Encapsulated Organic Colorants to Mimic Naturally Flawless Skin

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KEY WORDS: *encapsulated organic colorants, vibrancy, high chroma, multichromatic color, surface free energy, skin optics*

ABSTRACT: *In the present study, researchers discuss the benefits of using encapsulated organic colorants in cosmetic foundations, including higher chroma shades with tunable opacity, increased color variation of the foundation, and a surface energy profile optimized to skin.*

Ideally, color cosmetic foundations give a person the look of naturally flawless skin. Unlike many color cosmetic products that follow a cyclical, trend-driven pattern in their form, finish and color, the highest priority needs for a foundation remain more constant. Indeed, the most natural color cosmetic foundations are inspired by a combined knowledge of the color components, compositional nature and optical properties of healthy skin, as well as consumer preference.

Understanding skin biology, therefore, provides the best road map to creating color compositions most like real skin. Until recently, however, the ability of scientists to mimic naturally flawless skin has been limited by the colorants available for use in color cosmetic foundation formulations. A new encapsulation technology is presented here that addresses historical color limitations while offering new possibilities for delivering lifelike color to the skin.

Based on internally conducted consumer research, the authors found that more than 65% of women prefer a foundation that makes their skin look brighter. In order to provide a brighter color palette that maintains or expands the range of colors within the palette, it is desirable to increase the color vibrancy, or *chroma*, of the colorants used in the foundation.

Until recently, the ability to mimic naturally flawless skin has been limited by the colorants available.

While this may seem like a straightforward exercise, the colorants most suitable for use in color foundation are low-chroma inorganic pigments. While much higher chroma organic colorants exist and are approved for use on skin, they have historically not been used in any appreciable amount in foundations due to the fact that they are not stable in environments that contain water. In aqueous mediums, the organic colorants have a tendency to release free dye. This can both shift the shade of the composition as well as solubilize in the water in the stratum corneum, thereby creating an undesirable staining of the skin. Thus, there exists an opportunity to enable the use of higher chroma pigments for brighter shades with a more lifelike palette of shades suitable for use in aqueous environments.

A further opportunity for improving the appearance of color foundations is to mimic the naturally multichromatic color of skin. The color variation present in naturally flawless skin is very uniform. As people age, more hyperpigmented regions appear such as age spots and freckles, which are largely a result of damage from UV radiation. In order to hide skin imperfections, women turn to color foundations to create a more uniform coloration. The drawback to this is that, in the process of hiding imperfections, women can also remove all of the positive uniform color variation and inadvertently create a skin appearance that is less natural. This creates a further opportunity for color foundations: to hide skin imperfections while maintaining the microscopic color variation that looks more like naturally flawless skin.

A final opportunity for improving cosmetic foundations is to develop colorants that more closely match the surface energy of skin. Commonly used iron oxides have surface energy characteristics that are very different than those of bare skin. By more closely matching the polar and dispersive surface energy components of skin, the spreading properties, adhesive properties and overall appearance of the colorants can be improved.[1]

The authors have found that by using patent-pending,[2] stable and nonbleeding encapsulated organic colorants, they can address all of these foundation opportunities, which can in turn lead to an appearance that more closely mimics that of naturally flawless skin. These benefits include: higher chroma shades with tunable opacity, increased color variation of foundation that yet maintains coverage of imperfections, and a surface energy profile that improves pigment-skin compatibility.

Organic Colorants to Increase Vibrancy

There are many means to describe *color*. The CIE (Commission Internationale de l'Eclairage) is the international standards organization responsible for setting standards for color and color measurement. CIE XYZ (1964) is a mathematical model produced by the CIE that describes color in terms of synthetic primaries based on human perception. The primaries are imaginary mathematical constructs that model the eyes' response to different wavelengths of visible light (approximately 400–700 nm).

Such models allow perceived color to be specified unambiguously, unlike models such as RGB and CMYK, which define amounts of colorants rather than actual colors. The CIE-Lab is a mathematical derivative of CIE XYZ (1964) that describes colors using three synthetic primaries: L* (indicating lightness), a* (indicating red-greenness) and b* (indicating yellow-blueness). A further commonly used color model is a the LCh color model derivative of CIE-Lab that uses cylindrical coordinates of lightness (L*), chroma (C*), and hue (h*) instead of the rectangular coordinate system of Lab. For the purposes of discussion, the LCh color model derived from the CIE-Lab (1964) standard will be used moving forward.[3–4]

As has been described, creating more vibrant or synonymously higher chroma shades is an opportunity to improve overall foundation appearance. However, while higher color strength or saturation is desired, it is important to maintain the narrower range of hues and lightness that represent the spectrum of human skin tones across the globe.

