Emerging Technologies for Cosmetic and Personal Care Wipes

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KEY WORDS: *wipes, hot-melt, microfibers, nanofibers, chitosan*

ABSTRACT: *Although they initially were designed to cleanse, wipes increasingly are being designed for cosmetics and skin care. This article reviews emerging technologies in both wet wipes and dry wipes and their effect in the personal care market.*

Compared to the alternatives of jars, tubes, bars, re-useable sponges, washcloths and brushes, disposable wipes offer the advantages of convenient, compact, easy and personal portability and hygiene. This article reviews emerging technologies that have the propensity to enhance the properties of wipes, augment their deliverable attributes and increase their market penetration.

Wipes can be divided into the categories of wet wipes and dry wipes. Wet wipes consist of a fabric substrate that is impregnated with cleansing or skin care compositions. Dry wipes must be moistened before use. In recent years, major efforts have been spent to improve the softness and absorbency characteristics of wipe and pad materials, resulting in wipes of higher absorbency and better softness that alleviate skin irritation upon prolonged or repeated usage.[1]

Originally, wipes had a cleansing function, but increasingly wipes are being designed for cosmetics and skin care. For example, recent patent applications have disclosed dry cosmetic wipes in addition to moist wipes impregnated with lotions comprising mineral oil, fatty acid esters, fatty alcohol ethoxylates and fatty alcohols that function as moisturizers.[2]

Wipes containing lotions are well-known. Usually the lotions are compositions that are solid at room temperature and depend on being melted by body heat during the application process.[3] During use, moistened cleansing cosmetic wipes or pads are expected to produce foam. The quality of foam produced is an important cue to the consumer. Good quality foam, good cleansing and pleasant skin feel have been associated with an impregnating liquid comprised of a mixed nonionic/amphoteric surfactant mixture, a wax mixture containing a wax ester, a partial glyceride and a fatty alcohol ethoxylate, and a cationic polymer such as polyquaternium-10.

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Wet Wipes

Wet wipes typically contain a nonwoven substrate that is impregnated with a cleansing lotion. A typical cleansing lotion for this purpose would contain an oily phase as an emollient, moisturizing barrier, or fragrance; emulsifying surfactants; and an aqueous phase that could contain a rheology modifier. Wet wipes are designed to deal with the removal of relatively heavy soils such as makeup, and for this purpose, the lotion component is expected to be nonviscous. Such nonviscous lotions, however, can lead to problems in the package due to drainage of the lotion from the top sheets to the lower-level. It has been claimed that such drainage can be stopped by merely dispersing up to 1 percent of particulate material into the lotion.[4] The particulate material can be selected from a large range of materials; for example, polyethylene, polytetrafluoroethylene powders, poly methyl methacrylate, nylon, polymethylsilsesquioxane, cellulose or silica microspheres, and micronized waxes.

Hot-melt Surfactants

The use of disposable wipe products is ideal for encouraging young children to practice personal hygiene. They are easy-to-handle and the method of use is easily taught. It is important that the cleansing agent not irritate the oral mucosa, but safety alone is insufficient because even if a safe product caused eye-sting, the child would be discouraged from using it. Any disposable wipe product should not sting when it comes in contact with the eyes.

Procter & Gamble (P&G) researchers have approached this challenge by designing wipe surfactant formulations that are extremely viscous at room temperature.[5] The dilemma was to design a manufacturing process for these same surfactants, especially for the step of applying the surfactant to the wipe substrate. In response, P&G researchers designed a surfactant system that lost a fraction of its viscosity above 60°C, allowing it to be processed as a hot-melt, hence the nickname hot-melt surfactants. An example of such a surfactant system is one that contains 63.6% sodium laureth-3 sulfate, 23.8% cocamidopropyl betaine, 10.0% PEG-200 glyceryl tallowate, 10% polyquaternium-10, 0.5% preservative system, 0.5% whitener and 0.5% perfume.

Lotions that are applied to the wipe fabric in the melted state but solidify upon cooling to room temperature are known as hot lotions. Luu et al. point out the manufacturing difficulties associated with hot lotions:[6] "Semi-solid or solid lotions require cumbersome and costly heating systems such as melting tanks and heated equipment to deliver the lotion to the substrate. Additionally, cleaning of buildup and solidification of lotion on the production line's conveyer roll during and after the application process is another cumbersome and costly procedure incurred in connection with so-called hot lotions. Incorporation of water-based additives in such lotions is difficult due to phase separation and lack of uniform distribution of the additive in the lotion, either before or after application onto the product substrate. Further, hot lotions have a tendency to become stiff when excess lotion is used, and the final products tend to leave smears when used." To overcome these drawbacks, Luu et al. suggest the use of a waterless, gelled microemulsion as the lotion component.

