A Method to Determine Diffusion Particle Properties for Use in Optical Simulation

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Abstract: A method to determine optical properties for an unknow diffusion particle, which allows for optical simulation of that particle at a range of particle densities, useful for light guides, light pipes, or diffusion lenses.
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1. Introduction

LED based illumination optics, including general commercial and architectural lighting, as well as consumer product applications like light pipes and light guides often make use of milky white diffusing thermoplastics to help blend color and hide the appearance of the LEDs. Most plastic suppliers keep the properties of these diffusing compounds propriety which makes simulating their performance in software impossible. This paper explores a method to determine the material makeup by comparing its behavior to a wide range of optical simulations for a range of parameters and finding the closest matches. This allows a computer model to be constructed for that particular scattering material, which then allows optical engineers to vary the diffusion percentage to determine their desired level of diffusion.

2. Sample Material Testing

The first step is to measure the scattering properties of sample plaques of the material at several different loading levels. This is done with a benchtop goniometer and integrating sphere, and the result is a plot of the shape of the scattered distribution of collimated light passed thru the material as well as the reflectance, transmittance and absorptance. Figure 1 shows this for one type of diffusion additive in an acrylic substrate (n=1.491) at 3 different loading percentages.

Figure 1: Physical Test Results

3. Simulation To Determine Diffusion Particle Properties

Since the diffusion particle is unknown, the next step is to run a large batch of simulations for a wide range of diffusion particle properties, including index of refraction, particle shape and size, surface finish, and particle density. Figure 2 shows the results of these simulations. Within the entire set of results in Figure 2, there is a small set that has the same general scatter shape and relative reflectance and transmittance as the test results of Figure 1. In this material sample, particle indices of 1.4 and 1.6 resulted in the closet match to the test data. Further simulations were completed to narrow the range of particle indices and particle density, ultimately finding a particle index of 1.42 provided the best match to the test data. The range of particle density allow fully covered the narrow to wide beams seen in the tested samples, indicating that the range of 4-12% loading could be modeled with this set of particle properties.

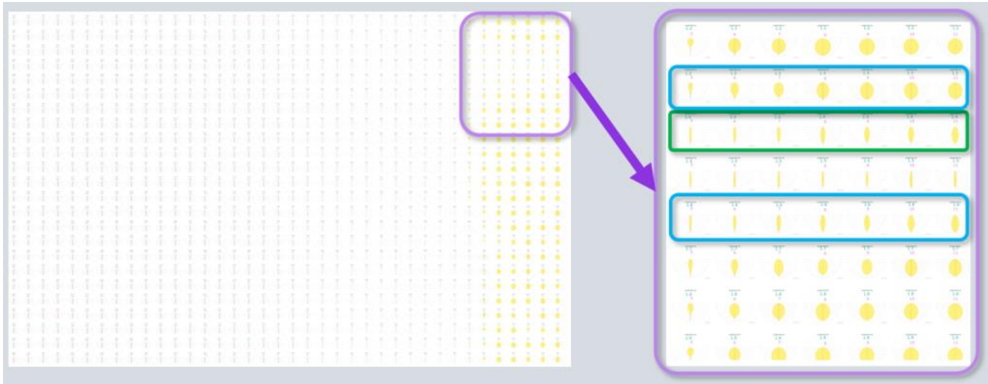

Figure 2: Varying Particle Index and Scatter Coefficient

Moving forward with a particle index of 1.42, a further refined set of simulations can be performed to determine the relationship between particle density and beam angle of diffusion. Figure 3 shows the resulting plot of Beam Angle versus Scatter Coefficient (a stand-in for particle density). The result of these simulations is an equation to allow computation of scatter coefficient based upon the measured beam angle. Since we also know the beam angle of the 3 sample plaques and their loading percentages, it is possible to create an equation to relate scatter coefficient to percent loading, which is the ultimate goal.

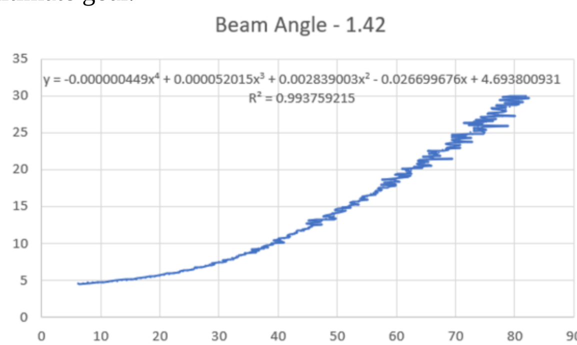

Figure 3: Beam Angle versus Scatter Coefficient

Applying the determined particle index and scatter coefficient results in a very close match of the Simulation Model to the Test Results as shown in Figure 4.

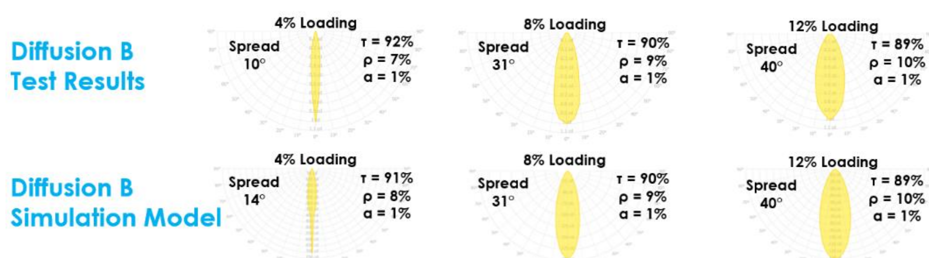

Figure 4: Comparison of Test Results and Simulation Model

5. Conclusions

Having the ability to model any level of diffusion particle loading to fully analyze an optical system is useful for an optical engineer and can save significant time during the design process. The method described here allows an optical engineer to determine the particle properties even if a material manufacturer isn't willing to provide this information. This then allows for simulation with any level of loading of the diffusion particle.