More than meets the eye: The science of unique skin color and its interaction with cosmetic foundation

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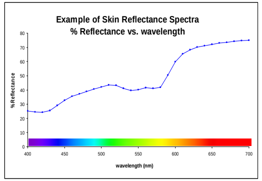
INTRODUCTION

Ideally, cosmetic foundations give the wearer the look of naturally flawless skin. But because current foundations are made of different colorants than the chromophores in skin (i.e., melanin, blood), optical issues can arise that lead to a variety of unnatural looks. Here we present an optical skin model to better understand the fundamental differences in skin color across the various color "defects" present in skin (age spots, blotchiness, dark under eye circles), as well as the differences across different population groups. Additionally, we have developed optical models for foundation make-ups. This understanding has lead us to design improved foundations that go beyond traditionally used foundation components by integrating an optical understanding of how light interacts with skin and skin covered in a thin foundation film.

Figure 1



BACKGROUND

Color & Spectra Fundamentals

Color of an object is an integration of how the human observer (vision system/brain) understands the interaction between objects and the lighting conditions surrounding us. The fundamental measurement which governs the color of an object is how it reflects and transmits various wavelengths of light in the visible spectrum (400 – 700 nm nominally).

This reflection and transmission of an object is measured using a spectrophotometer and the graph of reflection (or transmission) versus wavelength is called a spectra. Figure 1 illustrates an example of a Reflectance spectra for skin. Color Science principles (for example the CIE system) explain mathematically how to convert this spectra (when a lighting condition & observer is provided) to Color. <u>But the most fundamental measurement is the spectra.</u>

Color Modeling Using Kubelka Munk

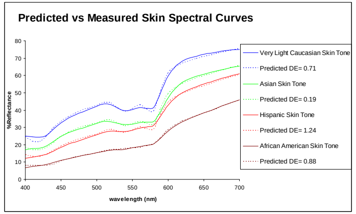
For many years, paint & textile manufactures have utilized the Kubelka Munk model to make a formulation match a target color. This model relates measured quantities (reflection and transmission) to two fundamental optical parameters: the absorption coefficient and the scattering coefficient, which are then used for optical predictions. This approach has also been extended into Skin Color in the dematological field[1] and is utilized to match target colors for cosmetic formulations (foundations & lipsticks).

RESULTS: Predicting Skin Color

Figure 2 is an example of a measured skin reflectance spectra compared to one predicted from our P&G Beauty Model. The model was created using known absorption coefficients of melanin & hemoglobin[2] and the known scattering coefficient of the dermis[1] from skin literature in a Kubelka Munk model with one new addition.

Taking skin physiology into account, P&G Beauty made a critical addition to these models to improve the fit : including an attenuation term for different wavelengths of light. Because skin is several millimeters thick, lower (blue) wavelengths will not penetrate as deeply[1]. Because the Kubelka Munk theory does not include this phenomena, we added a parameterization term to account for penetration depth as a function of wavelength. These models help us understand the physiological differences across skin tones which is critical for creating the most natural foundation colors to satisfy all women. It also allows us to fully understand the causal factors of skin defects which enables us to better design foundations and skin care products.

Figure 2

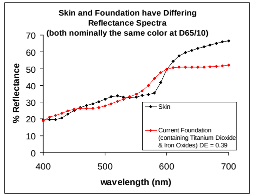


Challenges with Today's Foundations:

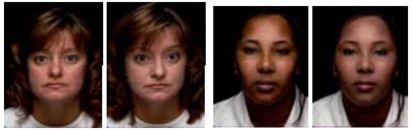
Current foundations contain iron oxide & titanium dioxide to create a "skin-like" color. With these materials, it is possible to nominally match skin's color (at a given lighting condition/observer), however the chromophores in skin are different than iron oxides & titanium dioxide. As a result, the fundamental spectra of skin is quite different than that of current foundations (see Figure 3).

We have conducted numerous consumer studies in which we give consumers a foundation, have them apply it and ask them how they rate it for satisfaction with shade. At the same time, we measure the Reflectance spectra of both their bare skin and their skin after applying foundation. These studies have shown us two of the key issues with foundations that occur over the range of skin tones from light Caucasians to deep African descent skin tones.

Figure 3



Too Light & Pasty



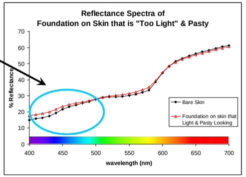
Bare Skin | Foundation too Light & Pasty | Bare Skin | Foundation too Light & Pasty

In a 2006 consumer questionnaire of 594 foundation users over the internet, 55% reported ever having an issue with a foundation shade being too light, too pale &/or too pasty. Examination of the spectra indicates one critical foundation optical issue is foundations can provide too much reflection in blue wavelengths compared to bare skin. Figure 4 illustrates an example of these curves. Note that this consumer did not like the shade, she thought it was Too Light & Pasty looking.

When the foundation provides too much reflection in the ~400 to 470 nm range, consumers consistently report the shade is pasty.

Note: Figures 4 & 5 show a thin film of foundation on the skin (not the foundation only color as in Figure 3).

Figure 4



Too Dark &/or Orange

Bare Skin

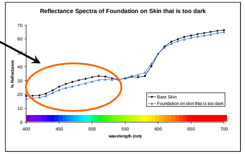
Foundation too Orange

Overlay of bare skin onto Foundation too Orange

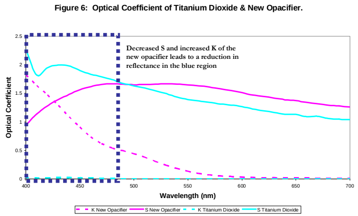
In the same consumer study 54% of foundation users reported ever having an issue with a foundation shade being too dark or too orange. Figure 5 illustrates an example of this effect. The consumer did not like this shade because it was Too Dark.

Another critical optical issue is foundations can provide too little reflection in the blue to green wavelengths (400 to 550 nm).

Figure 5



NEW OPPORTUNITIES



Using P&G Beauty's in depth knowledge of the optics of skin and thin foundation films, we have been able to define optical requirements for materials to use within foundations to minimize the above issues. To define these optical requirements, the scattering (S) and absorption (K) coefficients of current and new colorant materials for foundations were measured (Figure 6). This allows us to select new colorants that minimize reflectance in the blue region of the spectrum, via reducing the scattering coefficient in this region, increasing the absorption coefficient, or a combination of these approaches. Specifically this approach has allowed us to identify a potential new material for use in foundations which allows us to provide coverage to the skin while better matching skin's spectral curve. This will lead to a reduction in consumer observed pasty / ashy negatives.

References

1. Anderson, R.R., Parris, J.A., "The Optics of Human Skin," Journal of Investigative Dermatology, 77:13-19, 1981
2. Prahl, S., Oregon Medical Laser Center, http://omlc.ogi.edu/spectra
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This work was funded by P&G Beauty & Grooming.

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