The benefits of silicone as a production material and how it compares to common plastics [Whitepaper].

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What is Silicone?

Silicone is derived from the element silicon, which is naturally occurring. Silicon dioxide, for example, can be found in sand and quartz. However, there is an important distinction between silicon and silicone. Silicon is a naturally occurring element, whereas silicone is synthetic [3]. It is a man-made rubbery or liquid substance which is commonly used in many industrial and commercial applications, such as for sealants, adhesives, lubricants, medicine, cooking utensils, and thermal and electrical insulation (wikipedia).

Silicone is produced by combining the element silicon with other elements, such as oxygen. Silicone comes in many different forms, such as silicone oil, rubber, grease, caulk, and resin. There's a reason why the battle of silicone vs plastic has been quietly gathering pace and why silicone has become so popular as an alternative to plastic over the years and has been used in various industries [3].

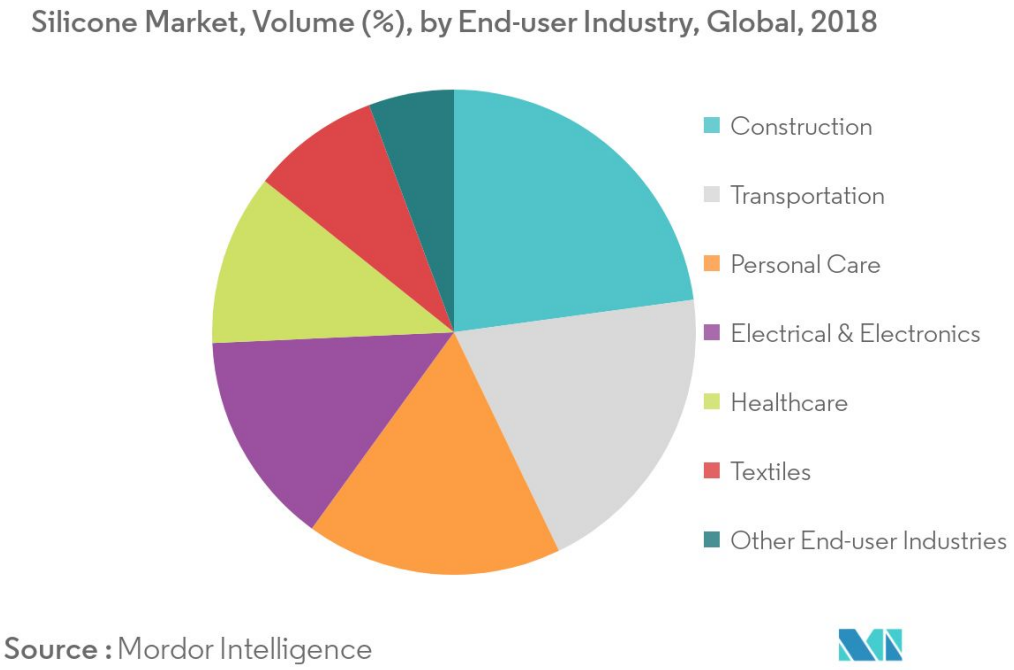

Figure 1. Silicone Market by Industry,
(Image source)

Technically, silicone could be considered part of the rubber family. But, if you define plastics widely, silicone is something of a hybrid between a synthetic rubber and a synthetic plastic polymer. Silicone can be used to make malleable rubber-like items, hard resins, and spreadable fluids. The flexible yet strong material, which has proven popular in muffin pans, cupcake liners, spatulas and other utensils, can go from freezer to oven (up to 428 degrees

Fahrenheit), is non-stick and stain-resistant, and unlike conventional cookware, comes in a range of bright and cheery colors [7].

