

Chapter 2

Cosmetic Science and Polymer Chemistry: Perfect Together

Anjali Patil* and Robert W. Sandewicz

Revlon Research Center, 2121 Rote 27, Edison, New Jersey 08818

*E-mail: Anjali.patil@revlon.com.

Cosmetic science has evolved significantly during the past thirty years. One of the principal drivers of such advancement has been the development of new color cosmetic formulations that deliver a combination of drastically improved functional performance and outstanding aesthetic properties. The key element enabling the creation of such high performance products is the increasingly widespread use of a broad spectrum of polymers in a wide range of color cosmetic formulations. The primary reasons for this trend are rooted in intrinsic attributes of polymers. Polymers typically are more substantive to biological substrates than are many of the fatty-based raw ingredients historically used in cosmetic formulations. Polymers also can be customized readily to meet very specific performance requirements. In some formulations, polymers have supplemented fatty-based raw ingredients as a means of improving product performance. In other formulations, advanced technology polymers have completely replaced traditional cosmetic chemicals in order to create products having superior skin adhesion and wear attributes. Polymer scientists should be aware of the safety and regulatory requirements peculiar to the cosmetic industry so as to engage cosmetic chemists in a productive way.

Introduction

American industrialist Henry Kaiser is credited with having coined the adage, “*Find a need and fill it.*” This advice typically is cited within a marketing context, yet it appropriately describes the ongoing relationship between cosmetic science and polymer chemistry. Classical polymer chemistry understandably might be viewed as part of a larger “smokestack industry”, conversely, the term *cosmetic science* at first glance might seem to be an oxymoron. How can aesthetics be reconciled with organic chemistry? What common ground could possibly exist between lipsticks and elastomers? Are the names *Ziegler* and *Natta* as synonymous with beauty as the names *Revson* and *Lauder*? Despite what might appear to be a glaring lack of similarity, both areas truly are more alike than might be imagined. Both fields are highly scientific in nature, are quite adept at harnessing new technologies to reconcile some challenging puzzles, and financially are very profitable. In short, both cosmetic scientists and polymer chemists make high performance, high value products through skillful implementation of advanced technologies or, as Mr. Kaiser would have said, by finding needs and filling them.

The common ground shared by cosmetic scientists and polymer chemists can be summarized by one word: *performance*. During the first three decades of the 20th Century, cosmetic manufacturers sought to transform their businesses from small, artisanal “cottage industries” into modern enterprises. They did so not only by use of clever and aggressive marketing strategies, but also by use of increasingly sophisticated chemical technologies. The net result: products characterized by outstanding aesthetics and performance-driven benefits. During that era, cosmetic chemists had the unenviable task of attempting to create such products using the relatively unsophisticated raw ingredients available to them. Chemists relied almost exclusively on time-honored, naturally derived raw materials such as fats, oils and waxes. Given the inherent variability of biological systems, the chemical and physical properties of natural ingredients sometimes varied considerably from lot to lot. Not surprisingly products intended to be both aesthetically pleasing and functional did not always perform consistently. The fact that early cosmetic products enjoyed *any* commercial success pays tribute to skillful formulators who were able to comprehend and manage the variability of a relatively small “chemistry set” comprised mainly of naturally derived raw ingredients.

During the years leading up to World War II, consumers demanded increasingly more sophisticated cosmetic products. Synthetic pigments became available on a regular basis, enabling formulators of staple cosmetic products such as nail lacquers and lipsticks to broaden their shade palettes significantly. Performance attributes such as ease of application, high gloss and improved adhesion to human skin and nails became more important. Fortunately, during this same timeframe, polymer chemists were busy creating synthetic organic polymers such as polyacrylates, nylon, polyethylene and polyesters. Considered rudimentary materials today, these revolutionary new polymers represented breakthrough technologies at the time. As with cosmetic chemists, dye and textile chemists had long grappled with the inherent performance shortcomings of

“biopolymers” such as cotton and wool prior to the advent of synthetic polymers capable of producing “engineered fibers” having more uniform and predictable chemical and mechanical properties.

The fruits of technical labor did not go unnoticed by the cosmetic industry. Founded at New York City in 1945, the Society of Cosmetic Chemists (SCC) became the cornerstone professional organization on which the discipline of “cosmetic science” was firmly established (1). Then as now, the scholarly journal of SCC served as the primary tool to communicate new raw ingredient technologies, formulation techniques, manufacturing advice, and product testing methodologies. Not surprisingly, new polymeric ingredients potentially useful to cosmetic formulators began appearing in SCC literature with increasing frequency.

Creators of advanced new beauty care products took note of such technical advances and began experimenting with new polymeric ingredients in formulations previously dominated by animal- and plant-derived raw materials (2). Due to aggressive competition, new formulations were required to attract increasingly savvy consumers who demanded constant innovation and ever more added value. New polymeric materials clearly would benefit formulators of such complex new cosmetic products. As with their counterparts in many other industries, cosmetic chemists realized that high performance products could be achieved only by selecting raw ingredients truly capable of sustaining such performance characteristics on a predictable basis. Leading edge products required far better chemical and physical properties than could be provided by most naturally-derived raw ingredients.

Many valuable new cosmetic ingredients came from such broad polymer classes as cellulose, polyacrylates, polyamides and hydrocarbons (3–6). Why this hunger for polymers in cosmetics? Once again, the word *performance* enters the equation. Clearly, very many non-polymeric synthetic raw ingredients are readily available to cosmetic chemists today. There are many formulations having performance requirements that are met adequately without the use of polymeric materials. Nevertheless, polymeric cosmetic ingredients help make higher performance attributes possible in ways that their “monomeric” counterparts cannot achieve. Polymers have structure/activity relationships that can be custom engineered to produce desired end objectives, and can be manufactured economically on a commercial scale to deliver such performance on a consistent, predictable and reproducible basis. Molecular weights can be tailored to formulation requirements. Thermal and mechanical properties can be “tuned in” as needed. Classical chemical properties such as surface activity, solubility, hydrolytic stability, oxidation resistance and other characteristics also can be designed in a precise and controlled manner. Clearly, cosmetic chemists have come to recognize and appreciate what polymer chemists have known for many years: the potential benefits of polymers in beauty care products are limited mainly by the imaginations of those who synthesize polymers and those who determine how best to use these materials in end products.

One of the many technological step-changes that have occurred in cosmetic science during the past 50 years involves the large class of polymers collectively known as *silicones*. Very many unique and important performance benefits highly

relevant to the cosmetic industry have been made possible through the use of these materials. As cosmetic chemists became familiar with the solubility and compatibility profiles of various silicones used in combination with traditional organic raw ingredients, the very real benefits of silicones became apparent.

Early silicones frequently used in cosmetic applications were homopolymers of dimethyl siloxane. Known as *dimethicones*, these liquid polymers were employed in many of the same applications as organic oils, to impart hydrophobicity and lubricity on the skin (7). Manufacturers also began offering various organically-modified silicones that were more readily compatible with traditional cosmetic raw ingredients, and that offered a broader range of visual and tactile properties. Silicone emulsifiers were developed to enable formulation of stable creams and lotions. Perhaps the most revolutionary silicone polymers used in cosmetic applications are *silicone resins*. Produced in various forms, materials such as *trimethylsiloxysilicate* (called *MQ resins* in silicone chemistry parlance) help produce cosmetic formulations having very tenacious adhesion to skin, thus enabling creation of entirely new classes of “transfer-resistant” lip and face makeup products (8–10).

