

## Consumer Solutions

# The Beauty of Silicone in Hair Care Applications

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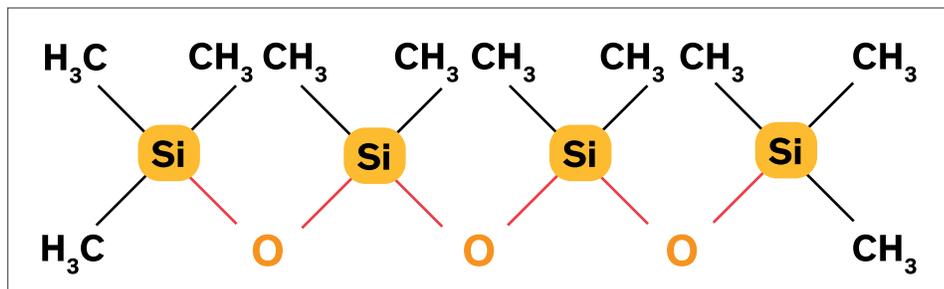
### Introduction

Silicone is a polymer that contains silicon and oxygen atoms. The main chain is Si-O and attached methyl groups. The structure is shown in Figure 1.

The variations on the structure to the right are almost endless, making silicone chemistry almost as broad as carbon chemistry. The following modifications can be made: molecular weight variations or adding organic functionalities, such as polyether, alkyl, amino, resulting in a range of materials, from volatile fluids to gums, waxes, and elastomers. The polymer can be oil or water soluble. Silicones are a very broad chemical family and not a single material.

The Si-O bond is very stable, not easily oxidized, and therefore inert, an advantage when in contact with biological tissues. The bond length of Si-O is 0.163 nm, and its angle is 130°, larger than the bond length of C-C (0.154 nm) and bond angle (112°), allowing oxygen and water vapor to permeate and therefore not interact with skin breathability.<sup>(1)</sup> There is also no evidence on negative impact to the scalp.<sup>(2)</sup> This is demonstrated by extensive silicone use in wound care products, as it can

Figure 1: Polydimethylsiloxane (Dimethicone) structure



avoid skin maceration. Indirectly related to permeability, several silicones among which are dimethicone, silicone wax, silicone polyether, and cyclomethicone, are shown to be noncomedogenic.<sup>(3)</sup> Their low surface tension makes silicone spread very well and also confers hydrophobicity. As a consequence of these physical and chemical properties, polydimethylsiloxanes (dimethicones) from 350 – 12,500 cSt are listed in the FDA Monograph: “Skin Protectant Drug Products for Over-the Counter Human Use; Diaper Rash Products,” issued in 1990. The level needed for a protection claim is as low as 1%. As early as 1953, silicone was used in hand cream to provide protection.<sup>(4)</sup>

### Silicone History in Hair Care

Silicones have been widely used in a range of hair care products since the 1970s. For example, silicones were used in hair sprays for plasticizing styling resins, and in 1975, “Toni” Gillette, a home permanent containing amodimethicone, was launched.

In the mid-1980s, a totally new application, hair serums, was launched. These materials mainly contain silicone gum dispersed in volatile silicones and were positioned to mend hair split ends. They also acted as conditioner for shine, easy combing and smoothness. These products still exist today.

In 1987, Procter & Gamble launched Pert/ Rejoice, a 2-in-1 shampoo that allowed consumers to wash and condition their hair using one product. The formulation was based on a new formulation technology that allowed the deposition of silicone polymer on the hair during the rinsing step – to aid combing while imparting a unique feel to dry hair.

At the end of the 1990s, amino silicones made their entrance in the hair color segment, providing protection against color fade and maintenance of color depth and gloss when added to the colorant formulation itself, but also from shampoos and conditioners in addition to their well-known conditioning performance.

Silicones have been used in hair care products for more than 40 years, but their use is as high as ever, as illustrated in Figures 2 and 3.<sup>(5)</sup> Silicones are present in more than 50% of new hair care products from 2010 to 2014.

