

Conference 5289A • Conv. Ctr. Room C2

Monday-Tuesday 19-20 January 2004 • Part of *Proceedings* Vol. 5289
Liquid Crystal Materials, Devices, and Applications X and Projection Displays X

Liquid Crystal Materials, Devices, and Applications X

Conference Chair: Liang-Chy Chien, Kent State Univ.

Program Committee: Dick J. Broer, Philips Research Labs. (Netherlands); Harry J. Coles, Univ. of Cambridge (United Kingdom); Gregory P. Crawford, Brown Univ.; Wolfgang Haase, Technische Univ. Darmstadt (Germany); Yong-Bae Kim, Konkuk Univ. (South Korea); Shunsuke Kobayashi, Science Univ. of Tokyo (Japan); Shui-Chih A. Lien, IBM Thomas J. Watson Research Ctr.; Shohei Naemura, Merck Japan, Ltd. (Japan); Shin-Tson Wu, CREOL/Univ. of Central Florida

Monday 19 January

SESSION 1

Conv. Ctr. Room C2 Mon. 8:30 to 10:10 am

Materials and Applications

Chair: Cees W. M. Bastiaansen, Technische Univ. Eindhoven (Netherlands)

8:30 am: Novel homeotropic alignment materials with alkylcyclohexylbenzene as side chain in polyimide (*Invited Paper*), Y. B. Kim, H. K. Lee, Konkuk Univ. (South Korea) [5289A-01]

9:00 am: Photochromic liquid crystals (*Invited Paper*), G. H. Mehl, M. Frigoli, Univ. of Hull (United Kingdom) [5289A-02]

9:30 am: Birefringence of monomesogen and bimesogen liquid crystals, J. Willmott, M. N. Pivnenko, Univ. of Cambridge (United Kingdom); M. Grasmann, J. Hannington, Dow Corning Ltd. (United Kingdom); H. J. Coles, Univ. of Cambridge (United Kingdom) [5289A-03]

9:50 am: Novel electroclinic organosiloxane materials for optoelectronic devices, M. N. Pivnenko, O. Haderl, M. J. Coles, Univ. of Cambridge (United Kingdom); M. Grasmann, J. Hannington, Dow Corning Ltd. (United Kingdom); H. J. Coles, Univ. of Cambridge (United Kingdom) [5289A-04]

Coffee Break 10:10 to 10:40 am

SESSION 2

Conv. Ctr. Room C2 Mon. 10:40 am to 12:00 pm

Photonic Applications I

Chair: Shin-Tson Wu, CREOL/Univ. of Central Florida

10:40 am: From nanostructured liquid crystals to electro-optic devices and lasers (*Invited Paper*), H. J. Coles, Univ. of Cambridge (United Kingdom) [5289A-05]

11:10 am: Novel polarization interference filters for wide spectral tuning of an optical null (*Invited Paper*), H. J. Masterson, J. E. Stockley, S. A. Serati, Boulder Nonlinear Systems, Inc. [5289A-06]

11:40 am: Fast switching dual-frequency liquid crystal optical retarder for beam steering applications, A. B. Golovin, S. V. Shiyanovskii, O. D. Lavrentovich, Kent State Univ. [5289A-07]

Lunch Break 12:00 to 1:30 pm

SESSION 3

Conv. Ctr. Room C2 Mon. 1:30 to 3:10 pm

Photonic Applications II

Chair: Harry J. Coles, Univ. of Cambridge (United Kingdom)

1:30 pm: Electrically controlled lens and prism using nanoscale polymer-dispersed and polymer-networked liquid crystals (*Invited Paper*), Y. Fan, S. T. Wu, H. Ren, CREOL/Univ. of Central Florida [5289A-08]

2:00 pm: LC vision application to malignant tumors detecting (*Invited Paper*), M. G. Tomlin, S. I. Vavilov State Optical Institute (Russia); S. Povzun, Military Medical Academy (Russia) [5289A-09]

2:30 pm: Polymer stabilized liquid crystal light modulators, S. H. Kim, L. C. Chien, Kent State Univ. [5289A-10]