Up to this point, polymers have been discussed solely within the context of cosmetic formulation technology. A meaningful analysis of the engineering applications of polymers used in modern cosmetic packaging applications warrants more than a cursory discussion, and is far beyond the scope of this document. Manufacturers of sustainable cosmetic packaging materials have struggled to achieve all the protective and aesthetic properties of conventional polymeric materials, but significant advances undoubtedly will be made in the development of bio-degradable, sustainable packages exhibiting chemical and mechanical robustness equal to that of conventional packages.

Another important but less obvious application of polymeric materials in cosmetic science is process engineering. Materials storage and shipping vessels used in the cosmetic industry historically were constructed of metal. In response to a wide variety of contemporary factors (i.e. enhanced corrosion protection, energy conservation, sustainability initiatives, ease of recycling, cost control programs, reduction of tare weight to mitigate shipping costs etc.) storage and transportation equipment built with polymeric materials have become more common in the industrial environment. *Intermediate bulk containers* (sometimes called *IBC's* or *totes*) can be constructed of polypropylene instead of stainless steel. As with an analysis of polymeric packaging materials, a discussion of the use of engineering polymers in chemical processing industries is a subject worthy of a separate discussion and is beyond the scope of this chapter.

Table 1 lists the functional properties of cosmetic ingredients alongside their expected consumer benefits, then to provide examples of polymers that have been utilized commercially to meet these requirements. Examination of this table reveals that appropriately selected polymers can provide nearly every functional property needed to achieve meaningful consumer benefits in all types of cosmetic formulations. Whether the final product form is solid (e.g. lipstick, deodorant), liquid (e.g. nail lacquer, foundation makeup, shampoo) or gaseous (e.g. perfume, aerosol hair spray) one or more polymeric raw ingredients may be

used in combination with multiple other cosmetic chemicals to deliver the level of performance required to meet consumer needs.

Table 1. Cosmetic Ingredient Functional Properties and Consumer Benefits

<i>Functional Property</i>	<i>Consumer Benefits</i>	<i>Polymeric Examples</i>
Film formation	Extended product wear; enhanced skin protection; improved product aesthetics	Nitrocellulose, polybutene, polyester resins, acrylates copolymers, silicone acrylate copolymers, polyurethanes
Transfer resistance	Tenacious product adhesion; enhanced skin protection; improved product aesthetics; reduction in number of product application cycles	Trimethylsiloxysilicate (<i>MQ resins</i>), silicone elastomers
Tack	Enhanced product adhesion	Polycyclopentadiene, polybutene
Emolliency	Enhanced comfort & protection	Dimethicone
Moisturization, chapping prevention	Improved skin condition; more youthful skin appearance	Hydrogenated polydecene, polybutene
Surface activity	Ease of application; enhanced product shelf life	PEG/PPG block copolymers
Structure development	Ease of application in stick products	Polyethylene, EVOAc
Rheological control	Ease of application; enhanced product shelf life	Hydroxypropylmethylcellu- lose, hydroxyethyl cellulose, polyacrylic acid, polyamides
Wrinkle effacement	Mitigation of appearance of undesirable skin surface defects; more youthful skin appearance	Nylon, PMMA, polyurethane crosspolymers
Gloss reduction	Mitigation of appearance of undesirable skin surface defects; more youthful skin appearance	Polyurethane crosspolymers
Pigment surface treatment	Ease of application; novel visual aesthetics	Reactive silanes

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Table 1. (Continued). Cosmetic Ingredient Functional Properties and Consumer Benefits

<i>Functional Property</i>	<i>Consumer Benefits</i>	<i>Polymeric Examples</i>
Ingredient encapsulation	Reduction in number of product application cycles, prevention of ingredient degradation, prolonged release of fragrance oils and active ingredients;	Acrylates copolymers, cyclodextrins
Color development	Products having novel visual aesthetics	Metal oxides and mica
Gloss enhancement	High shine appearance on lips or nails	Hydrogenated polyisobutene, Hydrogenated polydecene, phenyl silicones
Odor/flavor control	Fragrance/flavor longevity, elimination of malodors	Cyclodextrins

Technologies such as dendritic polymers might offer tremendous benefits in beauty care products once cosmetic chemists begin to understand how to best use these materials. The concept of “smart polymers” is equally intriguing, as is the field of composite polymers. In recent years, numerous smaller cosmetics brands have decided to market products identified as *natural*, *organic*, *mineral-based* and/or *bio-botanical*, largely in the hope of increasing market share among groups of consumers with whom such terms resonate positively. Conversely, larger cosmetic brands have chosen to market products based primarily on consumer-perceived performance benefits. It is interesting to observe that polymers either of natural or synthetic origin can provide important benefits regardless of specific market positioning. Driven by overarching “mega-trends” such as sustainability, environmental sensitivity, conservation of energy and natural resources, makers and users of polymers across all industries will discover creative new ways to exploit the great utility of these “compounds with many parts.” Cosmetic chemists have come to recognize and appreciate that potential benefits of polymers in beauty care products are limited mainly by the imaginations of those who synthesize polymers and those who determine how best to use these materials in end products. Equipped with high-tech polymers “in the toolbox”, successive generations of cosmetic chemists and polymer scientists undoubtedly will be more than able to support continuous efforts to “find a need and fill it.”

Film Formation

In the cosmetic industry, a “film-forming polymer” does not necessarily form a self-standing film. It can be a fluid film that enhances the wear of the product, extends sunscreen protection, imparts water or oil resistance, or improves product aesthetics. A large variety of polymers are used as film formers, such as hydrocarbons, cellulosics, polyesters, polyurethanes, and acrylics.

- *Hydrocarbons*: Commonly used hydrocarbon polymers are polybutene, polyisobutene, polycyclopentadiene, and poly(α olefins), frequently abbreviated as *PAO* (6). They are made by polymerizing α -olefins (α -olefin is an alkene with terminal double bond, e.g. 1-decene). An example of a PAO commonly used in cosmetic formulations is hydrogenated polydecene. Polydecenes are available in a wide viscosity range, and due to their non-greasy skin feel they are used in skin care, eye shadow, makeup, and lip products (11). The most commonly used polybutenes are lower molecular weight polymers (400-1000 daltons) and primarily are used in lip gloss formulations as they are very shiny and have good adhesion to lip surfaces. They are also used in eye makeup, eyeliner, blushes, foundation, mascara and makeup products. Hydrogenated polyisobutenes are mainly used in lip products along with eye shadow, eyeliner, and mascara (12).
- *Acrylates copolymers*: Acrylates are formed by free radical polymerization of different acrylic monomers, either via solution or emulsion polymerization. They are available in 100% solids form as well as in dispersions and emulsions. They are used either alone or as secondary film-formers along with nitrocellulose in nail enamel formulations (4, 13). They also are used in skin care products to extend sunscreen protection or wear. Mascara formulations often use acrylate copolymers with acid functionalities, neutralized with an alkali (14). As the emulsion coalesces during the drying period, a relatively durable film is formed on eye lashes.
- *Silicone acrylate copolymers*: These copolymers are prepared either by free radical polymerization of a silicone acrylic monomer with other acrylic monomers or by grafting (15, 16). Some copolymers have siloxane backbones with pendant acrylic groups e.g. poly(dimethylsiloxane)-g-poly(isobutyl methacrylate) as shown in Figure 1.
 This copolymer dissolves in cosmetic solvents such as isododecane and forms shiny adhesive films. These materials are used in high-performance pigmented cosmetic products, such as lip products and mascaras (17). Some copolymers have acrylic backbone with pendant silicone e.g. poly(isobutyl methacrylate)-co-methyl FOSEA)-g-poly(dimethylsiloxane) is used in lip products (18). Acrylic silicone graft polymers also can be prepared by free radical polymerization of dimethylpolysiloxane with polymerizable acrylic/methacrylic group on end with acrylic/methacrylic monomers as shown in Figure 2 (19).
 These acrylates/dimethicone copolymers form adhesive films that have good water and oil resistance. They are used in various pigmented cosmetic products as well as in skin care products for enhanced sunscreen protection.
- *Polyester resins*: Polyesters are formed by the reaction between a polyol and acids or acid chlorides. Polyesters used in lip products are generally synthesized using aliphatic fatty acids and fatty alcohols.