Sunscreen Wipes

The application of sunscreen is another task that is especially suited to wipes rather than conventional bottled lotions. Sunscreen lotions often have to trade skin feel aesthetics for SPF efficacy. The lotions usually are spread over the body by hand, and most sunscreen users prefer to wash the excess lotion from their hands after applying the sunscreen. However, since this product is applied outdoors, washing facilities often are not located conveniently enough to facilitate hand washing immediately after sunscreen application. This is one situation in which sunscreen wipes could be advantageous. Another is the use of wipes to encourage young children to apply sunscreen. A recent patent application is directed toward satisfying such needs.[7] In this application, the sunscreen lotion is impregnated into a wet wipe. A colored lotion lets the user know that the sunscreen has been applied uniformly to the body. Prior art exists for colored sunscreen lotions that lose most of their color when the product dries on the skin. This technology, in combination with the wipes vehicle, create the sunscreen wipe.

Microfibers

Microfiber fabrics are lightweight and relatively strong in comparison to conventional fabrics of the same weight. Microfiber fabrics usually are wrinkle-resistant, exhibit good fabric hand—an assessment of the quality of cloth by a textiles expert, retain their shape and resist pulling. Due to their smaller fiber cross sections, microfiber fabrics exhibit improved wicking capabilities. All of those properties are useful attributes for wipe fabrics.

The first stage of making microfibers is to spin multicomponent, continuous filament fibers. These multimember filaments are produced by combining separate melt extruded polymers in the spinneret hole. The resulting filament has contiguous segments of each polymer component extending along its entire length. The continuous filament is then melt-drawn to orient the constituent molecules and confer tensile strength on the fiber. The filaments then can be collected into bundles of staple fiber, which is subsequently spun and woven into cloth, or the fiber can be melt-spun directly into a non-woven web. The woven fabric or non-woven web then is subjected to immersion in a solvent for the dispersed polymer phase in the fiber, and that phase is dissolved, leaving the continuous filament polymer intact. At this stage the material has become a microfiber fabric.

As disposable wipes become more widely used, biodegradation of discarded wipes becomes more of an issue. Biodegradable microfiber fabrics may be one way to prepare useful and biodegradable substrates. One recent patent application is directed to preparing biodegradable microfiber from environmentally benign solvents.[8]

Poly (lactic acid) and poly (vinyl alcohol) are melt spun to form a bicomponent fiber with poly (lactic acid) islands in a continuous sea of poly (vinyl alcohol). The islands are arranged to form a large core of poly (lactic acid) at the center of the fiber surrounded by 12 poly (lactic acid) islets, all immersed in poly (vinyl alcohol). The poly (vinyl alcohol) component is removed by dissolution in water to produce biodegradable microfibers of poly (lactic acid). At the end of its useful life, the poly (lactic acid) microfiber fabric can readily be dissolved and hydrolyzed in caustic soda solution for easy disposal.

Nanofibers

Nanofiber materials offer the opportunity to tailor wetting, spreading and adhesion to levels that are nearly impossible within conventional fibers or even microfibers. Nanofibers can be defined as fibers having a diameter that ranges from a few nanometers to just less than a micrometer. Conventional melt-spinning techniques cannot reach down to the nanometer level because they are limited by Rayleigh instability. Rayleigh instability causes the fiber to break into droplets when the diameter falls below a critical size. The onset of instability is related directly to surface tension and reciprocally related to melt viscosity.

Nanofibers have become reality as a result of the development of a number of new processes, namely melt fibrillation, melt blowing, melt fiber bursting, melt film fibrillation and electrospinning. In all of these methods except electrospinning, fibers are extruded or co-extruded, then fragmented or fibrillated to form the nanofibers. In electrospinning, the spinneret is raised to a high voltage and the fiber is spun toward a grounded collection grid.[9,10] The electrical forces overcome the surface tension of the polymer solution or melt, and the spinning of nanofibers is enabled.