Types and applications of Silicone

We can draw the distinction between silicone used in the production of other products, or finished products made solely from silicone.[12]

Silicone products

Lubricants

- Silicone greases and fluids are PDMS (silicone oils). They are used as lubricants on rubber parts and in bearings and gears with rolling friction to maintain the functioning of machines. They are also used in food packaging and processing plants, as release agents on a wide variety of materials and equipment. It is also used as a food additive (E900), in shampoos, and as an anti-foaming agent in beverages or in lubricating oils.
  Silicone lubricants are also commonly found in the home, being used for lubricating furniture, or even in personal and medical lubricants.
  PDMS are a combination of silicon, oxygen, and carbon - when combined with a cross-linking agent, they become an inert, non-toxic, clear oil.

'Rubber'

- Many household utensils which are in direct food contact, e.g. baking molds, spoons, spatula, containers, gaskets and ice cube trays, are composed of silicone rubber. Baby soothers and feeding teats are also commonly made of silicone rubber.

  Silicone rubbers are produced on the basis of silicone fluids by cross-linking the linear molecules. In a process called high-temperature vulcanization (HTV) the cross-linking reaction is catalyzed by the addition of peroxides at high temperatures. HTV generates by-products, which can be removed by heating the final product before use. Alternatively, silicone rubbers are synthesized by cross-linking linear silicones containing functional groups (e.g. vinyl or hydroxyl) in the presence of catalysts (e.g. tin- or platinum based) and suitable reagents. These processes are named room temperature vulcanization (RTV). Depending on the underlying chemistry, one- and two-component systems are commercially available (RTV-1 and RTV-2).

Silicone used in the production of other products

Resins

- Silicone resins are commonly used as anti-stick coatings on kitchen utensils and in food processing factories.
  Silicone resins are made by cross-linking linear silicones, which provide additional OH-groups in the backbone as branching points.

Industrial additives

- Silicones are further used as additives in thermoplastic polymers to enhance the flow during manufacturing, the fire resistance and the surface finish of the product. Further, silicones find application in the pulp and paper industry as defoamers, additives and for de-inking. Silicone-containing plastics, paper and board is commonly used in food packaging.

Silicone vs plastic comparison

(Sources: 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13)

Aspects	Silicone	Plastic
Resistance	Silicones have plastic-like properties: flexibility, malleability, clarity, temperature resistance, and water resistance. Silicone has good high and low temperature resistance and good air permeability, especially good high temperature aging resistance. Thus, it is lasting longer.	Excellent in impact resistance and chemical resistance as well as in electrical properties and low temperature resistance. It is lightweight with a high strength-to-weight ratio, water resistant, and shock resistant. However, plastic has a low melting point, is highly malleable, and can be molded easily into basic or complex forms.
Durability	Silicone is highly durable, making it great to use as an adhesive, sealant or as insulation since it is capable of withstanding both high and low temperatures. Silicone can also be used for freezer storage, and will resist cracking or other deterioration that can result when using plastic containers in the same conditions.	The durability of plastic is both a blessing and a curse due to its long-lasting nature. A plastic water bottle holds our drink without leaking or making it too heavy to carry. Regarding the effect of temperature, plastic bags have a low melting point and aren't suitable to be used for freezer storage.
Ease of Use	Like plastic, it can be shaped or formed, softened or hardened, into practically anything. Silicone is easy to clean, nonstick, and non-staining, and so popular for cookware and kitchen utensils, too. And while water resistant, it is also highly gas permeable, making it useful for medical or industrial applications where air flow is required. There may be some small annoyances when using silicone over single-use plastic. Silicone	Plastic can be manufactured inexpensively and mass produced, can be molded easily into basic or complex forms or formed and softened or hardened into practically anything. Single-use plastics were made for convenience, and are strong and yet lightweight.