These polymers confer gloss, adhesion and water resistance. Polyesters used for nail enamel applications typically are produced by the reaction of dicarboxylic acids (e.g. adipic acid), polyols (e.g. glycerin, neopentyl glycol or trimethylolpropane) and acid anhydrides (e.g. maleic anhydride, phthalic anhydride or trimellitic anhydride). Such polyester resins produce soft films and often are blended with nitrocellulose to improve gloss, toughness and flexibility of nail lacquer films (4).

- *Nitrocellulose*: The first polymer used in cosmetic formulations was nitrocellulose (cellulose nitrate). It is produced by the esterification of cellulose (obtained from cotton fibers or wood pulp) with nitric acid and its structure is shown in Figure 3. Nitrocellulose lacquers first came into widespread use in the 1920's, mainly for automobile finishes and other industrial coatings applications (3).

Nitrocellulose is a dangerous explosion and fire hazard. Nitrocellulose is particularly explosive when dry, thus it must be wetted with ethanol or isopropanol to prevent detonation in transit. It readily degrades upon exposure to many common environmental factors, such as heat, sunlight, elemental iron and alkaline compounds. Classic evidence of the degradation of nitrocellulose solutions in organic solvent mixtures is a yellowing or browning of the bulk solution. In spite of these formidable shortcomings, it still is the main film-former used in nail lacquer formulations today (20, 21). Nitrocellulose is manufactured in various grades based on different solvent solubility profiles and molecular weights. Nitrocellulose used in nail products has a high degree of nitration for maximum durability and water resistance. Although it's neat films are inherently brittle, nitrocellulose forms durable, shiny films when adequately plasticized.

- *Cellulose Esters/Mixed Esters*: In order to avoid the hazards of nitrocellulose in a variety of industrial applications (including the manufacture of early motion picture film) polymer chemists undertook development of cellulose esters in the 1920's and 1930's. By esterifying the available hydroxyl groups of cellulose with acetic acid alone or with a mixture of acetic acid and either propionic or butyric acids, several useful polymers were created: cellulose acetate ("CA"), cellulose acetate propionate ("CAP") and cellulose acetate butyrate ("CAB"). These polymers do not present the explosion hazards of nitrocellulose, and they also are far more tolerant of a variety of environmental factors. They are soluble in a wide range of commonly available organic solvents, and are compatible with a broad range of plasticizers and other polymers. Cellulose esters/mixed esters exhibit very good clarity and color stability even with prolonged exposure to UV light, heat and other insults, making them particularly valuable for use in "non-yellowing" nail topcoat formulations (3).
- *Polyurethanes*: The first polymers containing the urethane linkage (-NCOOR-) were developed and prepared by Otto Bayer in Germany. Urethanes are esters of carbamic acid, having the structure RHNCOOR , where R is an organic radical. This basic reaction still is used in the

production of urethane today (22). Solvent based polyurethanes are used in nail products as secondary film formers and also in eye shadow, mascara, foundation and lipstick (23). Aqueous polyurethane dispersions are used extensively in mascaras, skin care as they form flexible films (24, 25).

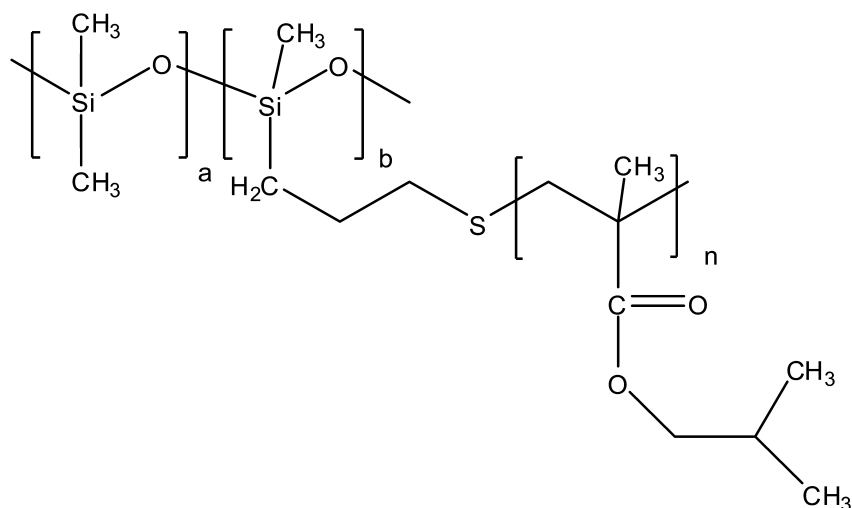


Figure 1. Poly(dimethylsiloxane)-g-poly(isobutyl methacrylate).

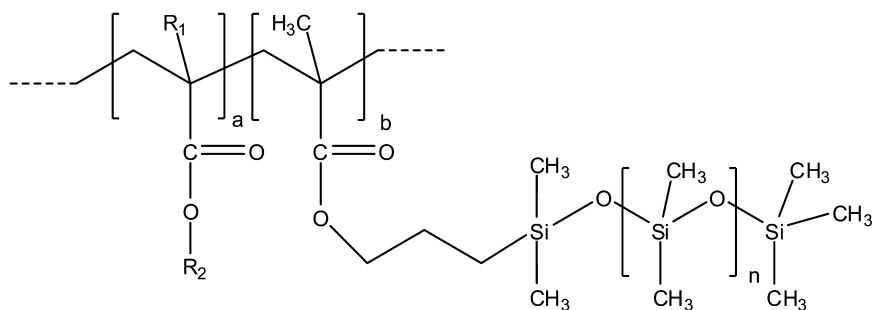


Figure 2. Acrylates/dimethicone copolymer (R_1 is H or alkyl group, R_2 is alkyl group).