Skin chroma, or vibrancy, is an important element of healthy-looking skin. This is related to the amount of hemoglobin that is the most highly chromatic, vibrant contributor to skin color.[5] The more blood flow in the skin, the higher the contribution that hemoglobin provides to the skin color. The importance of chroma on skin appearance can be visualized in **Figure 1**.

More than 65% of women prefer a foundation that makes their skin look brighter.

The images in **Figure 1** have been matched in hue and lightness, while the chroma is varied. These are bare skin images that have been modified using photo manipulation and not a cosmetic product. For illustration purposes, when comparing the images in **Figure 1**, the right image has been modified to have an overall C* value that is 15.0 units higher—based on the CIE XYZ (1964) derivation—than the left image. This variation in chroma fits well within the range of foundation shades offered in the marketplace today. Though the translation from computer images to print are not perfect, the images displayed here nonetheless show the strong dependence of chroma on overall skin appearance.

A novel organic colorant encapsulation technology[2] has been specifically designed to enable benefits in the area of increasing chroma while maintaining the hue and lightness range of human skin tones. Specifically, the use of organic colors such as FD&C Yellow 5 and D&C Red 36 in conjunction with the typically used inorganic pigments has been found to significantly increase the chroma of foundation shades.

Additionally, while traditional inorganic iron oxide colors also have the ability to modify foundation chroma, their high refractive index (RI), typically between 2.0–3.0, requires that highly chromatic shades are also high in coverage or contrast ratio (CR). For the purposes of the data provided here forward, CR values were calculated using a method by which foundation samples were applied to clear polyester panels[a] (P300-7C) using a 1 mil draw-down bar, dried at 50°C for 1 hr at 10% RH, then measured over an opacity chart (form 2A, white then black)[a] using a spectrophotometer[b].

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[a] *Lab devices were obtained from Leneta.*
[b] *The International Microflash 200d D65/10 spectrophotometer is a device from Datacolor.*

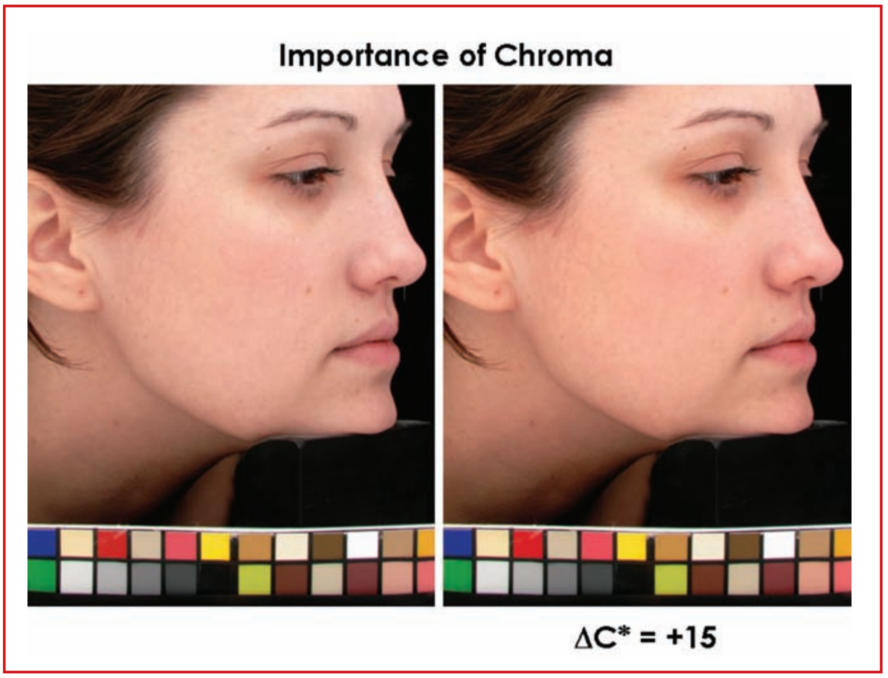

Figure 1. Bare skin with and without chroma enhancement

The problem with creating high CR foundation shades is that they can inherently appear monochromatic or false because they cover up nearly all of the color variation found in natural skin. The novel polymer-encapsulated organic colorants[c] FD&C Yellow 5, D&C Red 36, and FD&C Blue 1, prepared by a modified water-in-oil emulsion solvent evaporation method,[2] circumvent this problem because they have a comparatively low RI value of 1.20.