### Safe Use of Silicones in Hair Care Products

Silicones are among the most extensively studied materials used in consumer and industrial applications today. Dow assesses the safety of every product that is produced for the personal care industry. In addition, more than 1,000 studies have been conducted by silicone manufacturers to assess the safety of silicones relative to workers, consumers, the environment and manufacturing processes.<sup>(6, 7, 8, 9, 10)</sup>

Silicones are also typically used in antidandruff shampoos as part of scalp care, where they help to counteract the negative impact of anti-dandruff actives on conditioning.<sup>(11)</sup>

Figure 2: Silicone penetration in newly launched conditioners

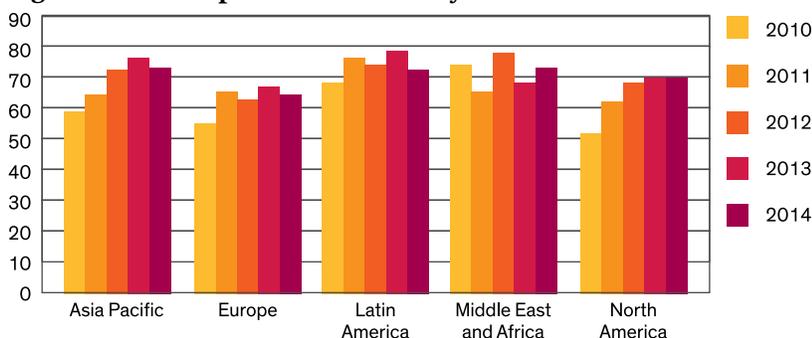
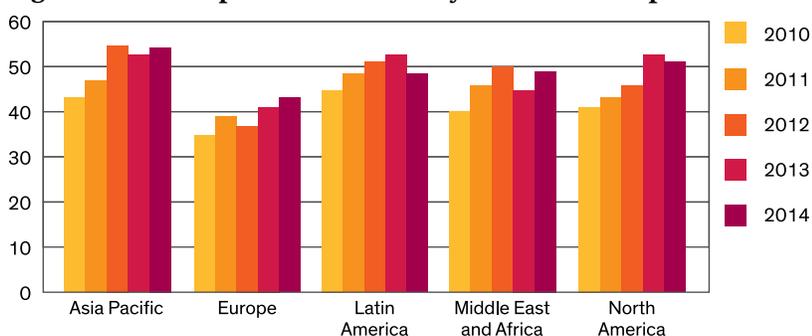


Figure 3: Silicone penetration in newly launched shampoos



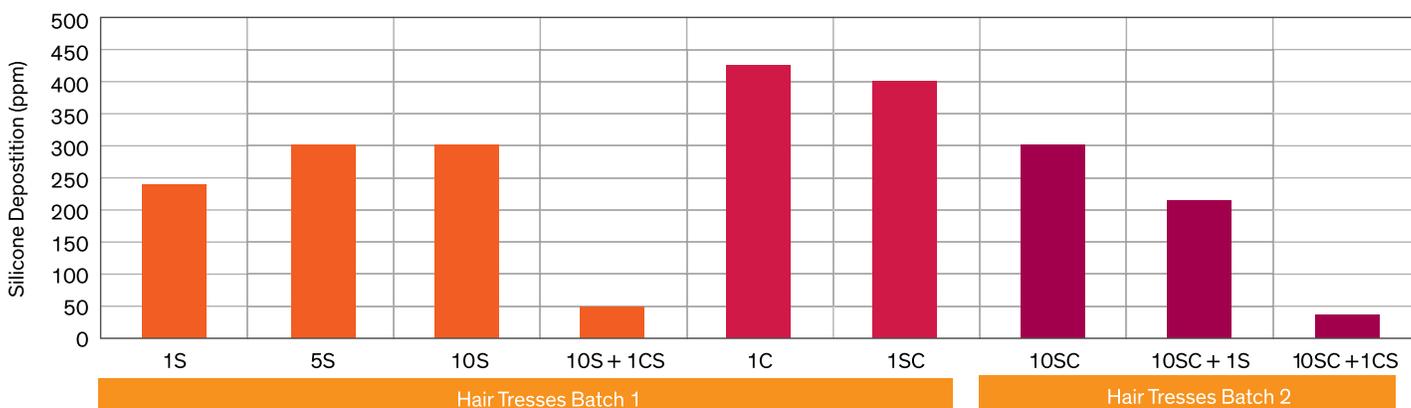
Additional information on the interaction of silicones with the hair and scalp can be found on hair care products manufacturer websites<sup>(12,13,14,15)</sup> highlighting the conditioning benefits of silicones and giving recommendations on which shampoo to select for specific hair needs, with silicone containing shampoos and conditioners recommended for damaged hair.

