The Chemistry of Fabric Softener

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History

The history of fabric softener begins in the early 20th century. The product was originally called “cotton softener” because of its intent to combat the roughness that occurred when cotton was dyed. It became a major home product in the 1960s when companies such as Procter and Gamble began marketing it. Fabric softener comes in two forms, a liquid, as it has always been, and dryer sheets [1].

Dryer sheets did not get their start until the late 1960s. Before the invention of dryer sheets, it was necessary to return to the washing machine during the rinse cycle in order to add liquid fabric softener. However, this changed when Conrad J. Gaiser, a chemist in the soap and detergent industry, wanted to make laundry easier for his wife. He constructed the first dryer sheet by applying liquid fabric softener to a piece of cotton. He obtained a patent for his creation in 1969 and sold the rights to Procter and Gamble, who sold the product under the brand name Bounce. Over the course of the next several years, the product underwent further development and improvement, and by 1975, it had gained widespread national use [2].

A 1970s advertisement for Bounce dryer sheets [3].

Although dryer sheets were created to be the more convenient form of fabric softener, this has not equated to the obsolescence of the liquid form. In reality, liquid fabric softener remains more widely used than dryer sheets. In the United States, annual sales of liquid fabric

softener total around $700 million, while annual sales of dryer sheets total around $400 million [1].

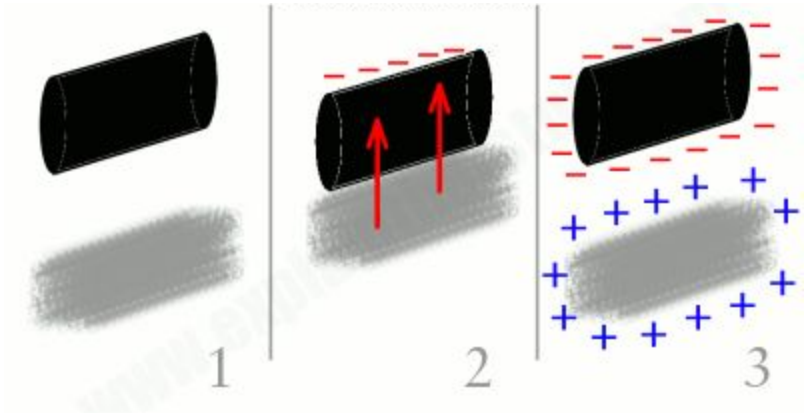
How and why is it used?

Liquid fabric softener is added during the rinse cycle. This is because liquid fabric softeners are typically cationic (containing positively charged ions), while detergents are anionic (containing negatively charged ions). If the two were to be combined, a solid, called a precipitate, would form from the reaction of the two liquids. Dryer sheets, alternatively, are simply placed in the dryer before starting it [2].

Fabric softener is used today to achieve a range of effects. Firstly, it is tasked with preserving and increasing the softness of laundry items. In addition, modern fabric softener is also expected to reduce static cling (discussed in "What is static cling?"), prevent the formation of wrinkles, promote color retention, protect against stains, and add fragrance. It must also be safe, affordable, and environmentally conscious [1].

What is static cling?

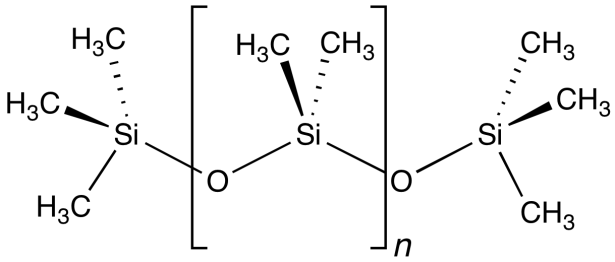
Static cling, or the electrical attraction between two materials that causes them to "cling" to one another, is a result of the same phenomena that generates static electricity. When two materials of differing electron affinity come into contact with one another, the material whose atoms have a greater electron affinity will gradually attract the electrons from the other material; the flow of electrons in this manner is known as static electricity [6]. The end result of this transfer is that the electron rich material gains a negative charge (see diagram from "How Static Electricity Works" to left), and the material which lost electrons gaining a positive charge. Some common examples of static cling include balloon's tendency to stick to various surfaces after being "charged" by application of friction, and in clothing following the drying process [4]. With respect to laundry in particular, the materials involved are two different fabrics, either separate articles of clothing or a weave of differing fabrics, that experience repeated contact and electrons become concentrated in the fabric electron affinity. This difference in charges is what causes clothes to stick to one another and feel uncomfortable as they cling to the skin [5].



