Silicon – the global player in cosmetics

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As a cosmetic agent, the element silicon plays a wallflower role: only at the first glance, though. As a matter of fact, the semi-metal is insignificant as an active agent. However, organic silicon additives and inorganic silicates are widely used in cosmetic products.

Silicon is a semi-metal and well-known as an essential component of chips and transistors. In Earth's crust it is the second most common element and can be found everywhere at our feet as sand, quartz or – in combination with aluminum – in clay, mica and other rocks.

Silicic acid & Co.

When one burns (oxidizes) silicon, then silicon dioxide (SiO_2) (or silica) will form which still today is used in some commercial abrasive hand cleansing products to remove obstinate dirt like tar, dyes or adhesives. These abrasive particles mostly are quartz particles (as e.g. sand from the seashores) which formerly were also applied in cosmetic peelings. Since quartz is a rather hard material, this specific cosmetic application has long since become obsolete.
The related silicic acid is a hydrated (water containing) silicon dioxide with completely different properties. The light powder with extensive surface is generally used as a separating agent for spice blends or table salt to increase the pourability. Silicic acid concentrates in diatoms for instance and is available on the market as diatomaceous earth (kieselgur). It braces the shoots of horsetail plants which in the German-speaking area are also known as "pewter weed" as it formerly was used to polish the pewter ware. Horsetail extracts also contain silicic acid and are used as additives in facial tonics and hair care products. Up to what extent the sales arguments that the product would strengthen skin, nails and hair, can be associated with the silicic acid content remains a secret, though. Astringent horsetail extracts contain further interesting ingredients like saponins and flavonoids. It is worth remarking that both connective tissue and skeleton depend on the intake of silicic acid. The human body contains about 20 mg silicic acid per kg at an average which is assimilated with the daily nutrition. The silicic acid content of beer made of barley and hops can be up to 50 mg silicon per liter.
Finely dispersed (colloidal) silicic acid – also known as aerosil – serves as a consistency agent for non-polar oils like paraffin oil. The results are oleogels (lipogels) which play a certain part in pharmaceutical applications, however, are not accepted in the cosmetic field due to their inconvenient haptic characteristics. An interesting fact is the absorbing capacity of aerosil for oils, a property which allows transforming oils into powders – a technique which is also of interest for processing food.
Silicic acid coated with titanium dioxide and iron oxide can be used in powders and make-up to minimize the appearance of wrinkles. Those raw materials diffusely reflect the light, reduce the contrasting effect of wrinkles and avoid a mask-like effect on the skin due to their skin-identical transparency. Generally, silicic acid is a frequent component of powders (INCI: Silica).
Another form of silicic acid is silica gel. It has a solid consistency and is offered in different grain sizes. It is highly hygroscopic (water-absorbing) and hence serves as a desiccant in laboratories. In the beauty institute, silica gel is used to transfer fresh flower fragrances into skin care oils by drying rose petals in the presence of oils and silica gel in a closed container.

Aluminosilicates

In natural surroundings, there are various minerals in which silicic acid is combined with aluminum oxide: aluminosilicates. The aluminosilicate Kaolin (or china clay) is used as a whitening pigment, as for instance in the manufacturing of powders and make-up. Kaolin forms with the decomposition process of feldspar. Feldspars are tectosilicates and, besides silicon and aluminum, they also contain elements like sodium, potassium, calcium and barium.
Micas belong to the scissile sheet silicates and are used in the field of decorative cosmetics. Micas have specific optical properties and, ground into fine powders, they can be coated with various layers like silicic acid (see above). In combination with quartz and feldspars they form rocks like granite and gneiss which decompose into clay in the course of time. Due to their expansive surface, clays and clayey

loams are processed into healing earth ("Terra sana"). As components of cosmetic packs and masks they absorb the body's own substances and, on the other hand, they release the added active agent components in a controlled way into the skin.
Compared with the removal of cream masks and modelages, however, it is rather laborious to remove the clay after the treatment. An appropriate product in this context is the emulsifier-free cleansing milk. Healing earths can be combined with various physiotherapeutic treatments. The specific property of clay as ion exchanger is still more distinct in zeolites. On a limited scale they even can be used as water softeners (phosphate replacement) or as an additive for bathing products. The aluminosilicate bentonite absorbs enormous amounts of water and forms inorganic, 5-10 % thixotropic gels. In combination with pigments, glycols and oils, bentonite and analogous aluminosilicates even are appropriate ingredients for the manufacturing of liquid make-ups.