2:50 pm: Toward measuring concentration gradients in polymer dispersed liquid crystals with secondary ion mass spectrometry, C. Kjellander, L. van Ijzendoorn, A. de Jong, Technische Univ. Eindhoven (Netherlands); D. J. Broer, Philips Research Labs. (Netherlands); M. de Voigt, H. Niemantsverdriet, Technische Univ. Eindhoven (Netherlands) [5289A-11]

Coffee Break 3:10 to 3:40 pm

SESSION 4

Conv. Ctr. Room C2 Mon. 3:40 to 5:10 pm

Display Technologies I

Chair: Akihiro Mochizuki, Nano Loa USA Inc.

3:40 pm: Threshold and grayscale stability of microcup electronic paper (*Invited Paper*), R. Liang, J. J. Hwang, H. Gu, J. Hou, X. Weng, Y. Chen, H. Zang, SiPix Imaging, Inc. [5289A-12]

4:10 pm: Modeling and measuring the effects of domain walls in liquid crystal displays (*Invited Paper*), D. K. de Boer, Philips Research Labs. (Netherlands) [5289A-13]

4:40 pm: Geometrical optics approach in liquid crystal cells with two- and three-dimensional director variations (*Invited Paper*), G. Y. Panasyuk, J. R. Kelly, P. J. Bos, E. C. Gartland, D. W. Allender, Kent State Univ. [5289A-14]

Tuesday 20 January

Plenary Presentation 8:30 to 9:15 am

San Jose Marriott: San Jose Ballroom

Digital Printing – An Image Processor's Perspective

Jan P. Allebach, Purdue Univ.

See pg. 6 for details.

SESSION 5

Conv. Ctr. Room C2 Tues. 9:30 to 11:20 am

Display Technologies II

Chair: Dick K. G. de Boer, Philips Research Labs. (Netherlands)

9:30 am: Polarization shielded V-shaped ferroelectric liquid crystal displays (*Invited Paper*), A. Mochizuki, Nano Loa, Inc. (Japan) and Nano Loa USA, Inc. [5289A-15]

10:00 am: Fast switching of frequency modulation TN-LCD fabricated by doping Ag-nanoparticles (*Invited Paper*), S. Kobayashi, Tokyo Univ. of Science (Japan); J. Thisayukta, Tokyo Institute of Technology (Japan); Y. Shiraishi, Y. Sakai, T. Miyama, T. Masumi, N. Toshima, Tokyo Univ. of Science (Japan) [5289A-16]

Coffee Break 10:30 to 11:00 am

11:00 am: Wide color gamut monitors: LED backlighting LCD and new phosphor CRT, H. Sugiura, H. Kaneko, S. Kagawa, M. Ozawa, Mitsubishi Electric Corp. (Japan); H. Tanizoe, NEC-Mitsubishi Electric Visual Systems Corp. (Japan) [5289A-17]

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5289A-11, Session 3

Toward measuring concentration gradients in polymer dispersed liquid crystals with secondary ion mass spectrometry

Charlotte B.K. Kjellander, Leo J. van Ijzendoorn, Arthur M. de Jong, Dirk J. Broer, Martien J.A. de Voigt, Hans J.W. Niemantsverdriet (Dutch Polymer Institute, Eindhoven University of Technology, NL)(LJI, AMJ, MJAV, DJB, JWN, Eindhoven University of Technology, NL)

Dynamic secondary ion mass spectrometry (SIMS) is usually applied to measure depth profiles in inorganic multi-layer systems. SIMS applied on organic multi-layer samples is highly complicated due to the complex fingerprint of masses which represent each component in the sample. Using multivariate statistics, we succeeded to decrease the number of variables required to represent the SIMS spectra and were able to separate layers in artificially produced two-layer samples. The method will be discussed for a.o. a sample of iBMA on E7/iBMA, being representative for polymer dispersed liquid crystals. Quantification of the E7 concentration is complicated by evaporation in the vacuum system. Infrared spectroscopy proved that the loss of E7 from iBMA can be prevented by capping the sample with poly(vinyl alcohol) while for a crosslinked diacrylate E7 is contained up to a concentration up to 21 weight%. Cooling to cryogenic temperatures during SIMS analysis is required to suppress evaporation. The depth resolution from SIMS of the two-layer sample of iBMA on E7/iBMA was determined by DFA to be 109nm, which is applicable for a typical optical grating.

