



Shaping LED diffuser performance with polycarbonate materials

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Abstract – The LED lighting market continues to grow, yet consumers are accustomed to the soft white diffused light from incandescent bulbs. To speed up adoption, manufacturers are utilizing plastic materials containing diffusion additives to offset harsh LED illumination and eliminate hot spots. It's important to choose the correct diffusion plastic to meet to meet transmission, color and UL requirements. In this paper, we examine how plastic selection, a diffusion package and color help designers achieve the desired look for their application.

Introduction

The LED lighting market is growing steadily due to consumer acceptance of the energy-efficiency advantages of LED technology. To speed up LED adoption, there are major efforts by various lighting manufacturers to offer LED bulbs and luminaires whose light quality is on par with incandescent bulbs. To remain cost competitive, many manufacturers choose plastic materials for their applications, due to greater design freedom and lower assembly cost.

Customers are accustomed to the soft white diffused light from incandescent bulbs, compelling lighting manufacturers of lamps and luminaires to seek efficient light-diffusion technologies to offset harsh LED illumination and to eliminate hot spots. There are many ways to achieve diffusion, such as adding a diffusion film or texturing the surface of the plastic. Yet in some cases, these methods can either add cost or do not achieve the same aesthetics as incandescent bulbs.

To this end, many plastic manufacturers incorporate precisely engineered diffusion additives into their plastic. The pellets that are subsequently created can be injection molded into parts such as lenses, or processed by extrusion into profiles, sheets and films. This "built-in" diffusion offers the advantage of eliminating a secondary operation that adds to system cost. Diffusion additives incorporated directly in the resin also allow for greater design flexibility in the molded shape, otherwise a secondary step may be necessary or may not be possible if the molded shape is complex. Diffusers can also be added to extruded sheet, film or profiles.

Another aspect to consider with LED technology is meeting UL requirements. Since many LED-based replacements are considered electrical enclosures, meeting UL 94 flame-retardancy requirements are

also necessary, such as stringent V-0 or 5VA ratings. Such ratings are not typically possible with acrylic and cyclic olefin copolymer, but are achievable with polycarbonate-based solutions.

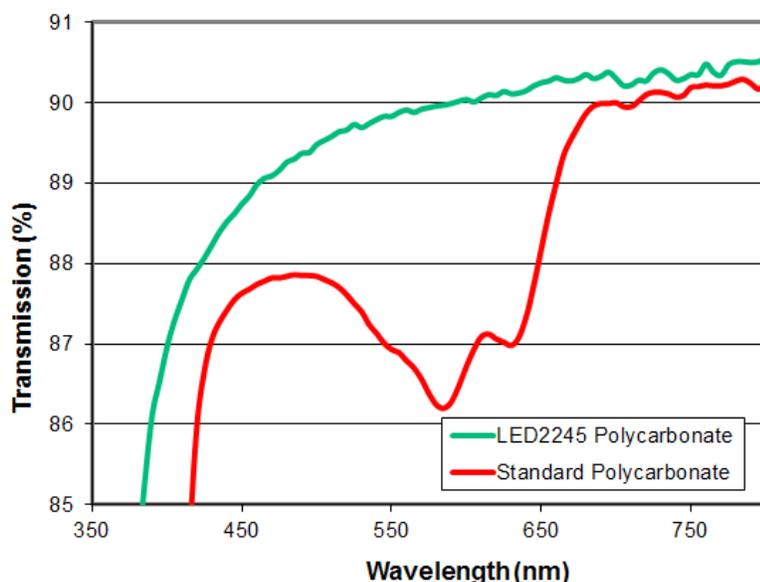
With these requirements in mind, choosing the correct diffusion plastic is critical to meet transmission, color and UL requirements.

Transmission

Diffusion additives result in transmission loss due to the light refracting and reflecting. There are ways to design a lamp or luminaire to try and extract every photon, for example, with the use of reflectors. However, the goal of plastic manufacturers should focus on mitigating these transmission losses. Scientists at Covestro realized that older diffusion technologies dating back to the 1980s were aimed at conventional lighting such as incandescent or fluorescent, and not optimized for LED light. Much of this older technology resulted in a high degree of light reflectance and thus lower light transmission, which often meant that lighting engineers had to design very high lumen LED packages to take into account the high output losses. For energy and cost-conscious LED designers, this was unacceptable.

In developing new diffusion polycarbonates, Covestro scientists realized that not only does the diffusion package need to be optimized, but the base resin as well. LED light has emission peaks near 450 nm and 550-650 nm, but standard polycarbonate absorbs at those wavelengths, especially in the 550-650 nm region, resulting in lower LED light transmission (Figure 1). Covestro previously created a line of transparent LED polycarbonate grades to mitigate this effect, and applied the same concept for new diffusion applications in injection molding, sheet and film products.