This allows for the creation of shades that are highly chromatic or vibrant without the requirement that they are high in contrast ratio, thereby providing a more natural beauty enhancement.

To illustrate this important benefit of the encapsulated organic colorants, two liquid foundations were prepared. The first foundation contained only inorganic colorants while the second contained a combination of inorganic colorants and a high level of the new encapsulated organic colorants (7.0% w/w encapsulated FD&C Yellow 5 and 7.0% w/w encapsulated D&C Red 36). Both foundations were formulated to have the same L* (63) and h* (44) values. When the foundations were compared using the method described above they were found to be equal in CR (both measuring 0.80 ± 0.04), whereas the foundation containing the encapsulated organic colorants had a positive ΔC* of 8.3.

[c] *INCI: Styrene/acrylates copolymer (and) ammonium styrene/acrylates copolymer, (and) zinc oxide (and) Blue 1 Lake, Red 36, or Yellow 5 Lake*

An opportunity exists using higher chroma pigments for brighter shades suitable for use in aqueous environments.

The use of novel, nonbleeding encapsulated organic colorants has enabled the development of foundation shades with chromas that are significantly higher than those created with inorganic colorants alone at comparative contrast ratios. This thereby addresses the consumer need for brighter, more life-like foundation shades while maintaining the desired level of coverage or contrast ratio. The net result is more degrees of freedom to creating a brighter foundation shade palette without sacrificing natural appearance due to artificially high levels of coverage.

Encapsulated Organic Colorants for Natural-looking Foundations

One of the primary reasons consumers use cosmetic foundations is to hide skin imperfections on the face. In order to maximize the efficiency of the inorganic colorants commonly used in foundations, it is desirable to have an average primary particle size in the 0.5–2 µm range. These small, high refractive index pigment particles deliver high levels of "hiding power"—coverage or opacity—that consumers look for in a foundation, but as has been noted, the trade-off is that these foundations can appear heavy and unnatural. This is primarily due to the fact that the small particle sizes (0.5–2.0 µm) that are used to create shade and coverage are perceived by the human eye as a monochromatic color.

Therefore, more coverage on the skin equals more natural color variation removed from the skin. This creates a less natural appearance at the expense of hiding imperfections. Thus, eliminating the trade-off between providing higher levels of coverage and maintaining the appearance of natural looking skin presents another benefit that encapsulated organic colorants can resolve. By making these colorants significantly larger than traditional inorganic pigments, they have the ability to increase the color variation of foundations in which they are incorporated.

Various color measurement tools can be used to assess how monochromatic or multichromatic a product and/or substrate really is. The authors have found one specialized spectrophotometer[d] in particular to be an effective tool for measuring multi-chromatic effects both in vitro and in vivo. Initially designed for dental applications, this device has been used successfully in numerous clinical trials.[6]

In this study, it has been found that the same instrument is a convenient tool for measuring spectral data on skin. The instrument takes a digital image with a resolution of 300,000 pixels over an 18 mm x 13 mm area and gathers full spectral data (400 nm–720 nm region) for each individual pixel. As a result, the instrument is able to compute the CIE-Lab C* value for each region of the image with dimensions of approximately 27.9 µm x 27.9 µm.