5289A-12, Session 4

Threshold and grayscale stability of microcup® electronic paper

HongMei Zang, Jiunn-Jye Hwang, Haiyan Gu, Jack Hou, Xin Weng, Ya-Juan Chen and R.C. Liang (SiPix Imaging, Inc., Milpitas, CA 95035)

Plastic passive matrix (PM) and active matrix (AM) electronic paper displays (EPDs) have been prepared by SiPix's Microcup® roll-to-roll manufacturing processes using ITO/PET films. The Microcup® displays have shown outstanding environmental stability and excellent physico-mechanical properties such as scratch, impact and flexure resistances even in high temperature and humidity conditions. Partly because of the unique Microcup® structure and top-sealing technologies, the electrophoretic fluid and its interactions with the cup and sealing layers may be optimized independently to achieve stable and distinct threshold characteristics with high electrophoretic

mobility. No complex electrode design was required to suppress undesirable cross effects for the driving of PME PDs. A PME PD recently prepared on inexpensive row-and-column patterned ITO/PET films has shown a contrast ratio of >10 , $t_{on} < 30$ msec at <40 V, and a threshold voltage of >15 V. More than 8 levels of grayscale with outstanding bistability have been demonstrated by either pulse width or pulse count modulation. No noticeable degradation of the mid-tone images has been observed even after the power was turned off for more than 5 days. Moreover, the electro-optical responses, particularly the threshold voltage and gamma of the PME PDs remain essentially the same within a wide range (20-60°C) of operation temperature.

5289A-13, Session 4

Modeling and measuring the effects of domain walls in liquid crystal displays

Dick K.G. de Boer (Philips Research Laboratories, 5656 AA Eindhoven, The Netherlands)

In many applications, the presence of domain walls limits the performance of liquid crystal displays (LCDs) in terms of brightness, contrast and response speed. Examples are found in wide-viewing-angle LCDs in which each pixel contains domains with different director orientations. Microscopic measurements of various types of LCDs are presented and compared with the results of advanced two- and three-dimensional simulations. The background of the modeling programs is reviewed, especially if new methods are used.

One example is that of a double-domain twisted-nematic (TN) LCD configuration that was made using photo-alignment. The shape of the domain wall and its effect on the transmitted intensity are described correctly by simulations. In another example it is shown that the experimental results for in-plane switching (IPS) structures can be understood with the help of advanced optical simulation methods that take into account diffraction effects. In a final example, the occurrence of domain walls in liquid crystal on silicon (LCoS) is discussed.

5289A-14, Session 4

Geometrical optics approach in liquid crystal cells with two- and three-dimensional director variations

George Panasyuk, Jack Kelly, Phil Bos, Chuck Gartland, David W. Allender, Felix A. Miranda (Kent State University, Kent, OH 44242) (GP, Department of Bioengineering, University of Pennsylvania, Philadelphia, PA 19104) (FAM, Applied RF Technology Branch NASA Glenn Research Center, Cleveland, OH 44135)

Threshold and Grayscale Stability of Microcup® Electronic Paper

*Prepared for
IS&T/SPIE Electronic Imaging 2004*

**HongMei Zang*, Jiunn-Jye Hwang,
Haiyan Gu, Jack Hou, Xin Weng,
Yajuan Chen and R.C. Liang**

SiPix Imaging Inc



*R&D: 1075 Montague Expressway. Milpitas, CA 95035
Manufacturing: 47485 Seabridge Dr., Fremont, CA 94538*

Presentation Outline

- RTR Manufacturing Process for Microcup[®] EPDs
- SiPix Microcup[®] EPDs Characteristics
- AMEPD Properties and Converting processes
- PMEPD Threshold Characteristics
- Applications for Microcup[®] EPDs and Summary
- Microcup[®] LCD