### Deposition of Silicone

Silicones need to deposit on the hair to provide the conditioning benefit. Many parameters can affect the silicone deposition: the type of silicone, the formulation, the cationic polymer and wash times. Silicones on the hair are easily removed after use of clarifying

shampoo. Figure 4 demonstrates that silicones deposit on the hair after use of shampoo and conditioners containing an amino silicone (DOWSIL™ CE-8411 Smooth Plus Emulsion: Bis-Diisopropanolamino-PG-propyl Dimethicone/Bis-Isobutyl PEG-14 Copolymer (and) Polysorbate 20 (and) Butyloctanol). This is necessary to achieve conditioning benefits, but the level of deposition does not increase with increasing number of shampoos, and the silicone can be easily removed using a clarifying shampoo without silicones (both for hair treated with a shampoo and a conditioner).

Figure 4: Silicone deposition and removal



Treatment: 0.8 g or 0.4 g / 1 g of hair, 1% silicone active Testing: ICP-OES S = Shampoo; C = Conditioner; SC = Shampoo and Conditioner; CS = Clarifying Shampoo (no Si)

### Silicone Benefits in Hair Care Products

Silicones are recognized as multifunctional ingredients in a variety of hair care products. With their unique set of chemical and physical properties, these highly versatile materials not only condition hair, but they can be used to add shine, make combing easier, provide color protection, help guard against damage from heat styling, enhance hair strength, repair damaged hair, give a perception of moisturization, aid curl retention, control frizz and add volume – or even reduce volume. In short, silicones can play major roles – whether in shampoos, conditioners, colorants or styling products.

**Color protection:** Silicones can help colored hair last longer, retain its vibrant look, and protect and enhance color and shine. Rinse-off conditioners containing different types of silicones have shown increase in color retention for hair that has been colored.<sup>(16)</sup>

#### Heat Protection

Protecting hair from excessive heat is clearly a need among many consumers. Hair dryers and other heated appliances first soften the keratin of the hair. If the appliances are too hot, they can actually cause water in the hair to boil, forming minute bubbles of steam inside the softened hair shaft, weakening the fiber and potentially leading to total fracture. Silicones are thermally stable and spread easily on the hair, forming a protective film to help prevent water loss from the hair shaft caused by the heat of dryers or heated styling tools.

#### Hair Strengthening

Heat, styling and color treatments are not the only causes of hair damage. Even common grooming habits like washing, towel drying and brushing can cause hair breakage. Silicones were evaluated for hair strengthening benefits using single fiber tensile measurements. Fiber treated with silicones exhibited higher load

**Table 1: Hair protection benefits for amino silicone**

DOWSIL™ brand Product	Protection						Conditioning
	Color		Heat		Strength		
	R/O	L/I	L/I	St	L/I	Si	
DOWSIL™ 8500 Conditioning Agent	●	●	●				Moderate
DOWSIL™ 2-8566 Amino Fluid	●	●	●				Moderate
DOWSIL™ AP-8087 Fluid	●	●					Moderate
DOWSIL™ CE-8170 AF Microemulsion	●						Moderate
DOWSIL™ 5-7113 Silicone Quat Microemulsion	●	●	●		●	●	Intensive
DOWSIL™ CE 8401 Emulsion	●		●				Intensive

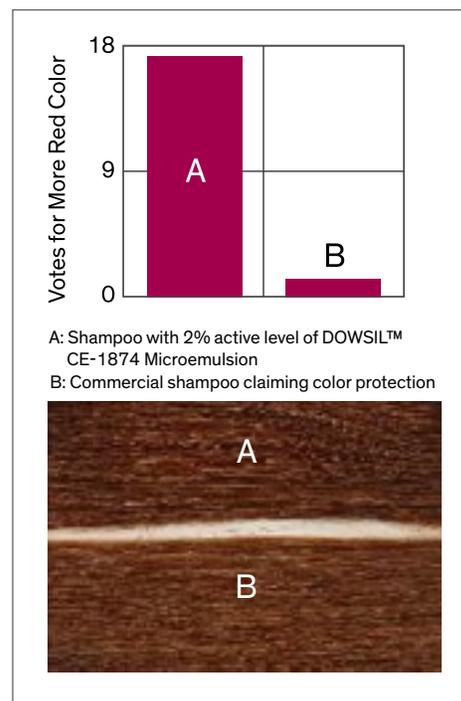
R/O = Rinse off; L/I = Leave on; St = Styling ● Excellent fit ● Good fit

resistance compared to untreated fiber, demonstrating hair strengthening benefits in leave-in applications.<sup>(17)</sup>

Amino silicone fluids (neat or in emulsion form) are examples of a silicone polymer that can provide a broad range of benefits for color protection, heat protection and strengthening as illustrated in Table 1.