From this set of 300,000 individual chroma values, a standard deviation of chroma is then calculated. A comparison of typical values for chroma variation

[d] *The Spectroshade spectrophotometer is a device from MHT Optic Research AG.*

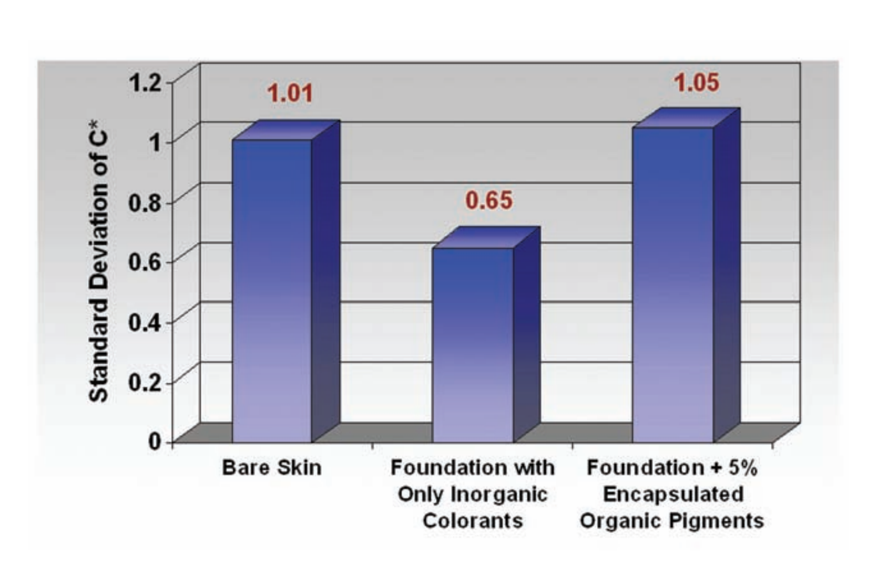

Figure 2. Chroma variation comparison of bare skin, foundation and foundation plus encapsulated organic colorants

of natural skin versus skin treated with a marketed foundation containing only inorganic colorants, versus a foundation containing both inorganic colorants and encapsulated organic, colors was conducted. In this experiment the foundation applications were applied at a dosing of 1 mg/cm^2, which has been determined to be a typical usage amount for most marketed liquid foundations.

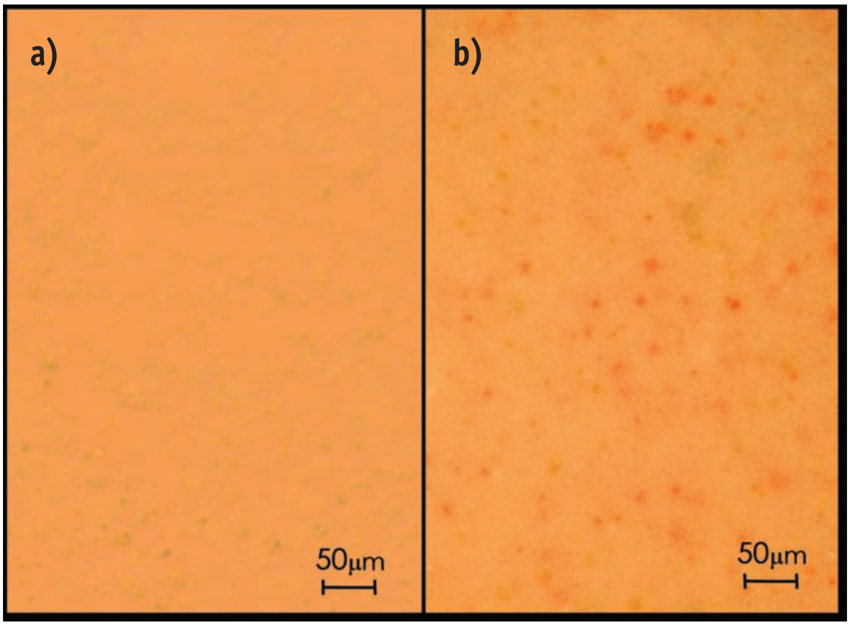

Figure 3. Microscopy images of foundation samples a) without and b) with encapsulated organic colorants

Through experimentation it was found that 5.0% of the encapsulated organic colorants (3.0% w/w encapsulated FD&C Yellow 5, 1.5% w/w encapsulated D&C Red 36, and 0.5% w/w encapsulated FD&C Blue) brought a traditional foundation back to the same level of chroma variation that was measured for bare skin. These results are shown in **Figure 2**.

The problem with creating high CR foundation shades is that they can inherently appear monochromatic.

Additionally, **Figure 3** shows comparative images of the foundation samples with and without the presence of the encapsulated organic colorants taken at 100X magnification using transmission light microscopy.