SiPix Revolutionary Electronic Paper



SiPix Microcup[®] EPDs provide:

Readability:

High Whiteness
Good Contrast Ratio
Wide View Angle
Ambient & Sun Light
readable

Portability:

Light Weight
Thin & Flexible
Durable
Writable/Printable
Format Flexible

Affordability:

Product reusability
Low Material Cost
Easy Manufacturing
Environmental Friendly
Low Power Consumption

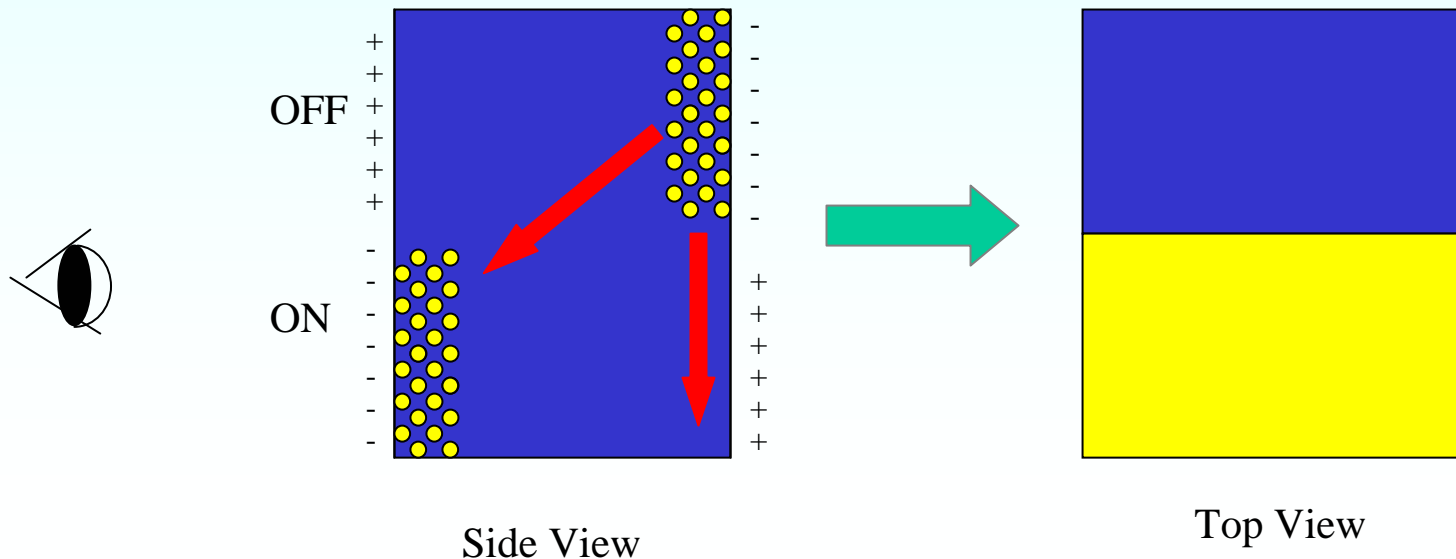
Electrophoretic Displays (EPDs) **SiPix**

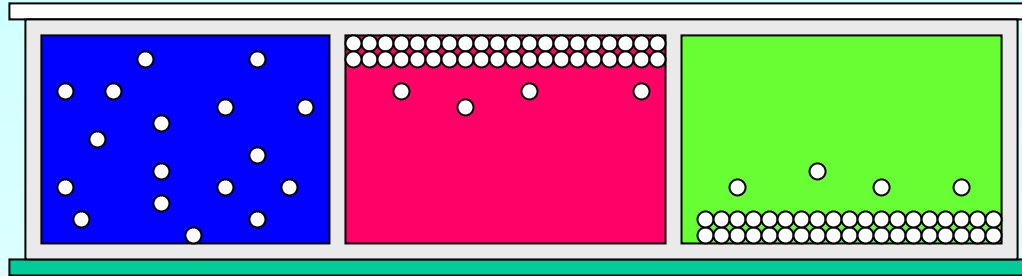
-Field-induced migration of charged particles in a dielectric fluid to create contrast. (First Disclosed in 1969)

-Advantages: Power consumption, bi-stability, view angle, contrast ratio (reflective).

