FLEXMatters: A Consortium for Production of Flexible Devices

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Abstract
The FLEXMatters initiative is building a collaboration of companies and universities to develop and produce flexible devices. Kent Displays leads the production of flexible displays using their bistable cholesteric technology. The FLEXMatters members are collaborating to develop the flexible manufacturing process that will are common to a wide variety of devices.

1. Objectives and Background

Many groups around the world are working to develop flexible displays.[1] In almost all cases the technologies being developed require breakthroughs in substrates or advanced active matrix addressing materials that are compatible with flexible substrates. For example, conventional polarizer based liquid crystal affects require non-birefringent substrates while OLEDs require highly affective barriers to the diffusion of oxygen and water vapor. All of these effects in addition to the electronic ink type materials require active matrix addressing to produce high resolution images which is also difficult to achieve using currently available materials.

For over a decade we have taken an alternative approach to producing flexible displays and related electro-optic devices[2]. With support from the State of Ohio through their Third Frontier Initiative we have established FLEXMatters . FLEXMatters joins companies and universities to develop and produce a variety of flexible optical and electronic devices. FLEXMatters includes three Ohio Universities and companies inside and outside the state.

Kent Displays leads the FLEXMatters initiative for the production of flexible displays. We are using liquid crystal affects that are compatible with commercially available substrates and passive matrix addressing. Kent Displays is poised to produce flexible liquid crystal displays utilizing their bistable cholesteric technology[3]

Figure 1: PDLC Windows, courtesy of 3M

The commercialization of PDLC windows over a decade ago clearly demonstrates the feasibility of producing liquid crystal shutters on flexible substrates using a continuous roll-to-roll process.[4] The PDLC films were produced on ITO coated polyester substrates and did not require any additional barrier layers to achieve long lifetimes. Figure 1 shows PDLC windows produced by 3M. However, like most liquid crystal affects, high resolution images require active matrix addressing.[5]

Over a decade ago, we reported prototypes of bistable cholesteric displays made on commercially available ITO coated polyester substrates. The electrodes were etched using standard photolithographic techniques. Polymers were dispersed in the cholesteric material and phase separated using a blanket UV exposure. The resulting polymer network provided mechanical strength.[6] We developed means of segregating the polymer into the interpixel region as a means of improving the brightness and contrast.[7] We also explored how stacking could be used to produce full color displays.[8]

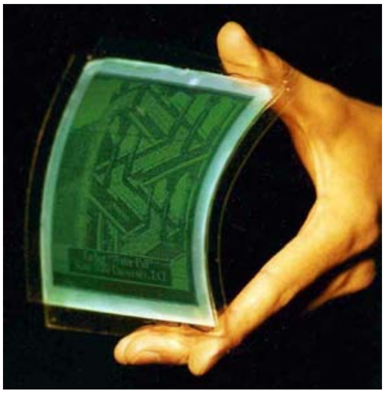

Figure 2: 320x320 bistable cholesteric displays made on polyester substrates

2. Results

FLEXMatters was established in the last year in order to support the development and production of flexible optical and electronic devices. FLEXMatters combines the research expertise of three Ohio Universities: Kent State University, the University of Akron and Bowling Green State University. Kent State Universities research strengths in liquid crystals and displays are complemented by the polymer science and engineering strengths of the University of Akron and the photochemical science expertise at Bowling Green. A number of companies have joined with these universities to develop the flexible electronic and optical devices.

In recent years Kent Displays has focused on the production of bistable cholesteric displays on a variety of flexible substrates including ulta-thin plastics, paper and fabrics. In order to adapt the bistable cholesteric technology to flexible substrates, Kent Displays has developed a variety of encapsulation techniques including emulsification and phase separation.

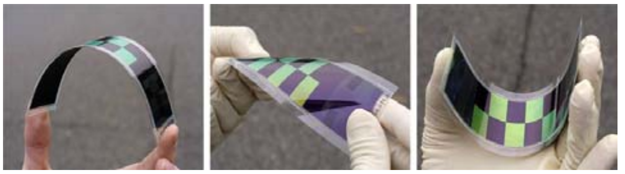

Figure 3: Flexible display using phase separation techniques and polyester substrates.

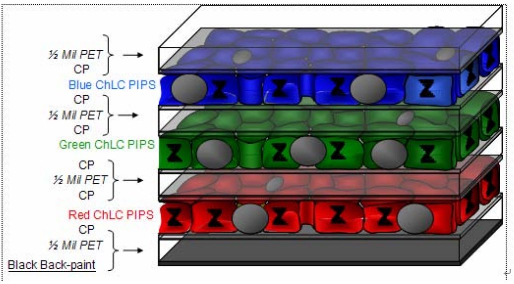

Figure 4: Schematic structure of stacked, full color cholesteric display.

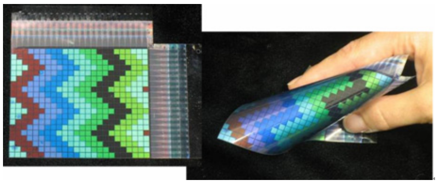

Figure 5: Full color cholesteric display made on thin substrates with transparent conducting electrodes.

Figure 6: Encapuslated cholesteric display made on a fabric substares

The first generation of flexible cholesteric displays uses two ITO coated polyester substrates with thicknesses of about 50 µms. The active material consists of about 20% pre-polymer dispersed in the chiral nematic mixture. This mixture is sandwiched between the ITO substrates with plastic spacers used to control the thickness.[9] Polymerization and phase separation is induced by a blanket UV exposure. Figure 3 shows a flexible display made using this process.

