Optical Coating Technology Enables Improvements In Solid State Lighting

Recent years have seen advances in Solid State Lighting (SSL). More advances are possible with new optical thin film-coating technologies.

by Robert Crase and David Gray

SSSL is one of the fastest-growing areas in the lighting market. As the efficiency of these systems improves, light-emitting diodes (LEDs) will gain a larger share of the lighting market. Gains in efficiency have been made at an ever-increasing rate during the past several years. As impressive as these gains have been, they were made largely through improvements at the chip level and were developed with a semiconductor approach to the problem. This article will discuss several proposed optical coating-based solutions to develop and extend improvements in SSL.

Chip-Level Improvements

LEDs can emit light from every direction, even from the bottom of the chip. Presently, a common practice is to deposit a metal coating on the bottom of the chip to reflect and redirect some of this light to the front of the LED. This metal coating, typically aluminum, is not a very effective reflector of visible light, but it is an extremely efficient reflector of heat. If this aluminum coating could be replaced by dielectric coatings, which would have higher reflection in the visible spectrum and would also transmit in the infrared spectrum, it would allow the LED to run much cooler.

Heat dissipation can be an issue with SSL systems. The current state of the art is to use conduction and a large radiating surface to remove the heat from the LED. The conduction at the first interface can be improved with the deposition of an index-matching stack at the chip interface. Using dielectric-coated mirrors (as proposed earlier), the last layer can be made of a material with superior thermal conductive properties. This LED package with the cold mirror is bonded to the heat sink, improving the conduction of heat away from the LED.

Packaging-Level Improvements

Many current white-light LEDs use a short wavelengthemitting LED to excite a phosphor on a cover lens. The short wavelength LED serves to excite the phosphor and add blue to the LED output. A dichroic coating deposited onto the outside surface of the phosphor-coated lens will reflect some of the excitation wavelengths of the LED (those that escape the system) back onto the phosphor for a second pass. Figure 1 shows the reflectivity of this dichroic coating.

Figure 1: Reflectivity of dichroic coating.

On the second pass, the phosphor will absorb more of the excitation wavelength, improving the output of the system. As the coating is dichroic, it can transmit white light without trapping it in the system, thereby increasing the white-light output of the LED package. The coating could be constructed to also reflect the ultraviolet (UV) waveband. This would serve to effectively eliminate UV wavelengths from the output of the LED. This step will make the LED safe for museum lighting, medical illumination, and other UV-sensitive lighting applications.

Reflectors for individual LEDs and SSL applications can significantly improve with advanced optical coating technology. The present state of the application is to use vacuum-deposited aluminum on these reflectors. The typical reflectivity of the aluminum is nominally 85% across the visible spectrum. Aluminum has been used because it is easily protected from environmental damage and can last in the system for many years.

DSI has developed a durable, silver coating for the concentrating photovoltaic market. The reflectivity of this durable silver, is 94% across the visible spectrum and is relatively angle insensitive. This silver can be deposited onto the reflector of an LED or SSL system, increasing the output of the SSL system by 10%.

One of the most common issues mentioned with an LED SSL system is the lack of a continuous color spectrum. To produce white-light, the LED systems use a very high color temperature, very blue, white LED. Alternatively, a short wavelength LED is used to excite a phosphor which produces the longer wavelengths' more yellow light. While there have been improvements in the quality of these two white-light sources, they are each missing some color components. These missing colors make LED systems difficult to use in applications that require good color rendition.

It is possible to create the proper white color and most colors by using red, green, and blue LEDs and by mixing and modulating these colors. However, this solution requires electronics, software, and a sophisticated feedback system. While functional, this is not a practical or cost-effective approach for a general lighting system. Attempts have been made to create a white system closer to the black body curve by combining different color LEDs and a white phosphor.

Figure 2 shows one of these systems overlaid with the same black body curve. The curve is closer to the black body, but colors are missing from the curve. It is possible to increase the output of the individual LEDs to try to add these missing colors, but the peak output of the LED will dominate the output spectrum. An optical coating can be used effectively to trim the output of this system. A notch filter will reduce the peak of the LED and bring the output of the system closer to the black body curve. By using this example as a building block, it is possible to create an LED system that mimics the color of a 2800K or a Xenon light source.

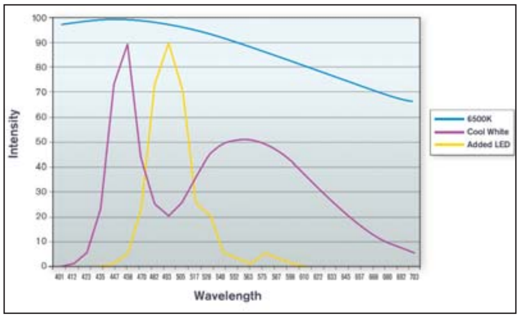

Figure 2: Cool white plus LED system (theoretical).

It is clear that SSL sources have made great advances in the past several years. The addition of the latest optical thin film-coating technologies will allow even greater advances in the future.

Robert J. Crase is Assistant Director of Commercial Manufacturing at DSI. He was Program Manager for the Commercial Products Division at DSI and Operations Manager at ZC&R Coatings for Optics where he was responsible for thin film design, product development, and business development. He earned his BA in Finance and Management and an MBA from Loyola Marymount University.

David W. Gray is the Engineering Supervisor and Equipment Build Manager at DSI. Prior to his current position, he was a new product development engineer. Mr. Gray began working in the thin film coating industry in 2000; at DSI, he has developed the spectral metal, solar silver, and plastic coating product lines. He received his Bachelor of Science degree in Physics from Sonoma State University in 2005.