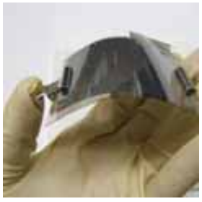
## Optical Design & Engineering

## Plastic film finds a new role in micro-optics

**Hiroshi Toshiyoshi**

*Plastic sheeting has the potential to extend the advantages of microelectromechanical systems technology to large-area devices such as image displays.*



The screen size of liquid crystal displays (LCDs) and plasma display panels (PDPs) increases with every passing year. Flat panel displays measuring over 65 inches are now commercially available even for consumer electronics. These large-scale devices are made not by conventional microelectronics fabrication processes, but by a combination of newly developed "classical" methods, such as silk-screen printing, ink-jet printing, and sandblasting. This means replacing entire production lines, which can cost upwards of $1 billion.

Image projection represents an alternative, less-costly solution for large displays. A good example is the digital light processing technology used in the Texas Instruments microelectromechanical systems (MEMS) mirror array, which did not require a new fabrication facility. At Expo 2005, in Japan, Sony unveiled a 2005-inch projection screen based on the company's proprietary GxL system, which employs a grating light valve. This technology, too, is compatible with CMOS. But the chip size is limited by the physical dimensions of the optical elements, so Moore's law does not apply: making the device smaller will not reduce production costs. The advantage of optical MEMS is that a small mechanical displacement has a greater effect on optical characteristics than do solid-state solutions. The question is how to maintain that advantage in extending MEMS technology to large-area devices.

We recently created a pair of plastic films based on Fabry-Perot interferometer pixels, which change their color by micromechanically tuning the optical interference cavity.[1] Unlike other MEMS devices, our approach is aimed at compatibility with roll-to-roll printing. Qualcomm has used optical interference to develop a reflective MEMS display. But our device relies on transmission, which allows viewers to see the color-filtered backlight.

The color pixel we developed consists of two sheets of poly(ethylene naphthalate) or PEN. The thicker base sheet (200μm) carries a semi-transparent aluminum reflector and a color-determining layer of sputtered silicon oxide. The thinner PEN film (16μm) has an additional layer of semi-transparent aluminum (10nm). The layers are bonded to each other with a photoresist spacer as thermal glue (0.6μm thick, 0.4~0.8mm mesh) in between to create an optical cavity. The aluminum layers also work as electrodes for electrostatic operation. When no voltage is applied and the PEN membrane is flat (OFF state), a white light source placed behind the pixel makes it look light grey. Applying a DC drive voltage of 120V to the pixel (ON state) brings the membrane into contact with the substrate and changes the length of the cavity, turning the pixel a vivid green.

Pixels of different colors can be prepared simply by using different thicknesses for the silicon oxide layer. For instance, red and blue pixels are made using 370nm- and 210nm-thick oxide layers, respectively. The color purity of the three primary colors obtained is still poor compared with that of cathode ray tubes (CRTs). Numerical simulation of the transmission spectrum suggests that color purity could be improved by using multiple layers to determine color or





RELATED LINKS
SPIE Letters: A virtual journal from the SPIE Digital Library
Bring Any SPIE Courses to Your Facility
Optical Design & Engineering in the SPIE Digital Library

three light-emitting diodes instead of a white source.

PEN films have the attractive characteristic that they are mechanically flexible, in contrast to silicon and glass. Because the device has a total thickness of less than 0.3mm, we can bend it to a radius of curvature of 5cm or less, and it still changes color.

We have achieved a proof of concept using a 10cm-wide plastic membrane. Our next step is to make an oversized version of the pixel array employing roll-to-roll technology. We believe the roll-to-roll process has promise because it enables layer-thickness control in the tens of nanometers as well as layer-to-layer alignment accuracy of several tens of microns. Naturally, other issues remain to be resolved, including low-voltage operation, electromechanical reliability, integration with thin film transistors, and the display of continuous-tone images, before we can claim to have a genuinely flexible display device.

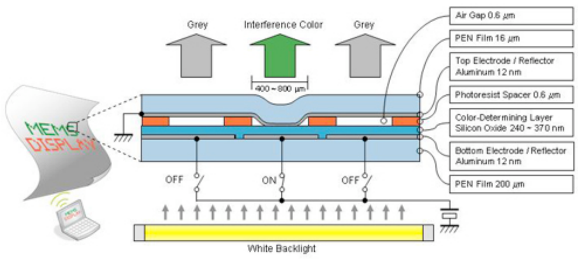



*Figure 1. The cross-sectional structure of the MEMS color pixel array is based on an electrostatically controlled Fabry-Perot interferometer.*

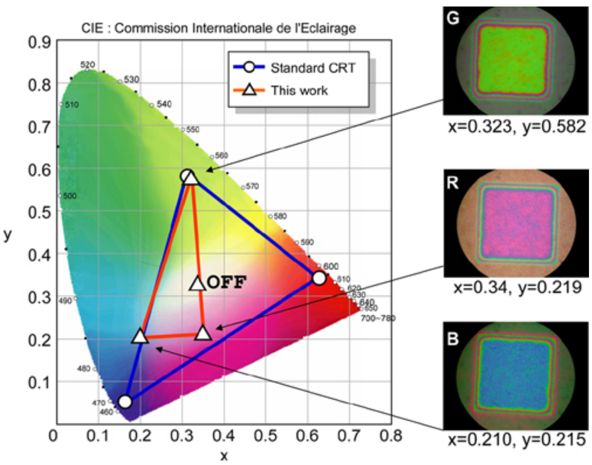



*Figure 2. The primary colors of the MEMS pixel array do not yet approach those of a CRT.*

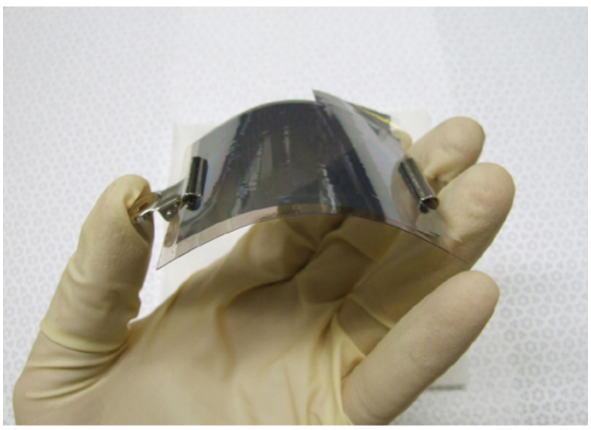


*Figure 3. Shown is the flexible Fabry-Perot interferometer color pixel array.*

## Authors

**Hiroshi Toshiyoshi**
Center for International Research on Micro Mechatronics, Institute of Industrial Science, University of Tokyo
Tokyo

Japan
Opto-Mechatronics Lab, Kanagawa Academy of Science and Technology
Kanagawa

Japan
http://toshi.fujita3.iis.u-tokyo.ac.jp/

Hiroshi Toshiyoshi is director of the France-Japan International Lab LIMMS (Laboratory for Integrated Micro Mechatronic Systems) at the Institute of Industrial Science, University of Tokyo. He is also a group leader in KAST (Kanagawa Academy of Science and Technology), where he conducts research on optical MEMS.

## References:

1. Y. Taii, A. Higo, H. Fujita, H. Toshiyoshi, Flexible transparent display by plastic MEMS,
12th. Int. Display Workshop / Asia Display 2005 (IDW/AD 05),
2005.

DOI: 10.1117/2.1200604.0184