TECHNICAL PAPER

Display Technology – Materials and Techniques

Author: Samuel Pellicori
Materion Chemical Coating Materials News

Display technology is an evolving field. On-going development by laboratories and companies is advancing the technology worldwide to meet more demanding requirements. Key properties driving these improvements include a high degree of color saturation, high black-to-white contrast and high spatial resolution. Familiar technologies used in today's common displays include LCD, LED, OLED and their hybrids. Future goals include achieving lower power and higher contrast in thin flexible formats. Also desirable is the ability to operate in high ambient lighting conditions which requires specific architecture. Currently, imaging displays range in size and application from cell phone-sized electronics to theater screens, video walls, and billboard-scale advertising panels. Following are some development highlights of display technology.

Phosphor Pixels

Some newer technologies include employing colored solid state diode lasers whose beams are scanned to compose individual RGB pixels. Individual LED RGB pixel arrays compose another display technology. One example of the latest technology [1] is Phosphor pixels that are stimulated by a 405 nm laser diode to emit RGB colors to produce images. The Phosphor pixels grouped as RGB triplets are currently made from powders incorporated as paints. The development of film-layer replacement materials are intended to improve color saturation, contrast and resolution properties.

Electrophoretic Displays

Among the evolving display technologies is a promising form based on electrophoresis. Electrophoretic displays involve the transport of charged particles, such as ions or microspheres, between two oppositely charged transparent electrodes. The separation of charges can be engineered to produce a medium that can display color and contrast changes in text or images. The medium can be made very thin as, for example, with "e-paper", electronic ink and "smart paper."

The field of electrophoretic image reproduction is relatively recent, and new materials are being investigated and applied in a variety of approaches. Electrophoretic display types include sub-classes defined by materials and pixel-addressing processes. Electrochromic display operation uses the change in the ion environment to modify the optical properties of an ion-supplying liquid. As voltage is applied through the liquid layer between transparent electrodes, mobile ions cause a thin film layer of Tungsten Trioxide (WO_{3}), for example, to reflect or transmit. The transparency of a window can thus be controlled by changing the applied voltage. See the following illustration (Figure 1) of an electrochromic smart window on the next page.

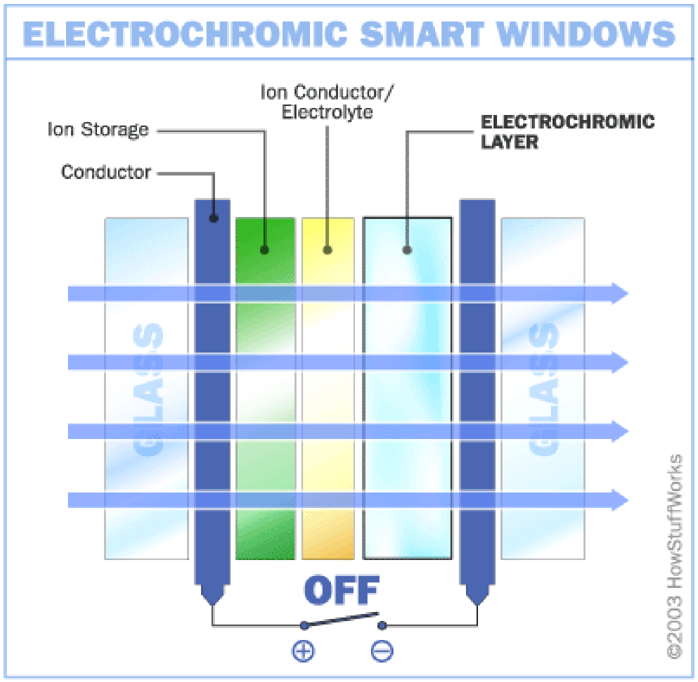


Figure 1. Basic construction of a smart window and similar electrochromic displays and devices. The electrochromic layer material is typically WO_3. Transparent ITO electrodes have + and – polarities and permit opacity control by means of a bias voltage applied across them.

Thin Film Materials

WO_3 is an excellent electrochromic material which can be used in information display, smart windows, and secret and military camouflage applications. Figure 1 shows the components in a typical configuration. The electrochromic layer WO_3 is easily deposited by e-beam and by sputtering, and the films can be amorphous or polycrystalline structures depending on deposition parameters. Low deposition process temperature makes WO_3 applicable for low-temperature substrates such as the polymers PET and PEN, and also for flexible display production. Vanadium Pentoxide (V_2O_5) is a similar compound that undergoes transparency control between absorptive and bleached states through applied voltage.

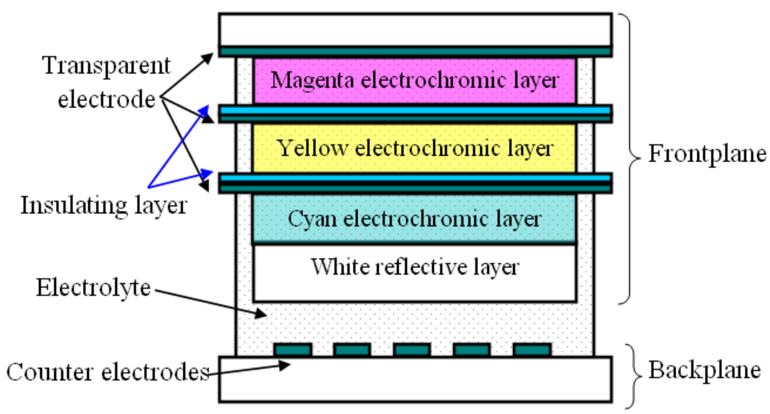
These films are porous in nature, permitting ions to pass through them easily. Voltage applied across the transparent ITO electrodes that sandwich the stack control the flow of Li+ or H+ ions through the electrolyte. The applied voltage causes the transport of ions from the ion storage layer through the electrolyte layer and into the electrochromic layer. When the voltage is applied, the sandwich is opaque. Power-off or polarity-reversal can be used to restore transparency.