In some cases, the fibers divide even further and form an electrospun nanofiber web mat on the collector. Nanofibers have enormous surface areas and a very small radius of curvature. A diverse array of nanofibers now can be produced, including branched nanofibers, tubes, ribbons and split nanofibers, nanofiber yarns, and surface-coated nanofibers.[11] If the nanofiber is hydrophilic and wetted by aqueous solutions, capillary action is greatly enhanced, and large amounts of aqueous solution will wick into the fiber array. The rate and amount of wicking can be controlled in fiber arrays that have a gradient of fiber diameter or intertwined fiber of different diameters.[12]

Clearly, nanofibers offer substantial advantages for disposable wipes, but commercialization has been limited by the relatively high cost of producing nanofiber matrices. A new process has the potential to bring down the cost.[13] This method uses melt fibrillation of high glass transition temperature (Tg) thermoplastic polymers and direct preparation of a nonwoven web. High Tg polymers are preferred rather than polyethylene and polypropylene because, as fibrillated nanofibers, they freeze faster into their final form. Suitable high Tg polymers include polystyrene homopolymers and copolymers, common polyesters, polyamides, polymethyl methacrylate, polycarbonates, poly (phenylene oxide), thermoplastic starch and poly (lactic acid).

The Lotus Effect

Hydrophilic nanofibers offer the opportunity for enhanced wicking of aqueous liquids. Paradoxically, a hydrophilic surface becomes more hydrophilic as a nanofiber array, and a hydrophobic surface will become super hydrophobic in nanofiber form. The enhancement of hydrophobicity arises from the curvature of the fibers that cause the advancing contact angle to increase above that measured on a perfectly flat surface. This phenomenon has been used for a considerable time for conventional fibers, and it has been used to waterproof fabrics such as raincoats and tents. The enhancement of contact angle on a regular fibrous substrate also is the principle that allows ducks to float. A well-preened duck is coated with hydrophobic fiber in regular array, and the geometric arrangement enhances the hydrophobicity to such an extent that it has given rise to the cliché, "like water off a duck's back."

When the fibers become nanosize, the effect is greatly enhanced, and the water drops roll around on the surface like ball bearings on a flat surface. This superhydrophobic effect is present in nature. The leaves of the lotus plant are covered in nanoscale hydrophobic protuberances that render its surface extremely hydrophobic and self-cleaning. Thus, the lotus plant emerges from the mud as a clean plant, and the superhydrophobic effect has been dubbed "the lotus effect."

Superhydrophobic nanofiber arrays offer the opportunity to construct thin fabric layers that are impervious to liquid water but would allow the free permeation of water vapor. This should be useful as a waterproof backing for wearable wipes.

Scrubbing Wipes

Conventional soft, nonwoven and woven wipes are designed to clean in circumstances that usually involve soil rollup or solubilization and mere wiping. Scrubbing wipes consist of a hard abrasive surface, and apertured surface abrasive wipes have been prepared by sandwiching the soft wipe between two hard plastic abrasive layers with conical protuberances.[14] The apertures are formed by processing an extruded thermoplastic sheet material over a perforated drum. Tredegar offers one example[a] of materials that are bonded to polyethylene (terephthalate biocomponent fiber spunlace material to make these abrasive wipes).

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Antimicrobial Wipes and Applicators

Solid antimicrobial delivery systems are important in the prevention of transmission of pathogens and in the inhibition of odors. Odors are produced on the skin in areas that are rich in apocrine, apoeccrine, sebaceous and eccrine glands. The most notable regions are the axillae, the feet, nipples, anus and genital regions. Apocrine secretions have a strong color that is rendered malodorous by bacterial (*Staph.epidermis*) hydrolysis of the secreted proteins.[15] Most strains of *S. epidermis* protect the host's skin by preventing colonization of dermatophytic fungi. However, in some cases, if *S. epidermis* gets into the bloodstream, it can become an opportunistic pathogen.

Pseudomonas aeruginosa are opportunistic bacteria that can infect skin and mucous membranes and, like other species of *Pseudomonas*, they readily adapt to their environment. *Candida albicans* is a yeast that normally inhabits the human gastrointestinal tract as a part of the digestive flora. However, it can transform into an invasive mycelial fungal form that binds readily to infect skin and mucous membranes. Antimicrobial wipes are directed toward the control of these pathogens on the body.

The incorporation of antimicrobial agents is also important in the sterilization of materials, such as plastics and fibers that deform at the temperatures needed for sterilization by autoclaving.

