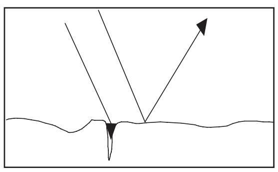
Light Diffusion Effects of Fumed Alumina

Introduction

In an aging population, the demand for cosmetic products that hide the effects of aging has significantly increased. Wrinkles and fine lines, the primary signs of aging, cause the skin tone to look uneven by trapping light in the crevices formed by the wrinkles. The trapped light appears to be absorbed and causes the appearance of dark spots. Unfortunately, many foundations and make-ups currently available on the market actually accentuate fine lines and wrinkles due to migration of the pigments in to the wrinkle crevices or effectively cover up the imperfections but create an unnatural, caked-on appearance. Therefore, the need exists for alternative particles, which can cover up the signs of aging, while projecting the natural skin tone. The journal article, "Quantification of the Soft-Focus Effect,"[1] by Dr. Emmert, outlines the criteria for such a particle, which if met would provide the optimum diffusion or soft-focus effect. The criteria are as follows:



- The diffuser particle needs to have minimal light absorption.
- The diffuser particle needs to have high total transmission to provide a natural appearance.
- Most of the light transmission needs to be diffuse, in order to provide an even reflection of light from the skin.
- The scattered reflection component of the total reflection needs to be high to obtain an even light distribution, independent of wrinkles.
- The specular reflection has to be minimal to minimize luster.

The scope of this paper is to review the light diffusion effects of various particles available today and compare them to the performance of Cabot's fumed alumina for cosmetics.*

Experimental Method

All evaluated particles were incorporated into the following formula:

Isopropanol	32%
Deionized water	32
Polyderm PE-PA (30% aqueous)	33
Light diffusion particle	3
	100%

The particles were dispersed in the solution under light agitation. The dispersions were then applied on to glass slides using a 50 µm (wet film thickness) bird applicator. The resulting air-dried films were estimated to be 5 µm in thickness with approximately 23% of the solid film being the light-diffusing particle.

The formulation for these experiments were chosen to solely study the diffusion effects of the particles, while yielding a durable film for handling during the analysis. The polymer was carefully chosen to ensure its refractive index (1.54) fell within the range of common cosmetic vehicles (1.33–1.6).

The optical properties were measured using a HunterLab UltraScan® XE.** The UltraScan XE is a dual beam xenon flash spectrophotometer with a wavelength range from 360 to 750 nanometers (nm). The sensor uses an integrating sphere to measure reflected or transmitted light. The sphere contains a specular exclusion port allowing measurements that excluded the specular components. Therefore, the following four types of measurements were made for each particle evaluated:

- Total Transmission (referred to as TTRAN)
- Regular or Specular Transmission (referred to as RTRAN)

*Patent pending.
**UltraScan is a registered trademark of HunterLab.

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- Total Reflectance (referred to as RSIN)
- Scattered Reflectance (referred to as RSEX)

Table 1 provides a list of the materials included in this evaluation.

Table 1

Particle	Refractive Index	Particle Size Range
No Particle	1.54	Polymer film
Titanium Dioxide	2.50	5–14 µm
Boron Nitride	1.74	6–15 µm
Nylon 12	1.53	5–15 µm
Cabot's Fumed Alumina	1.71	10–30 µm

Results and Discussion

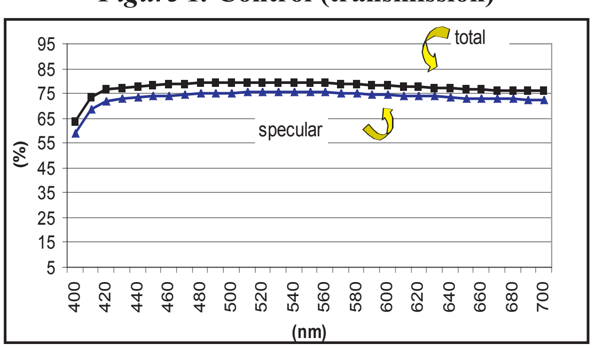
The results and discussions focus on the transmission and reflectance behaviors of the particles included in this evaluation as all absorption levels were considered sufficiently low. The absorption properties can however be calculated by difference.

$$A = 100 - (R+T) \quad \text{(eq. 1)}$$

The transmission results of the control sample (formulation with no particle) indicates an average total transmission of 80%, with the specular or direct transmission component being 94% of the total (refer to Figure 1). The high percentage of specular transmission is indicative of a film that is essentially transparent with no diffusion or haze.