Electronic Paper

The first displays based on electrophoresis produced black and white images which are popular in electronic paper ("E-paper"). The display uses black and white microspheres that are oppositely charged. Individual pixels consist of cavities with barrier walls that isolate and contain a small volume of these microspheres to limit lateral mixing. Each is essentially a separate electrochromic stack. As each pixel is addressed with a + or – charge, it reflects white or black, hence a high contrast image or text is displayed. This construction lends itself to flexible display material that can be produced on roll coaters. The micro-cavities are embossed on a polymer and introduced into subsequent processing steps.

The reproduction of colored images is more involved. It requires consideration of human color perception such as produced by mixing individual colored sources. For example, demonstrated by additive R, G, and B emitted light or C, M, Y (Cyan, Magenta, Yellow) subtractive mixing. In another rendition of the already mentioned B & W approach, the cavities are filled with bleachable dyes. Color can be produced in these displays by incorporating color-absorbing electrochromically-activated layers. In this structure, the central three layers are repeated with R, G, and B or C, M, Y layers interspersed. Now, individual color pixels can be addressed and color reproduced in a backlit display by addition (R+G+B) or in a reflecting display by subtraction (C+M+Y). The introduction of additional layers containing oxides of transition metals has enabled colored displays to be developed. Two approaches are in use: oxides of V, Mo, Nb and Ti are employed for cathodic coloring, and oxides of Ni, Co and Ir for anodic coloring. Figure 2 shows the construction of this color display device.

Figure 2. Construction of a display that produces color by subtractive combination of reflected light through individually addressable pixels [2].



Transparent Electrodes

The transparent electrode material of choice has historically been ITO whether for contacts in touch panels or for electrophoretic displays. As we have discussed in previous CMN issues, alternate transparent conducting oxides (TCO) are still under development but many are now available. Alternate TCOs are based on compounds other than Indium. Zinc-oxide- based TCOs are one example of compositions that are experiencing broader applications. While ITO can be deposited by e-beam (on high temperature tolerant substrates) or sputtering (on polymers), deposition of some of the ZOx compounds is possible only by sputter deposition. This is not a disadvantage, however, because display materials for large and small areas are often built in flexible mode using roll coaters. A limitation of ZOx materials is the need for further work directed to lowering the sheet resistance to the values that ITO readily achieves. The demand is application-dependent.

Cover Glass Coatings

The cover glass used on display and touch panels is thin, varying between 300 µm to less than 150 µm, depending on the application, size of display, and user handling. Anti-reflection coatings are applied to the inner surfaces, or the inner glass surface is laminated to the active surface, to eliminate glaring reflection from ambient lighting. Display glasses whether they are components of video displays or touch panel screens, require immunity to smudging and water exposure.

Hydrophobic and oleophobic surface treatments are applied to the externally exposed surfaces of the glass as part of the anti-reflective (AR) coating. Low surface-energy treatment increases the contact angle and water runs off the surface in the form of spherical drops. The coatings are fluorinated compounds, and can be deposited by evaporation as part of a wide-band AR coating. Panels used outdoors that are exposed to wet environments benefit from hydrophilic surface treatment. In this case, the water drops wet the surface to permit clear viewing instead of balling up. Oxide surfaces formed by high energy compacting processes such as sputtering tend to be hydrophilic. Figures 3 and 4 illustrate hydrophobic and hydrophilic surfaces.

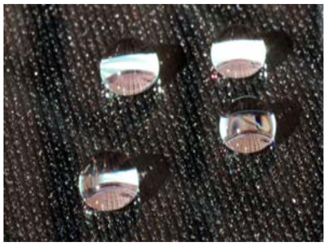


Figure 3. Hydrophobic AR coating on glass has a high contact angle. (Photo by S. Pellicori)

Figure 4. Hydrophilic coating on glass showing its low contact angle. (Photo by S. Pellicori)

The Future

Display technology will continue to evolve as new and improved image producing techniques and products are developed. As panels grow in size and durability, improvements in coating materials and deposition techniques will be required. Materion Advanced Chemicals offers a wide variety of material offerings, including metal oxides as mentioned in this article, in various forms such as evaporation materials and sputtering targets. For more information…
http://materion.com/Businesses/AdvancedChemicals/About/ContactUs.aspx

References

1. Prysm.com
2. Tohru Yashiro, Shigenobu Hirano, Yoshihisa Naijoh, Yoshinori Okada, Kazuaki Tsuji, Mikiko Abe, Akishige Murakami, Hiroyuki Takahashi, Koh Fujimura, Hitoshi Kondoh, "Novel Design for Color Electrochromic Display", SID 11 DIGEST© 2011.

Principal Contributor: Samuel Pellicori, *Pellicori Optical Consulting*, Santa Barbara, CA
Phone: 805.682.1922 Email: pellopt@cox.net