-Tradeoffs: Shelf-life, Image uniformity, Switching rate.

No Stable Threshold for Passive Matrix Driving.





- Roll-to-roll manufacturing processes:

- * High speed microembossing processes
- * Seamless filling and top-sealing processes

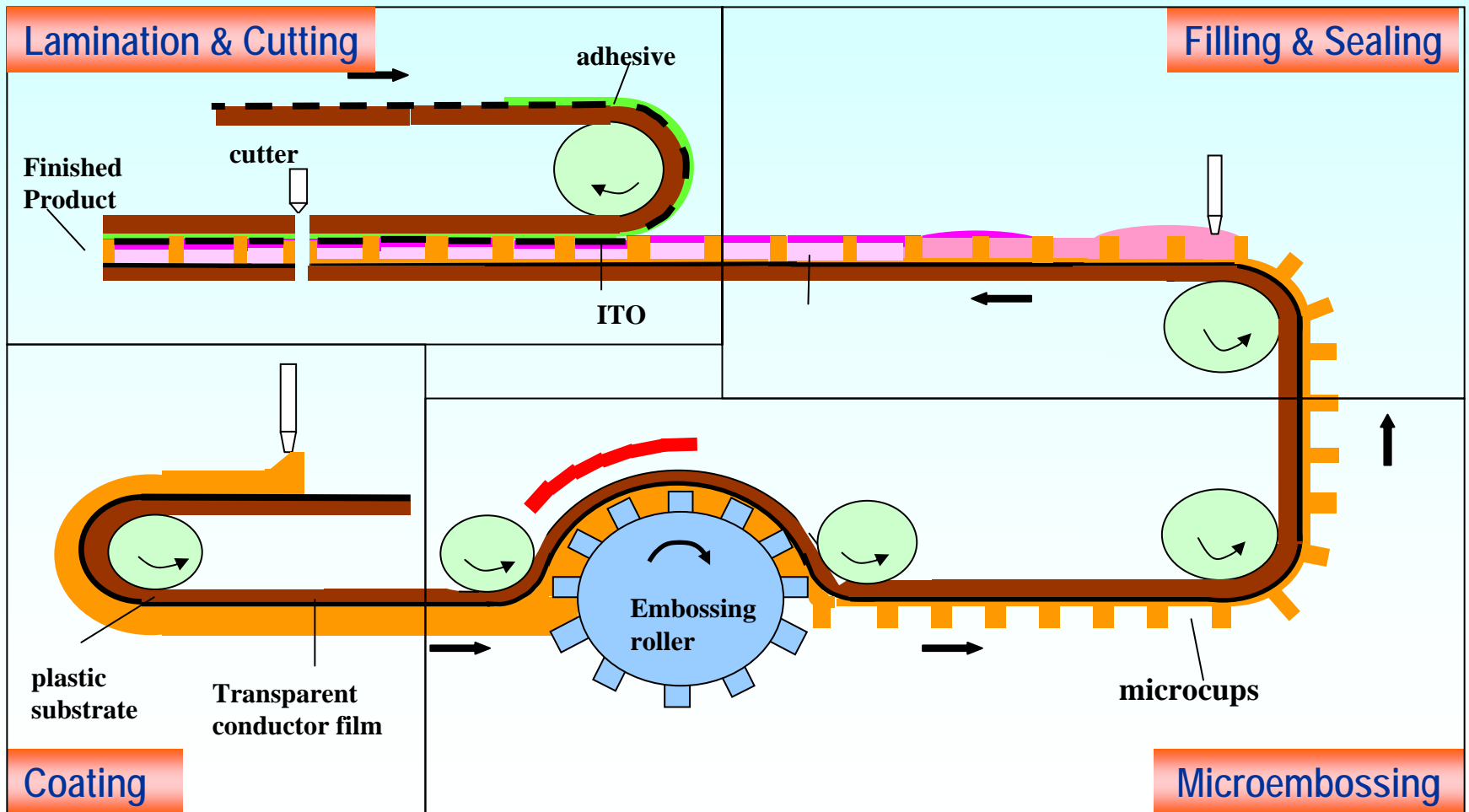
- * Submicron, non-aqueous density-matched particles