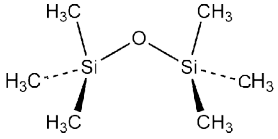
Talc

The naturally occurring talc (soapstone) is a particularly soft inorganic material. In powdered form it is called talcum, a magnesium silicate which feels like a lipid substance. It is a powder component and widely used in the cosmetic field as it facilitates and enhances the application of the powder. Fibrous talcum dusts involve a certain risk, though. Small particles of these dusts may cause granulomas in the lung, similar to asbestos and, they are not biologically degradable. Hence, the cosmetic market today continues to promote talcum free powders.

Silicones

In contrast to silicic acid and silicates, silicones are completely synthetic substances. Actually, their chemical term is siloxanes respectively polysiloxanes as they consist of shorter or longer subsequent silicon-oxygen units (-Si-O-Si-O-). Moreover, every silicon atom has two, and the first and last units of the chain have three hydrocarbyls. If these are two methyl groups we are dealing with dimethicones (dimethylpolysiloxanes) which are widely used in the cosmetic industry.
If the chains are ring-like circular structures, they are called cyclomethicones. Specific cyclic siloxanes are explicitly designated with the prefix cyclo and the suffix siloxane (as for instance cyclotetrasiloxane).
Methicones have only one methyl group at the silicon atoms as well as another hydrocarbyl which is explicitly listed in the INCI as an additive.
Besides the relatively simple basic types there is a multitude of other polysiloxanes. Instead of the methyl groups, there are other hydrocarbyls as well as different functional groups located at the silicon atoms. Accordingly, there are multifarious fields of application. Mainly their hydrophobic and conditioning properties are utilized in the cosmetics field.
There are volatile and liquid polysiloxanes which facilitate the application of the cosmetic products, and there are highly molecular even wax-like representatives which remain on the skin surface. The hydrophobic effect and simultaneously velvety feeling in skin care products is highly appreciated. The smoothening and adhesive effect is used in cleansing products and body lotions as for instance for the re-fattening of the skin. The obviously agreeable feeling on the skin subjectively simulates a skin recovery which objectively is non-existent. A broad field of application is given in shampoos and hair conditioning products.
A small selection of representatives is listed in the following whereas this list is not exhaustive:

Dimethicone (INCI): These siloxanes occur in a broad variety, from lower viscosity like water to higher viscosity, depending on their chain length. The most basic representative with defined chain length is hexamethyldisiloxane (INCI) which has a boiling point of 101°C and is as fluid as water, however, without its typical cooling effect. The fluid and volatile compounds are spreading and softening agents with low surface tension. They are frequently used in antiperspirants and deodorants and generally improve the combability of wet hair. The higher molecular, non-volatile representatives are frequently used in combination with mineral oils as lipid substances in creams as well as water-repellent skin protection products. It is quite a disadvantage for the industrial sector that fingerprints originating from silicone-containing products are quite difficult to remove from the work pieces. That is the reason why in this sector products often are promoted as "silicone free". By the way, this also is a disadvantage in connection with hair products since polysiloxanes may accumulate in the hairs with frequent use of shampoos or hair conditioners.



Hexamethyldisiloxane (INCI)

Cyclomethicone (INCI): This term refers to differently sized non-defined dimethylpolysiloxane rings. The defined cyclopentasiloxane (INCI) consists of a 10-membered ring and is used as spreading agent for highly viscous silicone oils. The combination allows treating hair ends and creating straight and shiny hair. The combability of wet as well as dry hair is improved. The six-membered ring of cyclotrisiloxane (INCI) and the 8-membered ring of cyclotetrasiloxane (INCI) even have stronger spreading properties. Like hexamethyldisiloxane they are volatile. Cyclic siloxanes are contained in lipsticks for instance where they replace part of the non-volatile hydrocarbons. Also deodorant sprays and aerosol products are equipped with these substances.