What is fabric softener made of?

Originally, liquid fabric softener was composed of a mixture of seven parts water, three parts soap, and one part olive, corn, or tallow oil. As chemistry advanced over the course of the 20th century, dihydrogenated tallow dimethyl ammonium chloride (DHTDMAC) came into use as a common ingredient. DHTDMAC is an example of a quaternary ammonium compound, also called a “quat.” [1] Quats are cations with the structure NR_4^+ , where R is either an alkyl or aryl group [7]. Both alkyl and aryl groups consist of carbon and hydrogen atoms, but the alkyl group takes the form of a chain, while the aryl group is a ring [8].

However, quats have the unfortunate side effect of making fabrics less absorbent, which poses a problem for use with certain items, such as towels. To combat this problem, modern liquid fabric softeners use formulas that combine quats with other ingredients. Today, fabric softeners use ingredients such as polydimethylsiloxane (PDMS), amine-functional and amide-functional silicones, and silicone gums [1]. These synthetic compounds are each variations on the rubbery material silicone, which is made up of a chain of silicon and oxygen atoms bonded to groups of carbon and hydrogen [9].



Structure of polydimethylsiloxane [10]

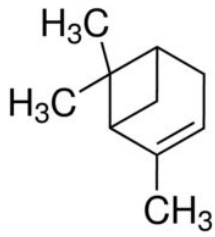
Oil and water do not mix [11].

Because these compounds are oily, an emulsifier must be added to stabilize the fabric softener. Without the emulsifier, the oily components of the softener would separate like oil does when poured into a cup of water. Additionally, liquid fabric softeners contain color and fragrance in order to appeal to consumers, and preservatives to make the finished product shelf stable [1].

Dryer sheets are made of pieces of nonwoven polyester fabric coated with a softener. Different companies that produce dryer sheets tend to use different softening agents. For example, Procter and Gamble (producer of Bounce dryer sheets) uses quaternary ammonium salts, while Unilever (producer of Snuggle dryer sheets) uses stearic acid, a fatty acid. Along with these chemicals, fatty alcohols and alcohol ethoxylates are also commonly used in softeners [2].

No matter what softening agent is selected to be used in dryer sheets, it is imperative for it to have a reasonably high melting point. Without a high melting point, the softener could start to melt while still in the box, causing the dryer sheets to become sticky [2].

Finally, dryer sheets are coated with fragrance molecules to increase their appeal to consumers. These molecules are chosen for their ability to withstand the high temperatures inside the dryer, which range from 125 to 135°F [13]. Unlike softening agents, it is not easy to find what chemicals are used to create fragrance in dryer sheets. This is because manufacturers are only required to disclose active disinfectants and known hazardous chemicals on their labels. However, a 2007 study by a University of Washington professor showed a studied dryer sheet to contain the moderate irritant alpha-pinene [14]. For more information on the adverse effects of fabric softener, continue to the section "Objections to Fabric Softener."



Structure of alpha-pinene [12]

How is it made?

Liquid fabric softeners are created by heating ingredients in a large, high quality, stainless-steel vessel, also known as a batch reactor. Vessels are hollow containers used to contain chemical processes while batch reactors are a type of reactor in which chemicals can react over an extended amount of time to create a “batch” of products. Since so many people use fabric softener, these reactors must be extremely large. With this size of reactor, engineers must make sure they are always in a safe and working order. These vessels typically have a jacketed shell, allowing steam and cold water to be circulated for temperature control. This feature functions as a more efficient method to create fabric softener while also allowing engineers to keep the environment safe. The tank has propeller type mixer which is controlled by a large electric motor to mix the ingredients.


Batch Reactor [17]

The first step to make liquid fabric softener is to fill the tank with a specified amount of deionized water, since the water acts as a carrier for the other ingredients. Deionized water is used because if the water contained metal ions, it could affect the performance of the batch, potentially leading to a poor quality or even dangerous batch. Formulations for fabric softeners can contain as much as 80-90% water. Next, the tank is heated using streams of hot water and mixing is initiated. When the water reaches the correct temperature, the emulsifiers are added, typically at temperatures between 70-80°C. High temperatures are used since the emulsifiers tend to be waxy, solid materials and high temperatures make it easier to work with them. For most formulations, emulsifiers make up between 1% and 10% of the contents. Next, conditioning ingredients are added, but since the conditioning ingredients used in softeners are not typically water soluble, they are added after the emulsifiers. A typical strength formulation consists of about 5% while more concentrated formulations usually use 10%.