- Proprietary driving mechanisms

- More than 85 US Patents Pending since 2000

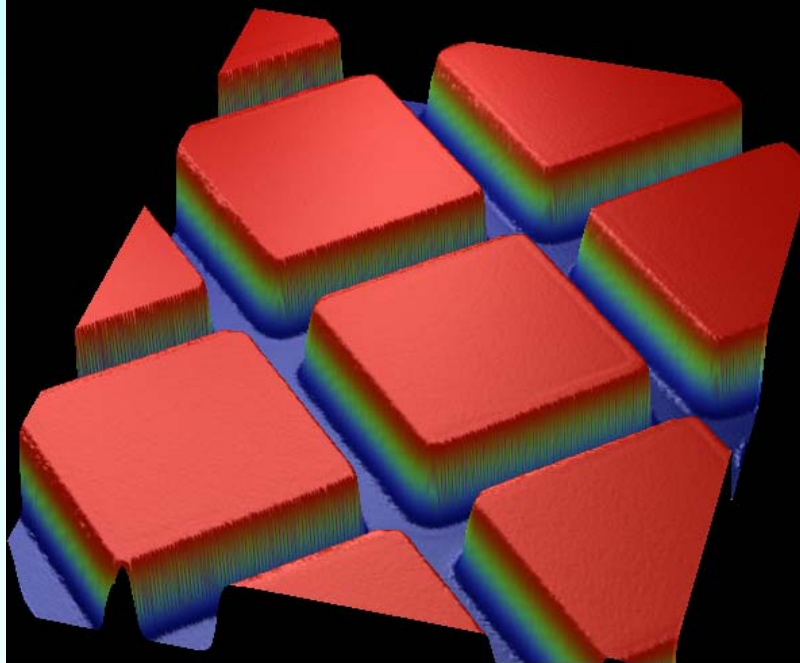
SiPix Roll-to-Roll Manufacturing SiPix

(Current Throughput ≥ 20 ft/min)

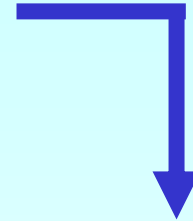


SiPix Embossed Microcups[®]

