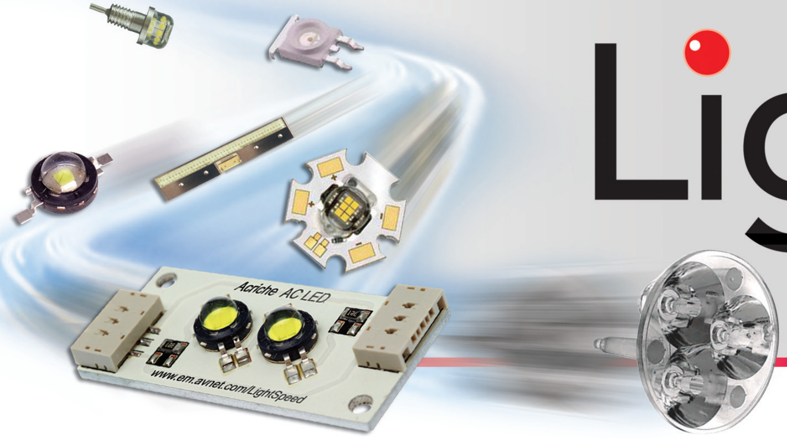

Light Matters

Designing illumination systems with high-brightness LEDs

The best color sensors and soap bubbles have something in common… thin-film technology.

Perhaps the most interesting portion of a soap bubble's life is when swirls of colors dance and move across its surface.

Figure 1 – One of Nature's interference filters

Recall that white light is composed of many colors, each corresponding to a particular wavelength. If you "absorb" certain wavelengths in the visible spectrum, the resultant reflected light is no longer white, as some colors will be absent. One of the most precise tools for selectively reflecting and passing colors is an *interference filter.*

An interference filter is a sandwich of semi-reflective surfaces separated by a "spacer" of given thickness. The internal reflection causes some wavelengths to interfere (e.g., a wave crest meets a wave trough and cancels out) while allowing a narrow spectrum to pass through. In practice there are often stacks of these sandwiches placed sequentially to achieve the desired passband edge shapes.

Since the refractive index of air ($n = 1$) differs from that of soapy water ($n \approx 1.3$), the film is semi-reflective on its inner and outer surfaces. Thus the soap film itself becomes our "spacer". Initially, this film might be many hundreds of nanometers thick, causing the longer wavelengths (red end of the spectrum) to destructively interfere. Without red reflecting back, the bubble appears greenish. As water evaporates and the film begins to thin, yellow wavelengths destructively interfere, leaving blue. Eventually green then blue wavelengths will no longer be reflected, and the bubble will appear magenta… then yellow… then… *pop!*

Generally, color sensors are built using photodiodes having broad-spectral response. So to distinguish the individual values of red, green and blue light, the photodiodes have red, green and blue filters placed above them. These are *absorption filters,* made from dyes or pigments. While this is often acceptable for some applications, it may not be good enough for precision control of high-brightness LEDs in lighting applications. This is due to their lossy filter characteristics (resulting is less sensitivity), dye stability and aging issues, and less than optimal passband overlaps.

Transmission	Interference filter	Absorption filter
Passband	> 95%	60% – 70%
Out-of-band	< 1%	10% - 20%

Table 1 – Typical characteristics of interference and absorption filters

For demanding applications, especially when used in a feedback loop to control lighting, we need miniature color sensors built with interference filters covering the photodiodes. Such a sensor could leverage thin-film manufacturing techniques to deposit sequential stacks of filters directly on the photodiode surfaces. The end-product would have high-sensitivity, precision passband control and edge-shaping, with superior long-term stability.

I recently started working with a company called MAZeT which is now introducing them. Their line of color sensors use interference filters deposited onto an array of PIN photodiodes. Particularly interesting in applications involving the human eye, some devices have interference filters tuned to mirror the eye's tri-stimulus response, as defined in DIN 5033 Color Measurement Standard. It "sees" light the way we do. A complete color-controlled (or white light color temperature controlled) system involves a color sensor front-end, microcontroller, PWM-driven color or bi-chromatic LEDs, and an optical feedback path for the sensor to sample the instantaneous mixed color/CCT being emitted. An evaluation board includes the sensor in a LCC8 package and USB interface. It's shown below on my business card.

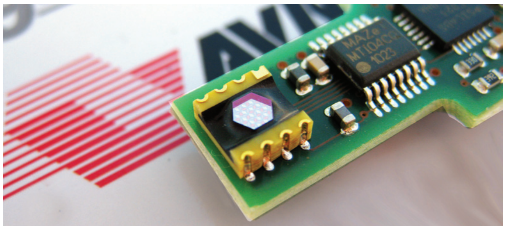

Figure 2 – A MAZeT color sensor (with hexagonal window) mounted to a small PCB

If you'd like more information on MAZeT, visit our website (**www.em.avnet.com/LightSpeed**) or send a note to **LightSpeed@Avnet.com**. Your questions and comments are always welcomed

Cary Eskow

is Global Director of the Solid State Lighting and Advanced LED business unit of Avnet Electronics Marketing. An ardent advocate of energy efficient LED-based illumination, he has worked closely with LED manufacturers, advanced analog IC and secondary optics vendors since his first patent using LEDs was issued two decades ago. Avnet works with customers through their national team of illumination-focused sales engineers who are experienced in thermal, drive stage and optics design. Prior to his LED lighting focus, Cary was Avnet's technical director and managed Avnet's North American FAE team.

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To learn more about designing an LED-based illumination system, go to:
www.em.avnet.com/LightSpeed