These results indicate that the use of novel encapsulated organic colorants enables the foundation to deliver a product film with a chroma variation significantly higher than that of a comparative foundation using only traditional inorganic colorants, and most importantly the resulting chroma variation proves comparable to natural skin.

Colorants to Match Surface Energy

An additional opportunity of creating encapsulated colorants is to choose a shell material that more closely matches that of skin. Surface energy matching is commonly important when trying to improve spreading properties as well as adhesion between two materials. Regarding cosmetic foundations, it has been shown in controlled studies[1] that matching the surface free energy (SFE) of the particulates in the foundation to that of the skin creates consumer noticeable benefits in a multitude of areas. Among the benefits to matching skin SFE, particularly the polar component of SFE, are such consumer-described attributes as improved skin comfort, a more beautiful finish, visibly closer fit to the skin, and higher overall preference versus traditional colorants.[1]

Regarding the design of the novel encapsulated organic colorants, which is the subject of this paper, the SFE of the encapsulation shell can be tailored to closely match the SFE of skin better than other commonly used colorants. Measurements of the polar and dispersive components of SFE have been conducted for a wide range of commonly available organic and inorganic colorants along with a similarly broad range of surface treatments. In **Figure 4**, the results of these measurements are plotted along with measures of SFE for the novel encapsulated organic colorants tailored to match clean, dry skin.

It can be seen by examining **Figure 4** that the skin is much less polar than commonly used colorants. In contrast, when the surface energy of the polyacrylate encapsulated organic colors are plotted alongside that of the washed skin, it can be seen that the surface energy components are extremely well-matched.

These results show that proper choice of the encapsulating material can improve on the difference in SFE between skin and colorants. This subsequently can allow for improved aesthetic attributes when these skin-matched SFE colorants are incorporated into foundation products.

Conclusion

Specially designed, patent-pending polyacrylate encapsulation technology has allowed new possibilities for delivering lifelike color to the skin. The use of these stable, nonbleeding encapsulated organic colorants can enhance today's foundation chassis by providing a means to boost chroma independent of opacity, restore the color variation found in bare skin, and optimize the surface free energy of the encapsulation shell to mimic that of the skin surface.

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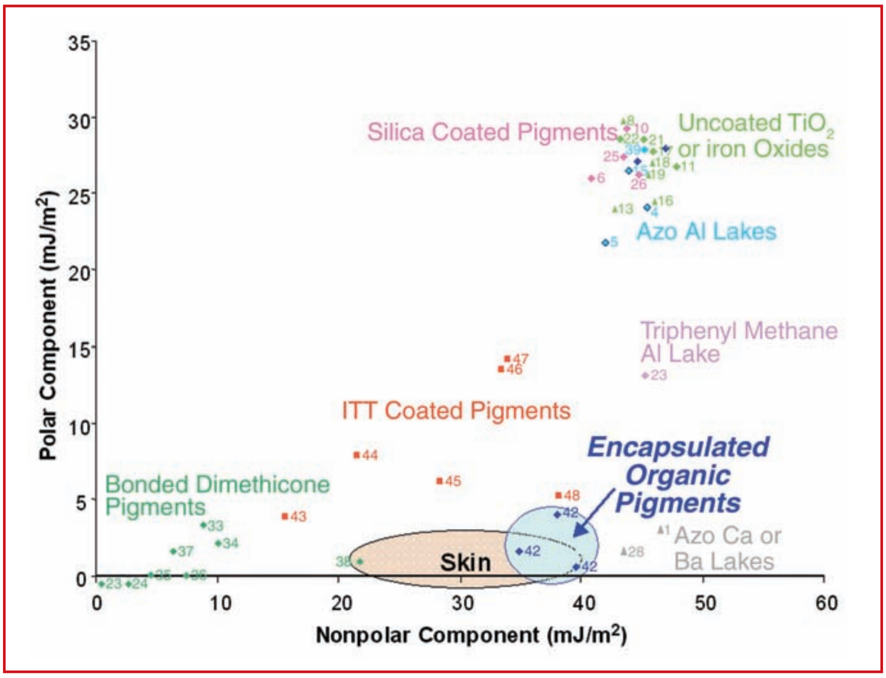

Figure 4. Surface-free energy mapping of particles