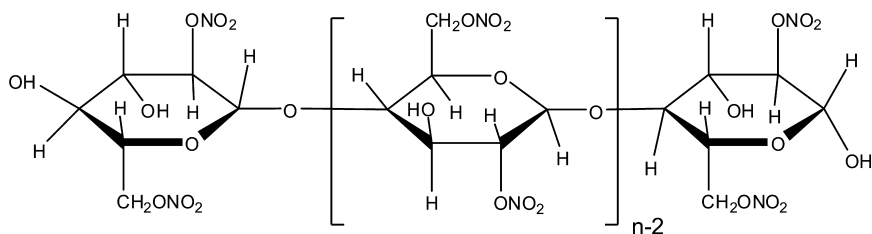


Figure 3. Structure of nitrocellulose.

Transfer Resistance

When a cosmetic product does not “kiss-off”, deposit on clothing or glasses, or when it resists removal by food (“food-proof”), it is called “transfer-resistant”. Transfer-resistant cosmetic products are less affected by water and oil as compared to conventional cosmetic products and are not easily affected by sebum or perspiration. Early transfer-resistant lip products were prepared by partially replacing the non-volatile oils with volatile solvents (26). These products were “kiss-proof” but they were not sufficiently durable to be described as “food-proof”. Robust food-proof products almost all have one thing in common: “MQ polymers”. In the “silicone alphabet”, an “MQ polymer” is more accurately described as trimethylsiloxysilicate or trimethylated silica. MQ polymers are highly cross-linked structures consisting of $\text{SiO}_{4/2}$ units. Trimethylsiloxysilicate is dissolved/dispersed in volatile solvents e.g. isododecane, volatile cyclic or linear silicones e.g. cyclopentadiene, hexamethyldisiloxane, etc. It also can be dissolved in non-volatile silicones (e.g. different viscosity dimethicones or substituted dimethicones e.g. alkyl or phenyl substituted dimethicones). There are large number of lip, eye, and face products sold today containing trimethylsiloxysilicate (8–10).

Tack

Although tack usually is not a pleasant feeling on the skin or lips, it is necessary to promote adhesion of cosmetic products to various biological substrates. Molecular weight and glass transition temperature play a role in determining tack of the polymer. Polyisobutylene with lower molecular weight has tack and an ability to flow and wet the substrate, and also imparts shine (27). Polyisobutylene forms an occlusive barrier and locks the moisture in, therefore, it is used in lip gloss. Hydrogenated polycyclopentadiene is used to enhance adhesion and shine. Hydrogenated polycyclopentadiene is synthesized by ring opening metathesis polymerization of dicyclopentadiene, then the double bond is hydrogenated. This is a low molecular weight (~500 dalton) polymer that is soluble in volatile and non-volatile hydrocarbons and imparts water-resistance to the formulations along with adhesion. Hydrogenated polycyclopentadiene is used lipstick, eye liner, eye shadow, makeup, foundation, and mascara (28).

Emolliency

An “emollient” is defined as an ingredient intended to soothe and protect skin, thus “emolliency” means the degree of skin soothing and protection conferred by a particular cosmetic raw ingredient (29). Historically, cosmetic emollients were liquid and solid fatty materials derived from plant and animal sources (e.g. castor oil and lanolin, respectively). Not surprisingly, emollients also can be derived from completely synthetic feedstock (e.g. octyl dodecanol).

Polydimethyl siloxane is called the dimethicone in cosmetic industry, this name conforms to INCI (the International Nomenclature Cosmetic Ingredient) nomenclature. Dimethicone is described as a MDM polymer in the silicone alphabet. Dimethicone has flexible silicone and oxygen (siloxane) to which methyl groups are attached. Dimethicones are hydrophobic and still have high permeability to water vapor. Although dimethicones have very low glass transition temperature, they are not tacky or sticky. Due to their low surface tension (24 mN/m), dimethicones can spread easily and wet substrates (e.g. skin or lips) easily.

Dimethicones come in a broad viscosity range from 0.65 cSt to thousands of centistokes. 0.65 cSt dimethicone is volatile and is used as a solvent or a diluent, while higher viscosity dimethicones are used as protective agents. Due to its hydrophobicity, low surface tension and ability to spread easily, dimethicone is recognized by the U. S. Food and Drug Administration as a protecting agent in topical skin care products (30). The skin protectant monograph allows dimethicone to be claimed as an active ingredient when incorporated into OTC (over the counter) products in concentrations of 1 to 30%. An anti-chapping claim can be made for a lip product if it contains at least 1.5% dimethicone.

Moisturization

The term “moisturization” is defined as a process by which skin is made smooth and supple by keeping it relatively moist. For most biological substrates, moisture is provided mainly by water. Maintenance of the proper amount of water on the skin can be accomplished by depositing a protective, hydrophobic barrier layer over skin surfaces to prevent or retard trans-epidermal water loss (known as “TEWL”) (31). This tactic sometimes is called “occlusion”. It has direct parallels in the plant world: cacti and other plants living in arid regions have waxy surface layers (“cuticles”) that effectively prevent loss of precious water. Following this approach, hydrophobic liquid polymers such as hydrogenated polydecene are used to “seal in” natural moisture, thus making the skin feel and look more moist and youthful. These polymers are more substantive than their mono-molecular counterparts, and in recent years have replaced older moisturizers such as mineral oil or petrolatum. A second method of moisturization involves attracting water to skin surfaces. This type of activity is called “humectancy”. Most humectants contain one or more functionalities capable of forming hydrogen bonds with water. While the archetypal mono-molecular humectant is glycerol (a 3-carbon tri-hydroxy alcohol) polymers having similar architecture also can provide humectant benefits.

Surface Activity

Some examples of surface active polymers are poly(ethylene oxide), poly(propylene oxide), and poly(ethylene oxide-propylene oxide) copolymers. They are prepared by homo- or co-polymerization of the corresponding ether. INCI nomenclature classifies homopolymers of ethylene oxide into two categories. Ethylene oxide polymers with molecular weights below 20,000 are designated as PEG-N, where N represents the number of ethylene oxide monomer units in the polymer (32). When an alcohol (e.g. methanol) is used to initiate the polymerization of a lower molecular weight methyl-terminated polyether, the INCI designation is PEG-N methyl ether. Polymers with molecular weights greater than 20,000 are referred to as poly(ethylene oxides) and the INCI designation is PEG-#M, where # is a whole number and the M indicates 1000, and together they represent the approximate number of moles of ethylene oxide in the polymer. For example, PEG-3M is comprised of 3000 moles of ethylene oxide. These high molecular weight poly(ethylene oxide)s are solid materials.

The difference between poly(ethylene oxide) and poly(propylene oxide) is a single methyl group, but that difference has significant implications. Poly(ethylene oxide) homopolymers are water soluble at all molecular weights and in all proportions. In contrast, presence of the additional methyl group in propylene oxide imparts hydrophobicity to poly(propylene oxide) homopolymers, making them water-insoluble. Random EO/PO copolymers are water soluble when they contain at least 50% ethylene oxide. Not surprisingly, block co-polymerization of EO and PO produces amphiphilic polymers that legitimately can be described as “non-ionic surfactants”. An entire class of surfactants is created by adjusting the EO-to-PO ratio in various block co-polymers across the full spectrum of HLB (“hydrophilic/lipophilic balance”) values. Hydrogen bonding is responsible for the affinity between water and the EO moiety of EO/PO copolymers. Because of this situation, random EO/PO copolymers exhibit a phenomenon known as “inverse cloud point”, defined as the temperature at which such polymers collapse upon themselves and precipitate from aqueous solution. As the solution cools, hydrogen bonds re-form, the polymer re-disperses and then re-dissolves. These polymers have a slippery feel. Due to their surface activity, they are very good for dispersing pigments or sparingly water-soluble raw ingredients into water.