Alkyl Dimethicone is the generic term for dimethylpolysiloxanes with a methyl group on the silicon atom partly exchanged by a longer hydrocarbyl. Examples in this context are cetyl dimethicone, stearyl dimethicone, C24-28 alkyl dimethicone and C30-45 alkyl dimethicone. If a methyl group is completely exchanged they are called alkyl methicone: hexyl methicone, stearyl methicone, cetearyl methicone, C30-45 alkyl methicone. The mostly wax-like substances are ingredients of skin care creams, sun protection and decorative cosmetic products as e.g. lipsticks, mascara as well as make-up. Long-chained alkyl residues cause occlusive skin conditions, similar to vaseline. Polymerized vinyl dimethicone (INCI) forms wax gels whose viscosity can be adapted with low-molecular siloxanes. Vice versa, it is used as a consistency agent in skin care creams.

Phenyl Methicone (INCI): These compounds contain a methyl and a phenyl group on their silicon atoms. Besides the conditioning properties they also offer interesting optical characteristics as they have the same refraction index as hair. They enhance both radiance and brilliance of the hair. On the other hand they form sliding films and create smooth hair.

Hydroxypropyl dimethicone (INCI) belongs to the dimethyl polysiloxanes with partial, functionalized alkyl groups which affect the conditioning properties due to their increased hydrophilicity. A further addition of propylene oxide and ethylene oxide results in copolymers like PEG/PPG-25/25 dimethicone (INCI). They combine the emulsifying principle of polyethylene glycols (PEG) respectively polypropylene glycols (PPG) with the conditioning characteristics of polysiloxanes. Hence, there is no need for emulsifiers ("2 in 1") or, they serve as co-emulsifiers and have anti-static effects. A common term for PEG copolymers with non-defined chain length is dimethicone copolyol (INCI). In esterified form, as for instance dimethicone copolyol behenate (INCI) they are used as humectants and emollients. Ethers, as e.g. with natural substances like beeswax (INCI: dimethicone copolyol beeswax) are also possible.
Dimethicone copolyol (INCI) and cyclomethicones are cleansing product components as they are able to dissolve lipophilic dirt particles. dimethicone copolyol supports a stable, thick foam and hence is applied in foam baths, shower gels and liquid soaps.

Cationic polysiloxanes are water dispersible like the above mentioned PEG derivatives, due to the fact that the amino groups contained in the alkyl residues, similar to quats, form salts when combined with acids which adhere rather well to proteins. Quaternium-80 (INCI) with its substantial hair coating features belongs to this substance group. Like the non-functional polysiloxanes, it improves the combability of wet and dry hair. It can be used to treat damaged hair ends. In comparison with the hydrophobic dimethyl polysiloxanes it is easier to remove with hair washing. Similar properties have aminopropyl dimethicone (INCI) and amodimethicone (INCI; ethylene diaminopropyl dimethicone). Amodimethicone hydroxystearate (INCI) is an example for a fatty acid salt. Also amides like stearamidopropyl dimethicone (INCI) are synthetized from amines and used as filming agents and corrosion inhibitors.

Dimethiconole (INCI) have Si-OH groups on their chain ends whose polarity improves the hair conditioning and anti-foaming features. It should be mentioned at this point, that the optimal solution frequently depends on a mixture of different polysiloxanes, specifically regarding the hair care sector.
The Si-OH group of the dimethiconole can be etherified in turn; in this case stearoxy dimethicone (INCI) or behenoxy dimethicone (INCI) will form. The ethers and esters as for instance dimethicone stearate (INCI) and dimethicone behenate (INCI) are used as emollients in skin care products.

Finally, also the siliconized silicic acids, as e.g. silica dimethyl silylate (INCI) should be mentioned which is used as a consistency agent.

Generally, silicones are highly tolerable substances and offer an almost universal field of application, i.e. the above mentioned examples only show part of the potential applications. On the other hand, however, they are not com-

patible with natural cosmetics and physiological concepts. In terms of skin sensation they are well accepted, however, unlike physiological lipid substances they do not support the recovery of the skin. In case of problem skins in the context of barrier and cornification disorders, the superficial feeling on the skin may be diametrically opposed to the actual skin condition.

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