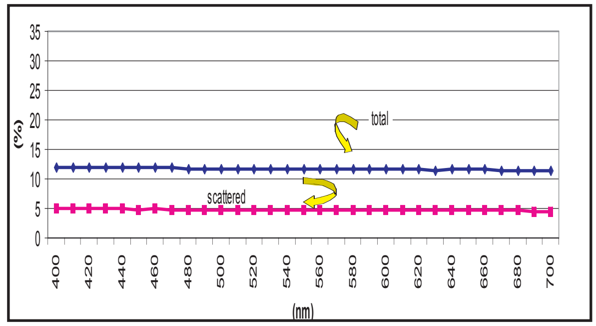
$$\%\ DTran = \%\ TTran - \%\ RTran$$
$$\text{where } DTran = \text{diffuse transmission} \quad \text{(eq. 2)}$$

Figure 1. **Control (transmission)**



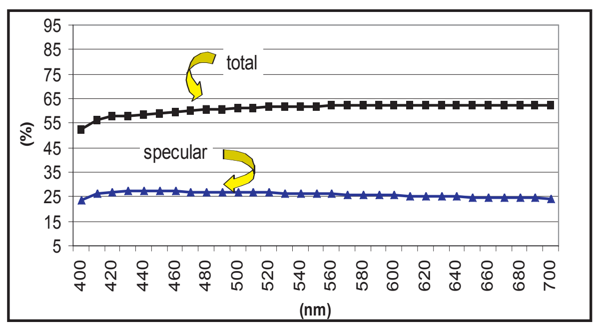
The reflectance measurements for the control show a high percentage (60% of total) of specular reflection signifiying a glossy film (Figure 2).

Figure 2. **Control (reflectance)**



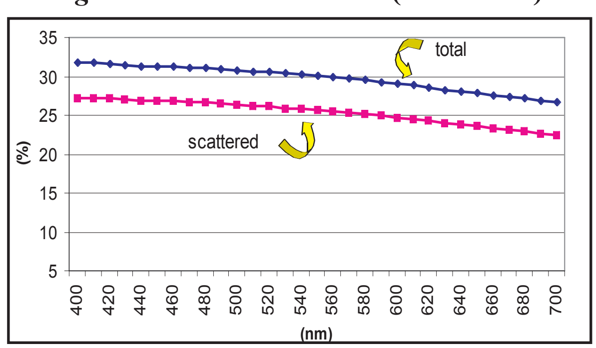
An effective comparative example to the control would be titanium dioxide. Titanium dioxide is known to impart a high level of opacity but yield films, which give a white and caked-on appearance. Transmission measurements of the titanium dioxide film support these observations (Figure 3). Titanium dioxide yielded a total average transmission of only 61% with a high diffuse component (low specular transmission), indicating good light diffusion, but low overall transparency.

Figure 3. **Titanium Dioxide (transmission)**



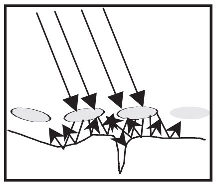
The overall high level of reflection (Figure 4) with a major contribution from the scattered reflection component produces the white film

Figure 4. **Titanium Dioxide (reflectance)**



appearance. The appearance is a product of the color of the particle reflecting light back to the observer.

The two examples discussed to this point were extreme examples and provide a means for interpreting the data collected on the other particles included in this evaluation. In order for a particle to provide a sufficient soft-focus effect, the following behaviors need to be satisfied:



- High total transmission (> 75%), to allow for the natural skin tone to reflect through.
- High contribution from the diffuse transmission component (> 50% of total), to evenly distribute the light reflecting back from the skin, while hiding imperfections.
- Low total reflection (< 20%), to prevent projection of the particle color.
- A high contribution from the scattered reflection component (> 80% of total), to minimize shininess.

Two commonly used particles for providing a soft-focus effect are boron nitride and Nylon 12. The former comes in a variety of particle size ranges as well as different surface chemistries. The high refractive index allows it to be used as a pigment. The sample evaluated for this study was selected because of its particle size range and hydrophobic surface chemistry. In comparing the transmission properties with titanium dioxide (another high refractive index pigment) it can be seen that the film produced by the boron nitride (Figure 5) has significantly higher transparency, making the film less opaque, but at the expense of higher specular transmission (less diffusion).

However, the total reflectance is much lower for boron nitride (Figure 6), with a large portion of the total reflectance being scattered. This translates to a film with much lower degree of whiteness, minimizing the caked-on appearance.

Figure 5. Boron Nitride (transmission)

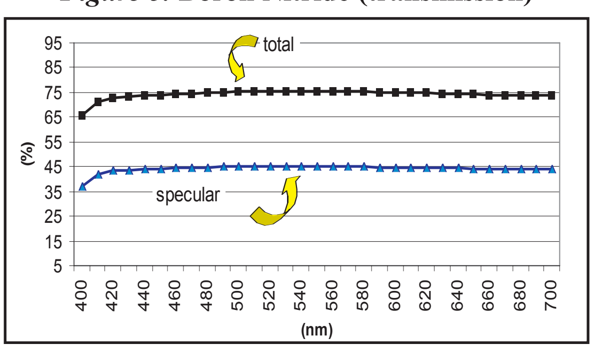
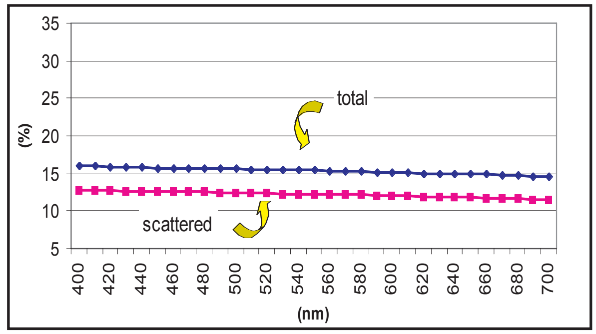