Structure Development

Cosmetic products are marketed in a variety of convenient forms. “Hot-pours” (e.g. lipsticks and anhydrous blush formulations) are very popular products (33). They are manufactured by melting and mixing solid, semi-solid and liquid fatty raw ingredients then casting the hot molten liquid either into molds or directly into final containers. This procedure has parallels to other industrial processes, such as steel casting in a foundry or injection molding in a plastics factory. Traditionally, hot pour formulations must incorporate one or more fatty “structuring agents” (e.g. waxes, lanolin, long-chain fatty alcohols, triglycerides etc.) to impart structural rigidity and to facilitate mold release by contracting

slightly upon cooling. Logically, various thermoplastic polymers can be used to supplement or completely replace waxes in hot pour products.

Synthetic waxes are either mixtures of long chain hydrocarbons primarily derived from petroleum or synthesized from monomers such as ethylene, vinyl acetate, vinyl pyrrolidone or organically modified dimethicones. Polyethylene used in the cosmetic industry is a linear low molecular weight homopolymer of ethylene. Polyethylene grades used in cosmetics have a melting point below 100 °C. Polyethylene imparts structure, increases overall hardness and crystallinity of the product and therefore, is used in a large variety of cosmetic products (e.g. lipstick, eye shadow, blush, eye liner, mascara, makeup, foundation etc.). It improves stability to cosmetic stick formulations due to its compatibility with commonly used cosmetic oils. It also is a good film former which aids in the delivery of actives. Low molecular weight ethylene and vinyl acetate copolymers (EVA) are used in eye shadow, eyeliner, eyebrow pencil, lipstick, and makeup products (34). Presence of vinyl acetate introduces slight polarity to the polymer and makes the copolymer compatible with triglycerides commonly used in cosmetics. EVA is used to modify the rheological properties of products. Crystallinity of polyethylene is interrupted by vinyl acetate and that helps in imparting gloss to the product. Copolymers of vinyl pyrrolidone with alkenes (e.g. eicosene, hexadecane, triacontene) are used for structure building. Silicone waxes and alkyl modified silicones are used to give structure as well as different textures to stick products.

Polyethylene and ethylene/vinyl acetate copolymer frequently are used to impart structure in lipstick and lip gloss formulations. Polymeric structuring agents have some important advantages as compared to their traditional counterparts. Waxes typically are extracted from inherently variable origins such as petroleum (e.g. paraffin), animal secretions (e.g. beeswax and lanolin) and plants (e.g. carnauba and candelilla waxes). In contrast, polymeric structuring agents generally offer improved batch-to-batch reproducibility, and their chemical, mechanical and thermal properties can be tailored to meet specific performance requirements.

Rheological Control

Color cosmetic products not only must be visually appealing, but they also must be aesthetically pleasing in several other important ways. Products applied to the surfaces of the human body must exhibit acceptable tactile properties during application and throughout the wear period. Control of product rheology is an extremely important topic in cosmetic science. Solid and semi-solid products must have structural integrity across a variety of storage and use conditions, yet they also must afford smooth, even film deposition during application. Liquid formulations must possess robust structure in order to suspend various pigments, yet they also must exhibit appropriate flow and viscosity properties with each use. Because color cosmetic products frequently have shelf lives of 36 months or longer, successful maintenance of long-term product stability is dependent upon

the correct selection of rheology modifiers. Rheological control is a critical factor in the new product development process, thus many different types of inorganic and organic rheological control agents are marketed to address various formulation requirements.

As might be anticipated, natural and synthetic polymers enjoy widespread use as rheological control agents in a variety of color cosmetic formulations (35). All raw ingredients in a formulation exert varying degree of influence on the rheological profile of the product, even those ingredients whose primary intended function is not rheological control. Polymeric materials are no exception to this rule. For example, nitrocellulose is used as a primary film former in nail lacquer formulations, yet small amounts of high molecular weight nitrocellulose sometimes are added to increase lacquer viscosity. Similarly, polyurethanes or acrylics may be used to form films in mascara formulations, yet they also can be used to increase product viscosity. Because polymers can perform a multiplicity of functions in a color cosmetic formulation, when discussing polymeric rheology modifiers it is convenient to focus on those polymers whose primary function is rheology control (i.e. viscosity modification).

Both naturally-derived and synthetic polymers are used as cosmetic thickeners. For anhydrous products and some emulsions polyethylene and EVA are used. High molecular weight grades of polybutene or ethylene/propylene/styrene terpolymers are used to thicken oil-based products (e.g. lip glosses). For water-based products (e.g. eye and face products) generally cellulose ethers and polyacrylic acid and its derivatives are used. Cellulose ethers are water-soluble polymers derived from cellulose, the most abundant polymer in nature. They are used as thickeners, binders, film formers, and water-retention agents. They also function as suspension aids, surfactants, lubricants, protective colloids and emulsifiers. Water-dispersible vegetable gums (e.g. acacia, carageenan, guar and xanthan gums) often are added to emulsified formulations (e.g. liquid makeup) to increase viscosity (36).

Poly(acrylic acid) is a workhorse polymer for water-based systems. In cosmetic applications this polymer is lightly cross-linked or hydrophobically modified. Alkali soluble emulsions (ASE) (35). are synthesized from acid and acrylate co-monomers. These polymers exist as collapsed random coils at low pH when the acid groups are fully protonated. The viscosity is low at an acidic pH and when acid groups are neutralized with alkali or organic amine, viscosity increases. Polymers like acrylates copolymer thicken by charge induced chain extension, chain entanglement and hydration.

Hydrophobically modified alkali soluble emulsions (HASE) are acid/acrylate copolymers with ethoxylated hydrophobes (37). When the acid groups present in HASE polymers are neutralized with alkali, they become anionically charged and thicken by the effect of charge induced chain extension and through association of the hydrophobic groups. Polymers like acrylates/steareth-20 methacrylate copolymer build viscosity quickly and can suspend pigments or particulates. They are used in creams and gels.

Another type of rheology modifiers are hydrophobically modified ethoxylated urethanes (HEUR). Since these urethanes are nonionic polymers, no neutralization is required. Polymers are stable in anionic, cationic and non-ionic

systems as well as from pH 2-12. They impart a creamy feel and therefore, are used in creams, lotions, makeup, and hair care and hair color.

Polyamide resins sometimes are used to increase product viscosity in formulations where bulk clarity is desired. Ether and ester modified polyamides are used in colored cosmetic products to enhance shine and for better compatibility with cosmetic ingredients. Polyamide-8, bis-stearyl ethylenediamine/neopentyl glycol/stearyl hydrogenated dimer dilinoleate copolymer (Fig 4) is used in lipstick to improve gloss (5).