Figure 7: Electronic Ski Goggles with lense made by AlphaMicron

Full color displays can be fabricated by stacking red green and blue layers that are separately addressed.[10] This approach is simplified by using thin plastic substrates. Transparent conducting polymer electrodes are ink jet printed one or both sides of these thin substrates. The resulting display is very flexible and rugged. Because the conducting polymer is well indexed matched to the substrates surface reflections are minimized. They therefore are higher contrast with a darker off-state than similar displays made using patterned ITO. Figure 5 shows a full color displays made using the thin substrates and stacking technique described above.

As an alternative to phase separation, the cholesteric mixture can be microencapsulated. This allows the materials to be coated on single substrates with conducting polymer electrodes ink printed on top. Using this approach Kent Displays has produced drapable displays on paper and fabric substrates, Figure 6. [11]

In addition to flexible displays the FLEXMatters consortium is exploring production of a variety of optical and electronic devices. For example AlphaMicron, also located in Kent, is now producing digital eyewear. Marketed under the UVex brand name, the AlphaMicron lenses switch between different absorbing state. They utilize dichroic dye and their patented VaLid technology to produce the lenses on flexible plastic substrates. Figure 6 shows the UVex ski goggles incorporating the AlphaMicron lenses.

The FLEXMatters coalition also includes a project led by the University of Akron for advance polyimide films that will produce flexible photovoltaic devices and improved substrates for a variety of electronic devices. Graftech International brings to the coalition a project to produce advance graphite thermal management films.

Kent State University is establishing the FLEXMatters Accelerator that will provide common research and development equipment and facilities for the manufacture of a wide variety of flexible devices. The facility will be used to perfect the reel-to-reel manufacturing processes and the related issues of singulation, connection of electronics and packaging. Participating companies will be work together in this facility to work on thse common problems

Figure 8 shows the organizations that are participating in the FLEXMatters initiative. With support from the State of Ohio the FLEXMatters initiative is dominated by Ohio based companies. However, we are already expanding the coalition beyond the borders of the state and the nation.

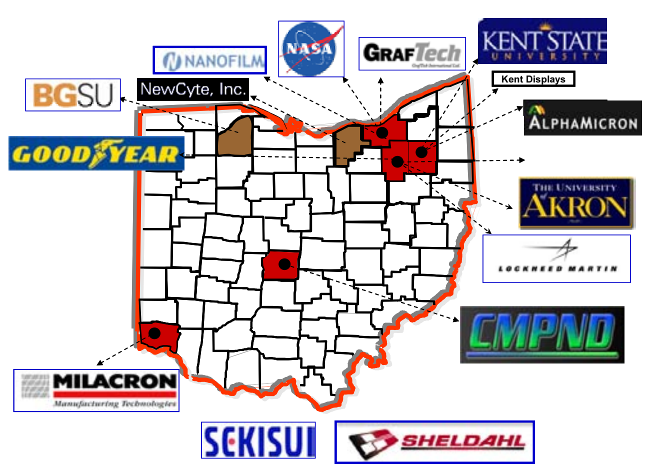

Figure : The FLEXMatters collaboration

3. Impact

It is clear that flexible optical and electronic devices are promising new products that over the coming decades promise to replace current devices made on rigid substrates. Moving to continuous rather than batch processing techniques offers the potential to greatly reduce the cost of these devices. Adding flexibility will also open entirely new markets. The FLEXMatters initiative is designed to develop the new materials and manufacturing techniques these new products will require. The first products will be relatively simple displays and digital eyewear. However, as we perfect the materials and manufacturing processes we envision producing increasingly sophisticated devices and eventually to make the entire device, including power supplies and drive electronics on flexible substrates.

4. Acknowledgements

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5. References

1. G.P. Crawford, editor, "Flexible Flat Panel Displays," John Wiley and Sonds, Ltd. England, 2005.
2. J.L. West, M. Rouberol, J.J. Francl, Y. Ji, J.W. Doane, M. Pfeiffer **,**Asia Display '95, Proc. 15th International Display Research Conference, 55, October 1995.
3. Ebru A. Büyüktanir, Anatoliy Glushchenko, Bentley Wall, John L. West, Maxim Mitrokhin, Børre Holter, , , Proceedings of SID - The International Society for Informational Displays, 2005.
4. P. Van Konynenburg, S. Marsland, and J. McCoy, Solar Energy Materials, 19, 27-41, 1989.
5. C. D. Sheraw, L. Zhou, J. R. Huang, D. J. Gundlach, and T. N. Jackson, M. G. Kane, I. G. Hill, M. S. Hammond, J. Campi, and B. K. Greening, J. Francl and J. West, Appl. Phys. Lett., **80**(6), 1088-1090, 2002.
6. J.L. West, M. Rouberol, J.J. Francl, Y. Ji, J.W. Doane, M. Pfeiffer, Asia Display '95, Proc. 15th International Display
7. Y. Kim, J. Francl, B. Taheri and J.L. West, Appl. Phys. Lett. 72, 2253-2255, 1998
8. J.L. West, V.H. Bodnar, Y. Kim and H. Wonderly, Proc. Intl. Display Works 99, pp. 235-238, 1999,. Sendai, Japan.
9. A. Khan, I Shiyanovskaya, T. Schneider, J. W Doane, SID Intel. Symp. Digest Tech. Papers, 37, 1728 (2006).
10. J. L Doane, D. Davis, A Khan, E. Montback, T. Schneider, I. Shiyanovskaya, Proc. Intl. Disp. Research Conference., 26, 9 (2006).
11. I. Shiyanovskaya, A. Khan, G. Magyar, S. Green, O. Pishnyak, J. W. Doane, Proc. Intl. Disp. Research Conf., 26, 32 (2006).