Application Note
Materials Testing &
Research

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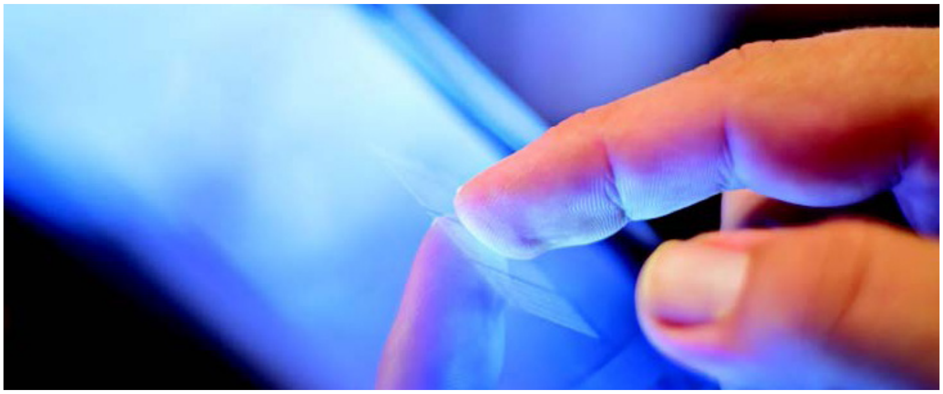
Measuring the Performance of Compact Visual Displays

Angular reflectance measurements of optically active materials



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Introduction

The prevalence of visual displays in everyday use continues to grow as the size, weight and power consumption is reduced and device mobility is subsequently improved. Optical displays, based on light emitting diode (LED) and liquid crystal display (LCD) technology finds broad industrial and domestic use. Examples of devices include mobile telephones, portable computers ranging from hand-held personal digital assistants (PDAs) to laptop computers, portable digital music players, LED/LCD desktop computer monitors, and LED/LCD televisions. In an industry where thickness improvements are measured in tens of microns, LED/LCD packages are becoming thinner as the manufacturers of electronic devices strive for smaller package sizes.

Displays use backlighting to illuminate the full display area and liquid crystals to control the timing and color of the emissions presented to the viewer (Figure 1). The backlighting often takes the form of a solid light guide in the shape of a slab or wedge. The illumination source can be cold cathode fluorescent (CCFL) lighting, more commonly referred to as an LCD TV, or LED based backlighting often referred to as an LED TV. Due to the importance of backlighting on picture quality, the labels overlook the fact that both TV types employ the use of LCDs to control images presented to the viewer.

The solid light guides used in backlighting are often made of an optically transparent polymeric material which is mass produced by, for example, injection molding. The optical and electrical efficiency of solid light guides are enhanced by the use of reflectors. The reflector films are strategically positioned to more efficiently utilize light that would otherwise exit the back surface of the solid light guide or the illuminating source (Figure 1).

Backlight reflectors used in light guides need to have a high reflectivity for efficient transport of light. Reflection values of >98% are typical reflectance targets as multiple (tens of) reflections through the light guide would otherwise quickly extinguish available light if much more than 2% was lost at each reflection event.

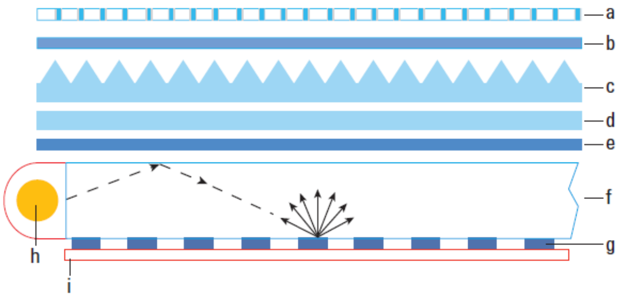

Figure 1. Cross section of products used in LCD construction:
a: LCD b-d: Varying film types to increase guide backlighting efficiency
e: Diffuser f: Light guide g: Dots for extracting light from the light guide
h: Fluorescent or LED light source i: Back reflector film (shown in red).

Multilayer optical coatings are used to generate the high reflectivities of the thin reflector films. The physical properties of the films, which are typically <100 µm thick, can be of a non-metallic multilayer polymeric material which can result in surfaces with optical activity. Optically active materials rotate the polarization state of light on a transmission or reflection event. More common are materials that are optically inactive where polarization interactions introduced by the sample only act to subdue a particular polarization component such as S, or P, not rotate it. While optical activity will typically have no direct consequence in end-use applications inside the display, accurate optical characterization (QA/QC) of the reflector prior to assembly requires careful consideration of these effects to ensure correct %R and %T values are recorded at the detector.