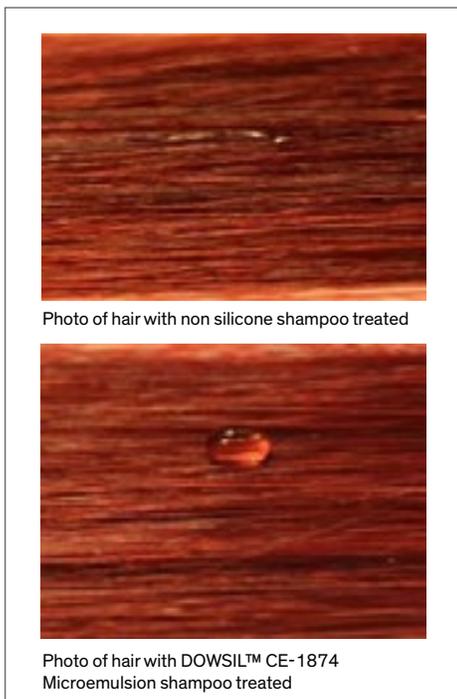
Because of their versatility in chemical structure and the way they can be delivered, silicones can also be used in clear systems, both shampoos and conditioners, extending the possibility for formulators to make clear hair care products without compromising on the performance. Recently Dow launched a new silicone polyether microemulsion, DOWSIL™ CE-1874 Microemulsion, which can be used in clear shampoos and rinse-off conditioners to provide shine, repair, color protection and smooth light feeling. The performance is illustrated in Figures 5 and 6.

**Figure 5: Hair color protection performance of DOWSIL™ CE-1874 Microemulsion**



Compared with a commercial benchmark, shampoo with DOWSIL™ CE-1874 Microemulsion had excellent hair color protection performance.

**Figure 6: Repair the damage hair with DOWSIL™ CE-1874 Microemulsion**



The shampoo with DOWSIL™ CE-1874 Microemulsion can repair damaged hair and restore the hair’s original hydrophobic property.

Another area where silicones are broadly used is leave-on conditioners, such as cuticle coats and hair oils (with significant growth in the market over the last 2 years). Volatile silicones, silicone gum, phenyl silicone, water soluble silicone, silicone emulsion and silicone resin can be added to leave-on conditioners to provide shine, smoothness, styling and ease of spreading. The silicone level in cuticle coat or hair oil is usually more than 10%. Table 2 illustrates an innovative formulation for a clear foaming hair oil.

**Table 2: Foaming hair oil formulation**

	Product name	INCI name	%
A	DOWSIL™ MQ-1600 Solid Resin	Trimethylsiloxysilicate	10
	Créasil® ID CG	Isododecane	20
B	Créasil® ID CG	Isododecane	7.5
	Isopar™ L	C 11-13 isoparaffin	20
	Klearol®	Mineral oil	30
	DOWSIL™ 556 Cosmetic Grade Fluid	Phenyl Trimethicone	5
	Jasmine Oil L.C.	Jasminum Officinale (Jasmine) Oil	2
	Almond Oil Flo	Prunus Amygdalus Dulcis (Sweet Almond) Oil	2
C	Argan Oil	Argania Spinosa Kernel Oil	2
	DOWSIL™ 2503 Cosmetix Wax	Stearyl Dimethicone	1
	Blanova Vitamin E Acetate	Tocopheryl Acetate	0.5
	Jasmine Absolute Indian Conventional	Jasminum Officinale (Jasmine) Essential Oil	q.s.

This foaming hair oil gives a unique sensory experience that tames frizz and boosts shine. Lightweight and non-greasy, it leaves hair smooth and easy to comb and style.

**Conclusion**

Silicones have very unique chemical structures and physical properties such as gas permeability, low surface tension and high stability, which translate into water and oxygen permeability, safe use in cosmetics and unique sensory properties, such as easy spreading and smooth feel on hair and skin. In hair care, silicones can

provide the following benefits: hair color protection, heat protection, hair damage repair, hair strengthening, hair shine and smooth feel. Silicones can be used for all hair types and across all hair care products such as shampoos, rinse-off conditioners, hair masks, hair sprays, hair serums, hair oils, styling products and dye creams, both opaque and transparent.

For more information on silicone in hair care application, please visit Dow’s website: [consumer.dow.com](http://consumer.dow.com).

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