	bags tend to take up a little more space in the freezer compared to plastic Ziploc bags, for example. But it's a small price to pay for reducing plastic use.	
Health and Safety	Silicone is generally considered safe to use with food and drink. Kitchen and bakeware products made from silicone are often marketed on the basis that they're safe. They're non-toxic, inert, can be heated as well as frozen and do not release any odours into food when cooking. Although there are some potential risks to be aware of. For example, there is concern that, when heated to high temperatures (above 149°C) silicone becomes less stable. It may also leach certain undesirable compounds known as siloxanes. Siloxanes are considered potential endocrine disruptors and some have been linked to cancers. In the meantime, one way to mitigate the risks of leaching is to buy silicone products that are marked as 'food grade.' Food grade silicone may still leach, but it does mean that it doesn't contain any chemical fillers. Unlike most plastics that are made from oil-based materials and contain BPA, latex, lead, or phthalates. Silicone has a backbone made of silicon which is a naturally occurring element and is the second most abundant element in the earth's crust, following oxygen.	Plastic particles or microplastics have been found in tap water around the world, in the oceans and in flying insects. A recent investigation in Italy also found microplastics present in soft drinks. In birds, the ingestion of plastic has been found to remodel the tiny fingerlike projections inside the small intestine, disrupt iron absorption and add to stress on the liver. The 8 million tonnes of plastic dumped in the sea each year is also the target of increasing campaigns, by the UN and others, mainly because of the dangers it poses to sea life. Many fish and other marine creatures consume the plastics, sometimes confusing them for food. Many plastics also contain BPA, latex, lead, or phthalates. Growing scientific evidence suggests BPA and phthalates may be associated with a variety of health issues, including hormonal and developmental problems.

Environmental Protection	Silicone generally has better environmental protection performance (such as no harmful chemicals) than common plastics. Unlike plastics that break down into dangerous microplastic pieces that can be ingested by wildlife and ocean life, silicone doesn't break down much at all. However, silicone is not biodegradable. Some argue that silicone's lack of biodegradability can be alleviated through good recycling practices, but it can be exceptionally difficult to recycle silicone at local recycling centres.	Millions of pieces of plastic are entering oceans around the world every day. This is directly linked to the deaths of 1 million seabirds every year. Plastic waste will take hundreds of years to break down. During this time, it will break down into increasingly small pieces until it becomes microplastics which are now thought to be entering the food chain and our bodies. Many plastics cannot be easily recycled, leading them to be disposed of in landfill. Bioplastics which are biodegradable or compostable are becoming increasingly common, but they still only account for a fraction of the global plastics output (around 1%).

Further reading about plastics compared to other materials

Read another Sofeast whitepaper to learn more about other alternatives to oil-based plastics.

What are Silicone's most useful properties: high durability, temperature tolerance?

Silicones have plastic-like properties: flexibility, malleability, clarity, temperature resistance, and water resistance. It also has good high and low temperature resistance and good air permeability, especially good high temperature aging resistance [7]. Thus, it is longer-lasting than other production materials when exposed to extremes. Like plastic, silicone can be shaped or formed and softened or hardened into practically anything [3]. It's easy to clean, nonstick, and non-staining, and is popular for cookware and kitchen utensils, too [6]. And while water resistant, it is also highly gas permeable, making it useful for medical or industrial applications where air flow is required [7].

Silicone is far longer lasting than plastic and endures extreme fluctuations in temperatures – from very cold to oven hot – without melting, cracking or otherwise degrading [2]. Reusable plastic containers may last a year or a few years if they are hand washed, but they end up getting scratched, foggy, broken and needing to be retired from use much sooner than similar items made from silicone [11].

Silicone is generally considered safe to use with food and drink. Kitchen and bakeware products made from silicone are often marketed on the basis that they're safe. They're non-toxic, inert, can be heated as well as frozen and do not release any odours into food when cooking [4].

When silicone degrades in the environment, is it as 'bad' as plastic?

Unlike plastics that break down into dangerous microplastic pieces that can contaminate the food chain, silicone doesn't break down much. However, silicone polymer (PDMS = polydimethylsiloxane) degradation will be relatively rapid during the warm months of summer, but will be slow during the cool, rainy months of fall, and may continue after the soil freeze-dries in winter. In addition, tropical soils contain minerals which are more reactive to PDMS than temperate soils, and PDMS degradation is expected to be up to ten times faster in tropical soils [14].

Sources

Aside from hyperlinks within the text, these sources have also been used to collate this information:

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