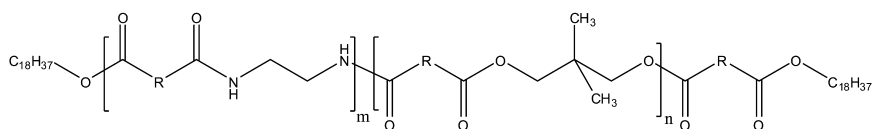


Figure 4. Bis-stearyl ethylenediamine/neopentyl glycol/stearyl hydrogenated dimer dilinoleate copolymer (where R is hydrogenated dimer dilinoleic acid).

It is not unreasonable to state that viscosity building properties vary directly with formula concentration. At low levels, a polymer may function primarily as a film former, but as polymer concentration increases, increased rheological structure is produced. When rheological control agents are added at very high levels, a liquid product gradually may become a semi-solid gel and then eventually become a solid product. Care must be exercised to ensure that end objectives are achieved.

Wrinkle Effacement

Wrinkles are commonplace skin defects, but many people regard their arrival as an ominous sign of advancing age. In their never ending quest to develop products that help create a youthful appearance, cosmetic chemists regard wrinkles as mortal enemies. Wrinkle formation is part of the skin aging process. Formulators of skin care products seek to prevent formation of wrinkles by influencing natural biological processes (e.g. skin hydration and collagen synthesis). In contrast, developers of color cosmetics primarily focus on covering and/or filling in wrinkles. A well formulated makeup product uses 3 different types of polymers to create a flawless finish: 1. film formers to fill in wrinkles; 2. polymeric powders to obscure the appearance of wrinkles; 3. polymeric humectants to attract and hold moisture to the skin. The subject of polymeric powders is intriguing.

The use of inorganic particulate materials (e.g. mica, sericite, silica or talc) to exert an “optical blurring” effect on skin is well known. More recently, synthetic polymeric “spherical powders” (e.g. nylon, polyurethanes,

polymethylmethacrylate) and naturally-derived polymeric powders (e.g. microcrystalline cellulose) have been used to supplement or supplant inorganic materials in makeup formulations to fill in and minimize the appearance of skin wrinkles. Occasionally, some polymeric powders also carry various surface treatments to enhance tactile properties and to increase resistance to water and sebum. Similar raw ingredients can be added to lip products (to reduce the appearance of lines and wrinkles on the lips) and nail care formulations such as “ridge filling basecoats”. While use of such materials provide significant “instant gratification” by changing surface appearances, longer-term benefits may be produced by incorporating hydrogen-bonding polymers to attract and bind moisture to the stratum corneum.

Gloss Reduction

Color cosmetics products are designed to deposit pigmented films onto various substrates on the human body (i.e. eyelids, eyelashes, face, lips and nails). Such films have finishes that are glossy, matte or somewhere in between. For certain types of products (e.g. lip glosses and nail lacquers) a high gloss film usually is preferred. Glossy lips appear moist and fuller in size, while lustrous nails appear to be very highly refined. Dark-colored products such as eye liners and mascaras sometimes use glossy films to create a deeper, richer appearance. Some color cosmetic products have low gloss finishes due to very high pigment concentrations (e.g. eye shadows and lip liners).

Liquid foundation makeup formulations frequently are developed so that their films exhibit little to no luster when applied to facial skin. There are several reasons for this. Liquid foundation products originally were developed as more convenient and less messy alternatives to traditional powdered facial makeup products (i.e. loose and pressed powders). Because the appearance of facial gloss often is associated either with perspiration or an oily complexion, a primary objective of foundation makeup is shine control. A secondary benefit of a matte finish makeup product is minimization of superficial skin imperfections such as fine lines and wrinkles (36). This phenomenon sometimes is referred to as “optical blurring”. Traditionally, inorganic materials such as clays and other silicates were used as “mattifying agents”. They diminish the appearance of film gloss by scattering incident light in multiple directions. In recent years, polymeric materials such as polyurethane, polyester powders also have been used to control gloss (38). Although polymeric materials tend to be more costly than inorganic powders, polymeric powders offer some important advantages. Because these polymers are manufactured by “additive” rather than “extractive” processes, desired performance properties can be “dialed in” with greater specificity. Perhaps more importantly, while inorganic powders are derived from mineral sources that may contain traces of objectionable heavy metals, polymers can be manufactured to high degrees of purity, an important consideration for cosmetic products.

Pigment Surface Treatment

Colorants can be used with impunity by most industries, but color additives intended for use in food, drug and cosmetic products are regulated closely in the United States by the Food and Drug Administration (“FDA”), and by similar regulatory agencies in other global jurisdictions (39). Such colorants (both inorganic and organic) are approved for cosmetic use primarily on the basis of their toxicological safety as opposed to other functional properties. *Dyes* are organic colorants that can be *dissolved* in certain solvents, while pigments (both inorganic and organic) are insoluble in their vehicles and must be *dispersed* in order to make them useful in color cosmetics. Because a limited number of approved pigments must be dispersed into a chemically-diverse group of cosmetic formulations, pigment dispersion is critically important to cosmetic chemists. Both chemistry and chemical engineering are needed for successful preparation of acceptable pigment dispersions.

While pigments may be dispersed mainly by application of intense mechanical energy, it is more preferable to augment “brute force” with some “chemical finesse”. This is accomplished by careful selection of the *pigment dispersion vehicle*, typically a liquid medium with which dry pigments are blended prior to mechanical energy. Polymers can provide some important benefits for pigment dispersions. Appropriate film former(s) and/or polymeric plasticizer(s) can be combined and dissolved in appropriate solvent(s) to form chemically-favorable dispersion vehicles. For example, nitrocellulose and toluene sulfonamide/epoxy resin can be dissolved into n-butyl acetate to form a suitable pigment dispersion vehicle for nail lacquer formulations. Individual pigment particles also can be *surface treated* with appropriate polymers to render them more readily dispersible in specific dispersion vehicles. For example, particles of titanium dioxide and iron oxides frequently are treated with very thin layers of dimethicone or other silicones to make their surfaces hydrophobic (40). Such treated pigments are more readily dispersible in various organic dispersion vehicles than their untreated counterparts. Surface treatment of pigments also can confer improved pigment suspension properties, an important consideration when formulating heavily pigmented products such as liquid foundation makeup. Hydrophobically modified pigments can enhance product application, spreading and wear properties, as they improve water-resistance of the products into which they are dispersed.

Ingredient Encapsulation

Modern color cosmetic formulations are a sophisticated combination of art and science. With thousands of raw ingredients from which to choose and infinitely many ways in which to combine them, contemporary products can be daunting to create and manufacture. Although cosmetic product chemistry might seem categorically mild, formulators are required to blend chemically-diverse materials while ensuring a high degree of safety, aesthetics and consumer value. Fortunately, advanced technologies are available to help the chemist achieve his or her desired objectives.

It is possible to protect sensitive raw ingredients from hostile chemical environments by encapsulating them inside polymeric capsules. There are some parallels to this tactic in other consumer product industries. A popular brand of candy uses a hard confectionary shell to protect heat-labile milk chocolate from melting (thus the tag line, “Melts in your mouth, not in your hand”). “Carbonless” business forms are coated with inks encapsulated in polymeric capsules prepared from urea-formaldehyde resins; these capsules release ink upon application of mechanical pressure from a ballpoint pen.