Figure 6. Boron Nitride (reflectance)



Another commonly used particle for producing a soft-focus effect is Nylon 12. Both the transmission and the reflectance data (Figures 7 and 8) collected indicate a high level of total transmission (85%), a high percentage of diffuse transmission versus total (60%) and a total reflectance of < 15% with a high contribution from the scattered reflection component (85% of total). The optical

Figure 7. Nylon 12 (transmission)

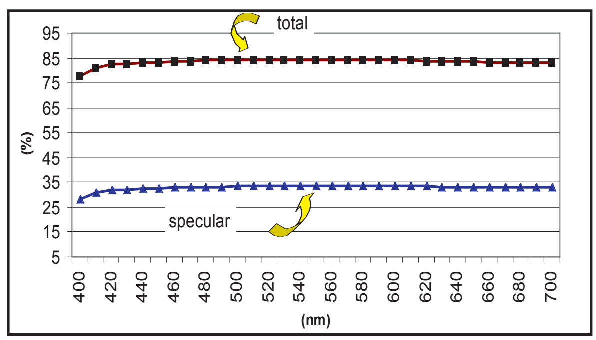
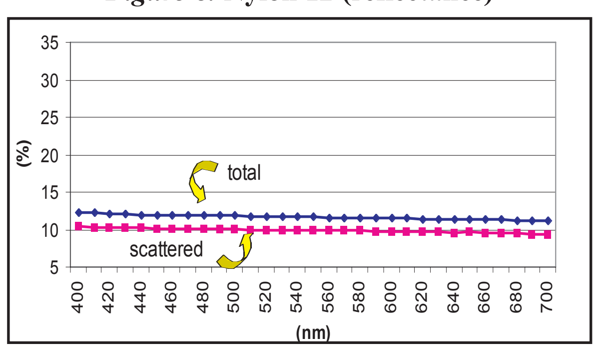


Figure 8. Nylon 12 (reflectance)



characteristics of Nylon 12 demonstrate its ability to provide satisfactory soft-focus effects.

Another particle, which is not commonly used in cosmetic formulations, but was evaluated in this study, is fumed alumina. Fumed alumina is a unique synthetic alumina oxide with a high degree of crystallinity. Fumed alumina (Figures 9 and 10) has a very high total transmission (85%), a large diffuse transmission component versus total (60%) and a low overall reflectance with a high percentage (87%) of the total being scattered reflection. Fumed alumina meets or exceeds all the behaviors required to provide excellent soft-focus effects.

Figure 9. **Fumed Alumina (transmission)**

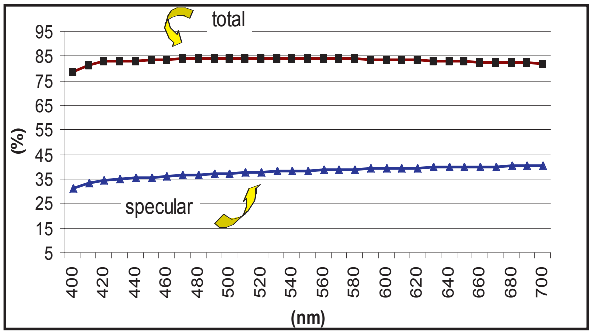
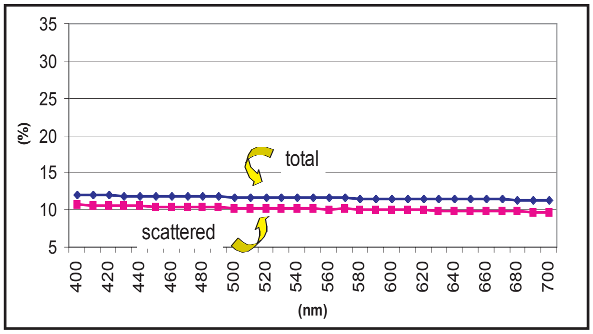


Figure 10. **Fumed Alumina (reflectance)**



Conclusions

A valid methodology has been developed to assess the light diffusion properties of particulates. The data has shown that Cabot's fumed alumina has the appropriate optical properties to yield soft-focus effects in cosmetics. Nylon 12 also offers the ability to produce a soft-focus effect whereas boron nitride, while meeting most of the parameters to achieve satisfactory soft focus, showed inferior performance.

Next Steps

Cosmetics formulations vary widely. Many are designed to provide a multitude of attributes, such as coverage, feel, durability and adhesion. The scope of the work presented in this paper only focused on light diffusion. Formulation development with the fumed alumina is required to assess its ability to provide the other performance properties necessary for cosmetics today.

References

1. Emmert, R, "Quantification of the Soft-Focus Effect," *Cosmetics & Toiletries Magazine,* 57, Vol. 111, July 1996.
2. Nakamura, N., Takasuka, Y., and Takasuka I. "Blurring of Wrinkles Through Control of Optical Properties," Reprint of the XIVth I.F.S.C.C. Congress, Barcelona, 1986, Vol. 1.
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