This is significant because the cost of producing plastic implements and non-woven wipes is considerably lower than their autoclavable metal or woven-fiber equivalents. The materials can be rendered suitably antimicrobial by coating with inherently antimicrobial polymers, by the incorporation of materials for controlled release of antimicrobial agents, by embedding solid antimicrobial particles therein, or by infusing antimicrobial materials into the free volume of polymer matrices.[16]

Antimicrobial coatings frequently contain copolymers with amine groups or quaternary ammonium groups[17,18] such as copolymers of t-butylaminoethyl methacrylate,[19] or antimicrobial carboxylates.[20] Silver, copper and zinc particles have been embedded into polymeric materials to render them antimicrobial[21] and this technology has been extended to silica[22] or zeolite[23,24] particles upon which the antimicrobial metals are adsorbed or deposited.

Melt-processable, antimicrobial thermoplastics would be particularly advantageous as materials to be included in sterile wipes for cosmetic and personal care applications. In this context, it is interesting that DuPont researchers recently have disclosed acid copolymers

[a] *Visipore apertured polyethylene film is a product of Tredegar.*

and ionomers for the controlled release of antimicrobial materials.[25] The copolymers contain ethylene, a carboxylic acid monomer, and a softening comonomer such as an alkyl (meth) acrylate in which the alkyl group has a length of up to eight carbon atoms. The softening monomer functions by disrupting the crystallinity of the polyethylene.

Ionomers are thermoplastic polymers that contain relatively small proportions of ionic monomers. The ionic comonomers cluster within the polymer matrix and this causes a closer packing of the polymer molecular chains adjacent to the cluster. The consequent loss of free volume reduces the mobility of the polymer chains, and results in an increase in the glass transitions and moduli of the materials.

One ionomer[b] from DuPont, for example, is a polyethylene that is rendered tough by the inclusion of ionic comonomers. Tetrafluoroethylene ionomers are useful as membranes for water treatment and for the separation of sodium hydroxide and chlorine gas in the chlor-alkali process. It is postulated that these membranes function by allowing the percolation of only small molecules and ions through the material via the ionic clusters. In the antimicrobial application, quaternary ammonium compounds or metals (silver is preferred) are incorporated into the structure and slowly released to prevent the growth of pathogens.

[b] *Surlyn is a product of DuPont.*

Chitosan and chitosan-metal compounds are known to have antimicrobial, antifungal[26] and even some antiviral activity.[27] Chitosan also is known to impart anti-odor properties. Chitosan is poly -[1-4]-β-D-glucosamine, and it can be derived by the hydrolysis of chitin. Chitin is widely available from the cell walls of fungi, and the exoskeletons of insects and crustaceans. DuPont researchers recently have disclosed a less-expensive and environmentally gentle method of attaching and cross-linking chitosan to a diverse variety of woven and nonwoven fabrics.[28] The process consists of cleaning the fabric surface by plasma treatment, polymerizing itaconic acid and triacrylate cross-linker on the surface by electron bombardment in high vacuum, and then passing the fabric through solutions of chitosan and acetic acid. The finished product is described as being suitable to use as personal wipes or articles of clothing that confer antimicrobial and anti-odor attributes.

All of these broad-spectrum antimicrobial/antifungal wipes are designed to indiscriminately kill the flora on human skin and topically treatable areas. It would be beneficial, however, to design products that would kill or detach harmful flora while allowing beneficial flora to continue to thrive on the upper layers of the skin. A recent study directed to that goal screened a large number of botanical compounds for their efficacy in this regard.[29] Green tea, horse chestnut, soluble wheat protein, yucca 70, yucca extract powder 50%, sea parsley, and cat's claw were identified as botanicals that increased the adherence to skin of the beneficial microorganism *Lactobacillus acidophilus.* In the future, expect the development of treatments that destroy or detach harmful flora while maintaining healthy cultures of beneficial microflora.

Summary and Forecast

Wipes represent a convenient and hygienic way to cleanse the surface of the body and topically deliver beneficial agents. The cosmetic and personal care industry can expect to see advances in the formulation of deliverable phases that are impregnated into wipe products. Advances in the ability to make inexpensive nanofibrous materials promise to greatly enhance the capillary-driven uptake of liquids into the wipe matrix. Advances in antimicrobial fibers offer opportunities to make wipes that are either broad-spectrum or selective biocides for treating the surface of the body and maintaining its health. The day will come when the body will be kept healthy and odor-free by wearable, disposable wipes with nanofibrous hydrophilic gradients on one side, nanofibrous breathable superhydrophobic materials on the other side and an antimicrobial layer in the middle.

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