The phrase “timed release of active ingredients” may seem to have been borrowed from the pharmaceutical industry, but it also is relevant to the cosmetics industry. While the term “active ingredient” has very specific implications in pharmacy, one or more “active ingredients” may be added to certain cosmetic formulations to produce specific performance benefits. Entrapment can be used to provide substantiation for certain marketing-driven raw ingredient claims. In this scenario, vitamins or botanical extracts known to be beneficial to the skin can be entrapped into a polymeric matrix, then released slowly over time (41). It is important to emphasize that it is not appropriate to use entrapment for all cosmetic active ingredients. Over-the-counter (“OTC”) drug products are regulated very closely by FDA in the U.S. and by similar regulatory agencies in other countries. OTC products contain active ingredients specified in detailed formal “monographs” issued by regulatory agencies.

Such active ingredients must be handled carefully in order to guarantee their required biological activity. Certain biopolymers can be used to promote timed release of active ingredients. *Cyclodextrins* are cyclic pentapolymers of glucose. They form hollow “open cup” structures that can be “filled” with a payload ingredient (e.g. flavor, fragrance, fatty esters, etc.). Manufacture of encapsulated raw ingredients generally is performed by third-party specialty suppliers having the necessary expertise and process equipment to produce acceptable end products. Generally, “payload” ingredients must not act as solvents for the capsules in which they will be packaged, thus cross-linked polymers are valuable for such applications. Chemical and physical properties of encapsulated ingredients must be tailored to the characteristic of their final products: encapsulates should have proper hardness, particle size and shape, solubility and surface chemistry.

Color Development

As mentioned previously, color additives intended for use in food, drug and cosmetic products are regulated closely in the United States by the Food and Drug Administration (“FDA”), and by similar regulatory agencies in other global jurisdictions. Traditional organic pigments are complex aromatic compounds; while so-called “effect pigments” are based on the chemistry of various metal oxides and mica.

Dry pigments intended for use in nail lacquer formulations must be dispersed into nitrocellulose/plasticizer mixtures under high shear using specialized equipment. This process is termed “chipping”, and is performed by special

manufacturers trained to deal with the dangerous explosion and fire hazards presented by nitrocellulose (3). Mixed cellulose esters can be used instead of nitrocellulose to produce safer dispersions.

Gloss Enhancement

The term “gloss” refers to the ability of a surface to produce specular reflection. This property is highly prized in the color cosmetics industry because it connotes moisture, refinement and luxury. Moist lips also tend to appear larger and plumper than dry lips. Wet eyelashes appear fuller and darker, thus “wet-look” mascaras are valuable products. Matte finish nail lacquers are not mainstream products because to many users they appear dull and worn. Classic gloss promoting cosmetic ingredients are lipophilic compounds such as oils of animal, vegetable, mineral and synthetic origin (e.g. lanolin, castor oil, mineral oil and isopropyl myristate, respectively) (42). These materials are used extensively in lip products, an application where high gloss is important. Not surprisingly, gloss also is promoted by a wide range of cosmetically acceptable polymers.

Hydrocarbon polymers such as hydrogenated polycyclopentadiene and polydecene exhibit outstanding luster. Nitrocellulose, styrene/acrylates copolymers, and phenyl silicones all confer significant gloss to a variety of products (43). Thermoplastic polyester resins (e.g. adipic acid/neopentyl glycol/trimellitic anhydride copolymer) are glossy secondary film formers in nail lacquers (13). Specialized proprietary “bio-polyesters” (e.g. sucrose polycottonseedate, the product of exhaustive esterification of sucrose by cottonseed oil fatty acid) are used in lip products (44). Aromatic groups (e.g. phenyl, benzyl) have inherently high indices of refraction, thus polymers rich in styrene monomer content (e.g. styrene/acrylates copolymers) are glossy film formers.

Odor/Flavor Control

Color cosmetics have very attractive visual impact, but they also must satisfy tactile, olfactive and sometimes gustatory aesthetic requirements. For example, fragrances are important for providing aesthetic enhancement as well as malodor control (45). Flavoring agents and artificial sweeteners often are added to lip product formulations to enhance taste. Unfortunately, fragrances and flavors are complex mixtures of volatile compounds that evaporate readily, making them challenging to use during manufacturing and storage. Many cosmetic products encounter significant amounts of heat during manufacturing and filling, thus preventing fragrance loss is an important consideration. Entrapment of fragrance can be a desirable tactic in such situations. Fragrance oils can be mixed with reactive monomers (e.g. acrylate monomers) then become “entrapped” upon formation of the polymer. In this situation, the polymer serves as a “fixative” by delaying release of entrapped fragrance oils. Cyclodextrins perform similar functions. “Loaded” cyclodextrins can deliver fragrance oils over time, while “empty” cyclodextrins can be added to products to scavenge malodors (46).

Polymers and Color Cosmetics: Formulation Guidelines

As with all chemicals, polymers must be selected thoughtfully and handled with care throughout the new product development process. Many thousands of cosmetic chemicals are available to formulators of color cosmetic products, thus raw ingredient selection is not a trivial matter. The logical first step is to identify the intended biological substrate(s) to which the product will be applied: eye, face, lip and/or nail. The next task is to determine the physical form of the product (i.e. liquid or solid) and its desired performance attributes (e.g. easy application, long wear, one-coat color deposition, water resistance etc.). Finally, the proposed package must be considered: stick, tube, bottle, jar, pump, etc.). Implicit in these considerations is whether one or more polymers are required to help achieve formulation objectives. In some instances, use of time-honored non-polymeric raw ingredients may be adequate; this is particularly true for many “natural” cosmetic products. On the other hand, as demonstrated previously in this chapter, development of modern, high-performance color cosmetic products typically requires use of polymers to accomplish demanding tasks. When the use of polymers is contemplated, it is necessary to consider the following general factors:

Formulation Type and Characteristics

At the outset, it must be determined what specific physical form the new product must have in order to meet overall performance objectives. Color cosmetic products can be solids (e.g. lipsticks), semi-solids (e.g. lip gloss gels), liquids (e.g. nail lacquers) or aerosols (e.g. aerosol mousse foundation makeup). Once the basic product form has been determined, it is necessary to evaluate the various types of chemical formulations that might be used to create the desired end product. In many instances, the type of chemistry that ultimately will be used will be dictated by product history, corporate preferences or a formulator’s technical acumen. Generally, it must be determined whether the base formula will be hydrophilic or hydrophobic, and if the desired performance of the final product requires formation of relatively durable films on the skin, hair or nails. This decision helps determine which types of polymers might be added to influence product aesthetics and performance, especially the type and degree of required structure modification and/or film formation. For example, in hydrophobic formulations such as a lip gloss, incorporation of a hydrocarbon polymer (e.g. hydrogenated polydecene) would be appropriate for enhancement of adhesion, gloss and water-resistance (11). Similarly, the structural integrity of a lipstick can be improved by addition of polyethylene or eicosene/vinyl pyrrolidone copolymer to augment structure-building waxes such as carnauba. For high performance lip formulations, silicone resins (e.g. trimethylsiloxysilicate) dissolved in a cosmetically-acceptable volatile hydrocarbon solvent (e.g. isododecane) help promote strong skin adhesion and transfer-resistance (8–10).