Experimental

Samples

The sample measured was approximately 50 x 50 mm (w x d) and approximately 100 µm thick (Figure 2). The reflective surface was protected by a semi-transparent clear film which could be easily peeled off before measurements were taken. The thickness of the sample and its flexibility was accommodated during mounting to ensure that a flat surface was presented to the incoming beam.

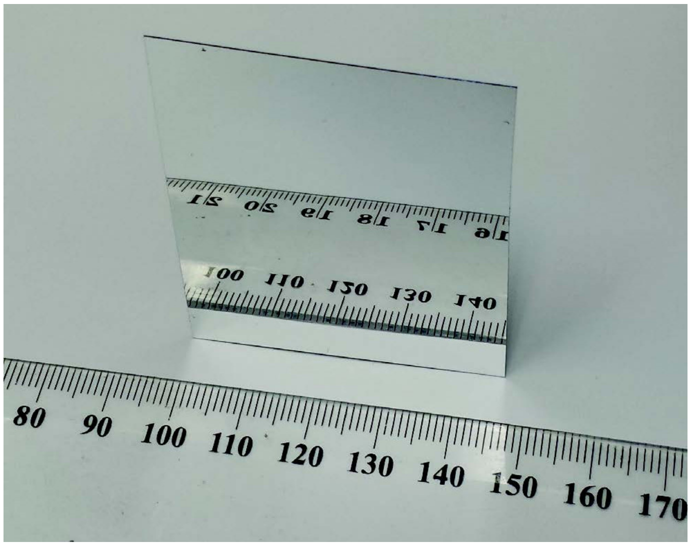

Figure 2. Reflector sample.

Optical activity of the sample was demonstrated before measurement in the Cary 7000 UMS by illuminating the sample with s-polarized visible white light at an angle, and viewing the specularly reflected beam from the sample by eye through a second polarizer. The Maximum intensity of the reflected beam was observed by rotating the viewing polarizer a few degrees from the S (0 deg) position.

The angular off-set between the incident s-polarized light and the visually detected light confirmed optical activity, or optical rotation of the light. This practical test confirmed that a depolarizer would be required to be inserted before the detector during the spectrophotometric measurements.

Instrumentation

- Agilent Cary 7000 Universal Measurement Spectrophotometer, p/n G6873AA

The Cary 7000 Universal Measurement Spectrophotometer (UMS) is a highly automated UV-Vis-NIR spectrophotometer system. The UMS performs variable angle transmission and absolute reflectance measurements. The linearly polarized beam that is incident on the sample can be used to measure transmission, and by rotating the detector assembly about an axis through the sample and perpendicular to the plane of incidence, in reflection, as indicated in Figure 3.

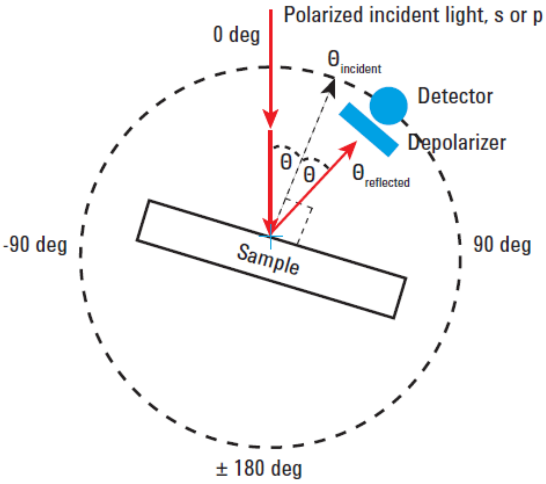

Figure 3. Schematic of the Cary 7000 UMS. Light incident onto the sample can be s, or p polarized. The detector module allows mounting of a depolarizer immediately before the detector. Absolute specular reflection of transmission can be measured.

A depolarizer was placed after the sample but before the detector to correct for the optical rotation imposed on the reflected light by the sample. The depolarizer before the detector and the polarizer before the sample were included in the single baseline measurement taken before each sample collection was made. The Cary 7000 UMS only requires a single baseline to be collected for all %R measurements at any angle for a given polarization. This unique feature dramatically improves the speed of analysis and sample throughput possible on this system.