Figure 1. Transmission curves of polycarbonate

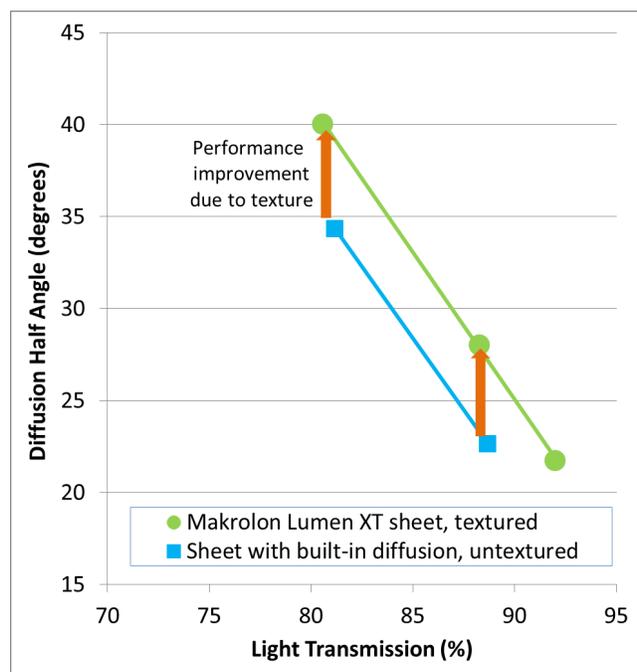


To achieve a high lumen output while maintaining an acceptable level of diffusion, Covestro utilizes a light diffusion technology focusing on light refraction versus reflection: an optimized particle mixture is added to the polycarbonate, where the proprietary size and shape allow the light passing through the resin to effectively bend around the particles, dispersing the light while maintaining a high overall light transmission. Comparison of this new diffusion technology to an older technology demonstrated an increase in light transmission from 70 percent to 77 percent while maintaining the same level of diffusion.

Another advantage of built-in diffusion is that surface texture can be added to provide a good balance of diffusion and transmission. In injection molding applications, a textured surface is a result of optimizing the tooling surface. The diffusion achieved with this method can lead to higher light transmission since there are no particles to interact with the light, however it will require a separate tool for every diffusion level required. Similarly, textured surfaces can be achieved with extruded parts and film, with the same caveat as injection molding.

A combination of surface texture and built-in diffusion can achieve high performance while also offering a range of diffusion levels. Figure 2 illustrates this strategy. The combination of built-in diffusion and surface texture on Makrolon® Lumen XT polycarbonate sheet from Covestro improves the overall performance, resulting in higher light transmission for a given diffusion level. Varying the built-in diffusion yields product options at multiple diffusion levels.

Figure 2. Effect of surface texture applied to built-in diffusion on Makrolon® Lumen XT polycarbonate sheet from Covestro



Color

Diffusion technology not only affects the LED light transmission, but also the color of the LED light exiting the plastic. As shown in Figure 1 above, standard polycarbonate tends to absorb at 450 nm and 650 nm, in part due to a general purpose coloring package added to neutralize the slight yellowish hue of the polycarbonate created during the manufacturing process. When an older diffusion package is added, the net effect is that it lowers the color temperature of the LED light passing through. To mitigate this effect, Covestro created a new diffusion color in order to minimize absorption at these wavelengths. In Table 1 below, the net effect can be seen: The older diffusion package reduces the color temperature by 165K, while the new diffusion package reduces color temperature by 61K.

Table 1. Comparison of correlated color temperature of diffusion packages

Scans	Color Temperature (K)	Color temperature difference (K)
LED only	5971	0
LED + old diffusion	5806	165
LED + new diffusion	5910	61

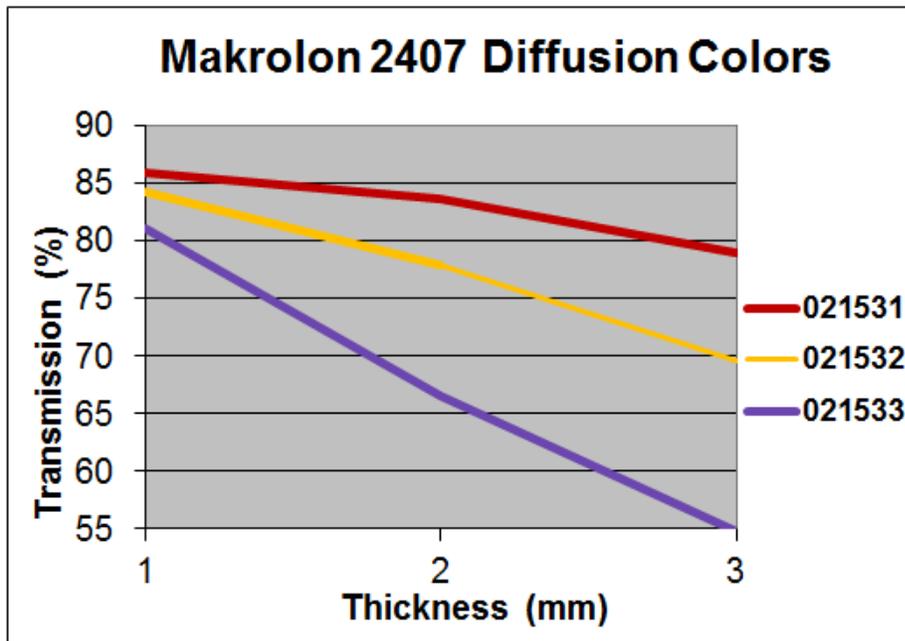
But what if the designer desires to change the color of the light? Experts at Covestro Color Competence and Design Centers can fine-tune the color of the diffusion package to create a broad color palette for customized applications.

The Complete Package

Judicious selection of plastic, a diffusion package and color helps designers achieve the desired look for their application. To help achieve this goal, Covestro created a new line of diffusion colors, as seen in Figure 3, to create low, medium and high levels of diffusion with light transmission properties much higher than older technologies. This allows designers to customize part thickness, amount of diffusion or the distance between the plastic and the LED source to create the desired effect and light transmission.

Finally, many of these diffusion packages can be added to flame retardant grades for applications that require UL 94 compliance.

Figure 3. Transmission of diffusion colors as a function of thickness



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