If a water-based formulation is desired, it must be determined if the product warrants use of a more complex type of formulation (e.g. an emulsion, a solution or a suspension). An aqueous suspension product such as a tinted cheek gel

contains large amounts of water, thus it can be thickened with a hydrophilic polymer such as polyacrylic acid or PEG-3M. If a product must be an emulsion, the type of emulsion system must be determined: oil-in-water (O/W), water-in-oil (W/O) or mixed. For example, liquid foundation makeup products requiring a light skin feel might use an O/W emulsion base, and a hydrophilic polymer such as vinyl pyrrolidone homopolymer can be added to build viscosity and form a water soluble film. Conversely, a waterproof mascara product requires hydrophobic films produced by W/O emulsions. In this application, certain hydrocarbon resins (dissolved in cosmetically-approved light petroleum distillate solvents) could prove useful for their adhesion and durable film formation attributes.

Solvent Selection

When preliminary formulation type and characteristics have been determined, the next major consideration is selection of an appropriate solvent system. In aqueous systems, water is the primary solvent, but addition of surfactants or coupling agents may be useful if one or more hydrophobic raw ingredients need to be incorporated. In some instances, small amounts of ethanol or isopropanol may be added to enhance the solvent power of water. In anhydrous systems, it is necessary to determine which polymers must be dissolved. Modern anhydrous color cosmetic formulations can use inorganic and/or organic solvent systems. Inorganic solvents are “volatile silicones” (e.g. trisiloxane, cyclopentasiloxane and low molecular weight dimethicone) commonly used to dissolve various silicone polymers (e.g. high molecular weight dimethicone etc.). These solvents are virtually odor-free and have a dry feeling when applied to skin surfaces. Evaporation rates can be adjusted by blending silicones of different boiling points.

Organic solvents vary considerably according to specific formulation requirements. Volatile hydrocarbon solvents (e.g. C7-C15 isoparaffins, petroleum distillates, isododecane, isohexadecane) can dissolve a variety of polymers (e.g. silicone resins, rosin esters, styrene/acrylate copolymers) that are useful for enhancing adhesion, hydrophobicity and transfer-resistance. Such volatile hydrocarbons frequently are used in high performance lipstick, mascara and foundation makeup formulations and therefore must be free of residual aromatic solvents. The broad category termed “oxygenated solvents” includes a variety of compounds having one or more oxygen-containing functional groups (e.g. carbonyl, ester, ether and hydroxyl). Examples of oxygenated solvents include alcohols (e.g. ethanol, isopropanol), ethers (e.g. PEG), esters (e.g. n-butyl acetate), glycols (e.g. butylene glycol), glycol ethers (e.g. dipropylene glycol mono-methyl ether), ketones (e.g. acetone) and organic carbonates (e.g. propylene carbonate). Many solvents have harsh odors and may present significant fire hazards, thus they must be handled with care. Silicone solvents generally are not irritating, but some hydrocarbons and oxygenated solvents can be harsh on the skin, therefore care must be exercised when contemplating their use in color cosmetic formulations. Nail lacquer formulations are not applied directly on skin, and can use most oxygenated solvents with impunity. With the exception of ethanol and some glycols, most oxygenated solvents see limited use in color cosmetics.

Packaging Design

A favorite slogan of industrial designers is, “Form follows function”, which also is very applicable to design of packages for color cosmetic formulations. Perhaps an even more relevant expression would be, “Begin with the end in mind.” Many conventional cosmetic containers are incapable of preventing evaporation of volatile solvents. More importantly, some cosmetic applicators and packages are constructed from polymers that can be attacked by certain solvents, causing package damage and eventual loss of product integrity. When the use of any volatile solvent (including water) is contemplated, it is absolutely imperative that package design engineers be informed immediately. Modern cosmetic packages frequently incorporate various “hermetic sealing” devices to prevent undesired solvent evaporation.

Manufacturing Considerations

Many color cosmetic formulations involve manufacturing and filling processes requiring application of heat. When considering the use of polymers in color cosmetic formulations, it is important to determine if process heating equipment capable of achieving required melting temperatures is available for use. More importantly, if use of volatile solvents is contemplated, it is very important to ascertain that process equipment can be sealed to prevent evaporative losses during processing at elevated temperatures. If flammable solvents must be used, electrically-powered process equipment and surrounding devices (e.g. lights, telephones, laboratory testing equipment, forklifts, fans, etc.) must be specially designed to prevent ignition of hazardous atmospheres: such installations are termed “explosion proof” (“XP”). Additionally, appropriate fire suppression equipment must be installed and maintained at locations where flammable solvents are stored and handled.

Economic Constraints

While use of polymers and solvents can facilitate the creation of numerous high value color cosmetic products, such raw ingredients sometimes may contribute to elevated costs of goods. This is not unexpected, given that synthetic polymers are “value added” raw ingredients and volatile solvents mandate the use of sophisticated packaging and processing techniques. As with all other business decisions, it is necessary to perform risk versus benefit analyses to determine if the potential benefits of polymer use outweigh their perceived disadvantages.

INCI Nomenclature

From a regulatory standpoint, it is a global requirement that all raw ingredients used in cosmetic formulations be given an “INCI name” (INCI = **I**nternational **N**omenclature of **C**osmetic **I**ngredients). The conferral of an approved INCI name on a raw ingredient does *not* indicate the raw ingredient is *approved* for use in cosmetic products. Rather, an INCI name is a formal descriptor that must be used

for mandatory ingredient labeling purposes should that raw ingredient ultimately be used in a final cosmetic product. Obtaining an INCI name for a raw ingredient is a process that is neither complex nor costly. Any manufacturer planning to market a polymer or other raw ingredient to the cosmetic industry should contact the Personal Care Product Council to obtain detailed information regarding the INCI registration process (47).

Summary

Color cosmetic formulations have evolved considerably during the last 30 years. Time honored product formulations focused primarily on attractive appearance and pleasing textures. In today's highly competitive global marketplace, color cosmetic formulators simply cannot depend on advanced pigment technologies to achieve significant commercial success. Cosmetic consumers have become increasingly more sophisticated, and they demand multi-benefit formulations in every product category. In response to such market-driven challenges, the performance attributes of color cosmetic formulations have improved steadily and impressively. Products have become easier, safer, more convenient to use than ever. They also offer the modern consumer a greater degree of choice and a higher level of value for the money.

The products of today arguably are the very best products the cosmetic pigment industry has created, yet in today's marketplace novel aesthetics cannot "carry the day" alone. Formulation technologies must keep pace with demand for constant innovation. In light of the information presented in this chapter, it is not unreasonable to assert that modern, high performance color cosmetics simply would not exist without the judicious use of polymers. Ironically, some contemporary cosmetic products are marketed under an "all natural" banner. Many such products exploit the unfounded fear of chemicals held by some consumers, and therefore they revert back to unsophisticated formulation technologies. These are best described as "niche" products. They generally are shunned by mainstream consumers, who prefer the level of performance that simply cannot be achieved by products relying mostly on natural raw ingredients. Clearly, the futures of polymer science and cosmetic science will remain closely intertwined, as chemists from both disciplines continue to heed Henry Kaiser's old adage: "*Find a need and fill it.*"

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