or even higher, and preferably at least 7.1.

In the de-inking process undesirable foam is encountered most commonly when high temperature and high agitation are experienced. It is also at this time that maximum detergency is needed to remove ink from the paper. Standard antifoam compounds are based upon hydrophobic silica, ethylene bis-stearamide, silicone oils, or mineral oils while effective at the high temperatures and agitation conditions, become insoluble at lower temperatures and deposit on process equipment causing what is commonly referred to as pitch. Control of foam and pitch is critical to efficient operation of a de-inking operation. Silicone compounds, both fluids and compounds, are commonly formulated into products used in this application.

Antifoam Formulations for Textiles

Antifoam formulations are employed in textile wet processing during scouring, desizing, bleaching and dyeing operations. The scouring, desizing and bleaching operations remove foreign materials such as warp size, processing oil, dirt and natural waxes from the fabric. This is done prior to dyeing in order to insure a well prepared substrate that will accept dye evenly.

The processes employ surfactants for wetting and detergency that create foam. Foaming must be controlled in order to maintain proper liquor to goods ratio that insures adequate fabric preparation. Antifoam formulations employed for these processes utilize emulsified hydrophobic silica, silicone oil, mineral oils and emulsified bis-stearamide, waxes in mineral oil

Dyeing processes also employ surfactants that foam as wetting agents and after scour agents to remove loose dye stuff. Foam must be controlled during the dyeing process with materials that do not redeposit on the fabrics.

Detergent Systems

Foam in laundry processes must be controlled. The presence of uncontrolled foam in home laundry applications presents a major consumer problem. Consumers do not want to see any persistent foam in the laundry process, particularly in the rinse step. Antifoam compounds desired for detergent applications must:

1. have the ability to remain effective over a wide range of temperatures;
2. have the ability to be stable over a wide ranges of pH;
3. have the ability to be non-spotting, that is to be rinsed off completely with water;
4. be safe for contact with food.

Antifoam compounds for use in detergents can be found in many type of formulated products including dishwashing detergents and rinse aides, home laundry formulations, home laundry softeners, window cleaners, alkaline metal degreasers, hard surface cleaners, acid cleaning of metals, bottle cleaning formulations and many others.



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