Results and discussion

Reflectance data was collected at four angles of incidence (AOI); 70, 60, 45 and 30 deg over the spectral range 300–1200 nm (Figure 4). The sample demonstrated its design intent by displaying reflectance >98%R over the visible wavelength range (400–800 nm) (Figure 5).

The multi-angle measurements showed consistent performance over a broad angular range in the region of interest (400–800 nm) and angular dependence outside this range (>800 nm). High AOI >60 deg also showed some diminishing of the %R quality in the 600–700 nm and 800-900 nm region. The spectral dependence of the %R profile at these angles demonstrates that some color alterations are to be expected for high angles of incidence.

The importance of depolarizing the light after the sample, but just before the detector, is demonstrated in Figure 6. In this figure, absolute reflectance is measured with and without the use of a depolarizer. Without the use of the depolarizer the optical activity of the sample causes the %R values to artificially exceed 100%. This is compared directly to the result where a depolarizer is used which corrects for the optical rotation of the light and gives the correct values.

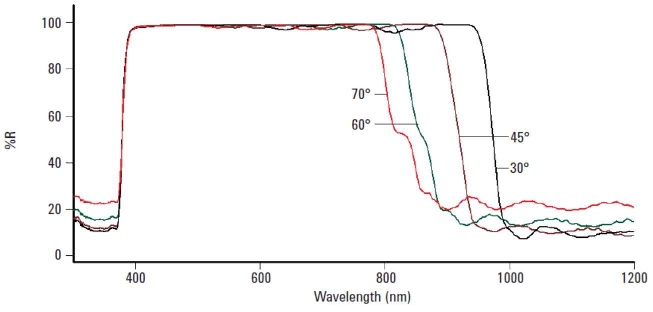

Figure 4. Reflection of backlight material at 70 (red), 60 (green), 45 (brown), 30 (black) degree s-polarized light.

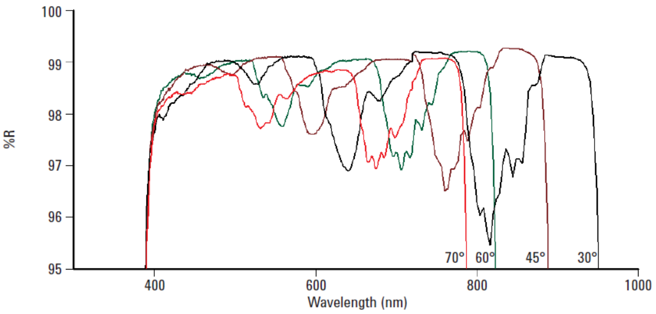

Figure 5. Magnified view of Figure 4 showing reflection of backlight material at 70 (red), 60 (green), 45 (brown), 30 (black) degree s-polarized light.

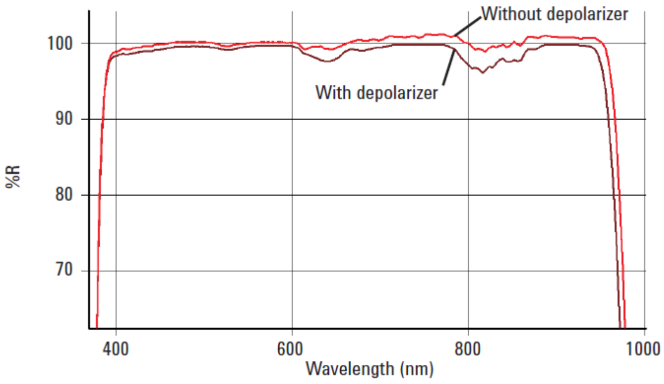

Figure 6. Demonstration of the importance of using a depolarizer after the sample but before the detector. Absolute reflection of backlight material at 30° s-polarized with a depolarizer before the detector (brown) and 30° s-polarized WITHOUT a depolarizer before the detector (red).

Conclusions

The Agilent Cary 7000 UMS was shown to be a valuable tool for measuring the optical properties of next generation materials used in optical displays. The optical rotation imposed by the specialized polymeric coating on the sample was accurately measured by using linearly polarized incident light and depolarizing the reflected light before it was detected and processed.

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DE44313.0404050926

Printed in the USA, May 11, 2021
5991-2508EN