Once the water, emulsifiers, and conditioning ingredients are added, the addition of silicones can happen in two ways. For pre-emulsified silicones, they are added late in the process at lower temperatures and when there is less mechanical agitation in the batch. When higher molecular weight silicones that have not been pre-emulsified are used, they are added to the batch at high temperatures with a high level of agitation to ensure an even dispersion of silicone oil droplets.

After these ingredients have been added to the batch reactor, they are ready to undergo the final processes. The ingredients are heated using more hot water streams and are mixed using the large motorized mixer until the batch is homogeneous, a state in which the entire batch has the same consistency or is in a single phase. Cool water is then circulated to lower the temperature. During this process, the remaining ingredients such as preservatives, dyes, and fragrances are added at low concentrations (no more than a few percent for fragrances and less than 1% for preservatives and dyes). When complete, a sample is sent to the analytical chemistry lab to ensure it meets quality control standards for solids, pH, and viscosity. The remainder of the batch is then either pumped to a filling line or stored in tanks for later use.

To get the fabric softener to the public, they must be packaged and prepared for shipment. The first step is to divide the batches into smaller containers for customers to purchase. In the filling line, plastic bottles are fed onto a conveyor belt. The size of these bottles can vary. The filling line then carries the bottles to a filling nozzle where the correct amount of softener is discharged into the bottle, and the bottle moves down the packaging line to receive a cap. Filled and capped bottles are packed into cartons and stacked pallets for shipping [1].

To make dryer sheets, the same general process is done as with the creation of liquid fabric softeners. Instead of bottling the liquid fabric softener, it is used along with fragrance chemicals to coat polyester sheets. This leads to what is commonly known as a dryer sheet.

Dryer Sheets [18]

How does it work?

Both liquid softener and dryer sheets are used to reduce static, wrinkles, and leave your clothes smelling nice. However, they work in different ways. Liquid softeners are added during the wash cycle, allowing it to permeate into the fabric fibers of clothes. The benefits of the softener are then maintained as they are dried, preventing static cling while leaving the clothes with a nice scent. Unlike liquid fabric softener, dryer sheets are added when the clothes are being dried. Dryer sheets reduce static cling by balancing the loose electrons caused during the drying process with the positively charged ions found in fabric softener [15]. The heat from the dryer causes the stearic acid or other softening coating on the sheets to melt and coat the clothes [16]. Depending on the company, the softener used can vary. The “softness” of the clothes is felt because the dryer sheets leave a coat of fatty acids which is slippery; however, most describe this feeling as softness. Like using liquid fabric softeners, the clothes are left with a nice fragrance.

Objections to Fabric Softener

Objections to fabric softeners are multiple and voiced with great frequency and volume. This is largely due to claims that various chemicals found in the substance have detrimental health or environmental effects, namely quaternary ammonium compounds, artificial fragrances and colors, and preservatives . Quaternary ammonium compounds, the component of fabric softeners that actually make the clothes feel soft, may be toxic to the respiratory system and may also trigger asthma. Furthermore, most added fragrances share that trait in addition to causing skin irritation and several artificial colors have been linked to cancer later in life. Beyond potential for personal harm, the opponents of fabric softeners point out that the chemicals in fabric softener are quite toxic to most marine life and detrimental to the environment in general both due to this toxicity and their longevity. [19]

All this said, the counter to these objections are well worth regarding. Though fabric softeners can be linked to respiratory irritation and health concerns for asthmatics, proponents of the substance point out that severe effects occur when exposed to repeatedly for long periods of time according to their opponents own studies [20]. It follows that if clothing treated with fabric softener is allowed to air out and not treated with great frequency, these effects can be mitigated. Similarly, the chemicals which opponents connect to cancer are present in very small amounts, and are, according to supporters, a non issue when used responsibly. Proponents argue that this combined with fabric softener effectiveness, as touched upon in other sections, is enough to make use of the substance.

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