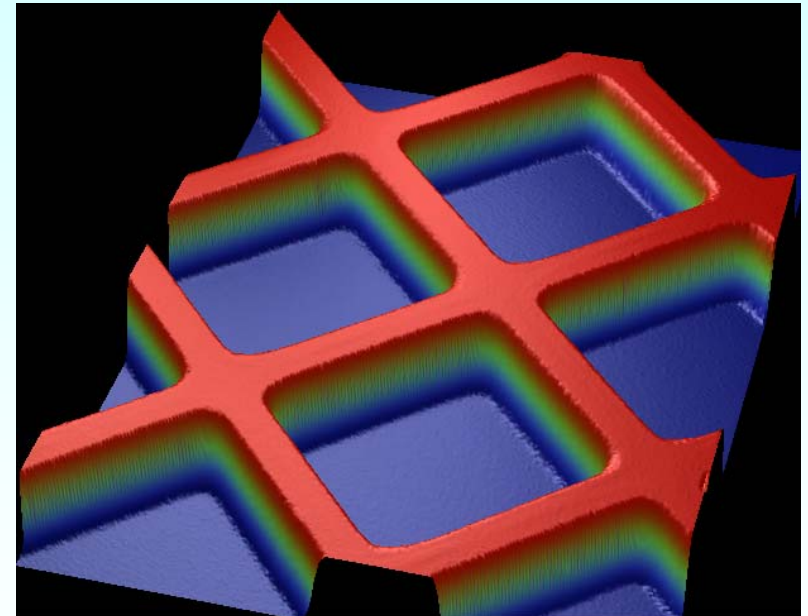
SiPix



**Profilometer picture of Mold
from Microembossing roller**



Microembossing

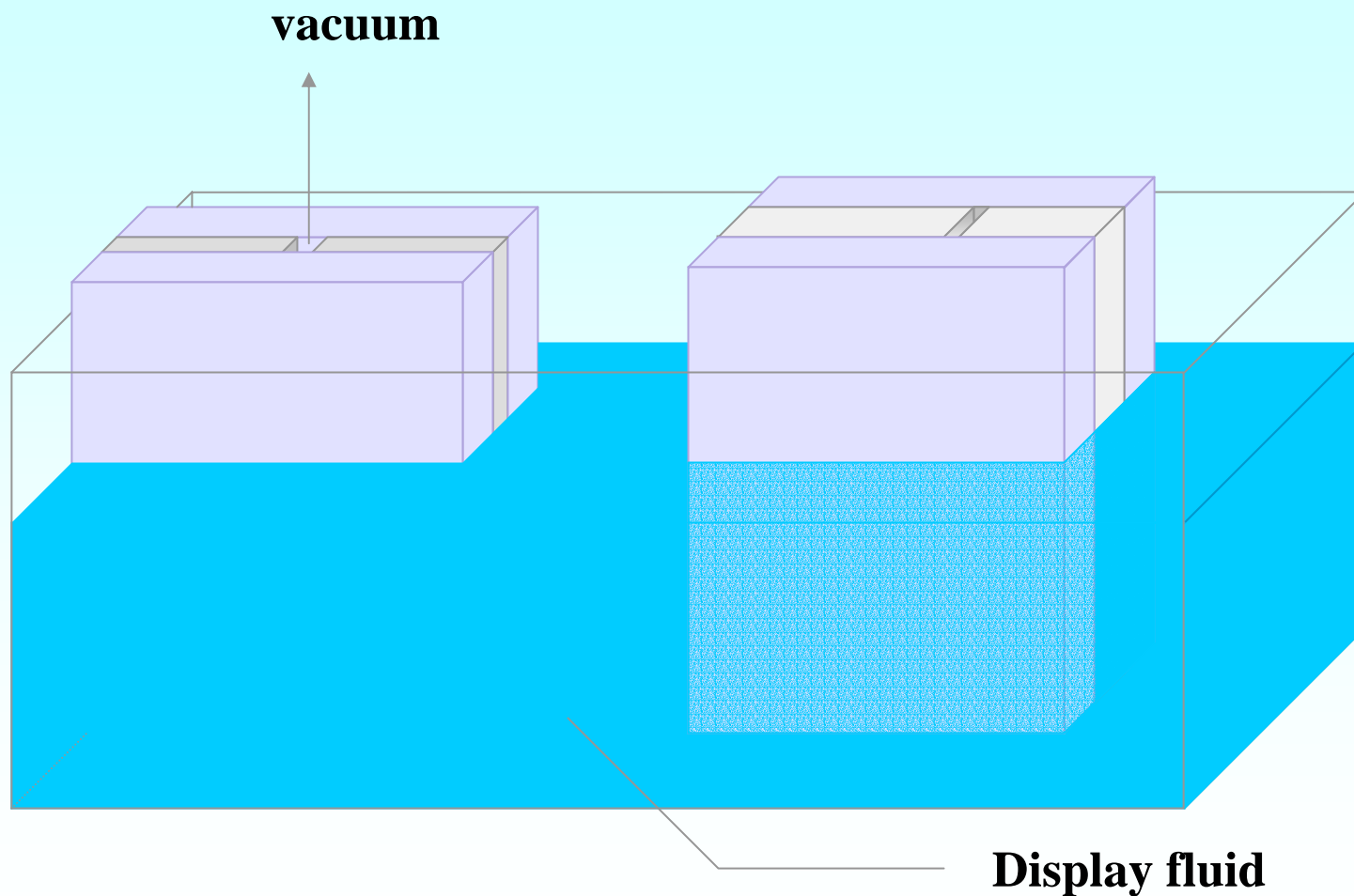


Embossed microcups

***Microcup size: 40-200um
Street width: 5-25um
Depth: 12-40um
Microcup shape: rectangular, square,
hexagonal***

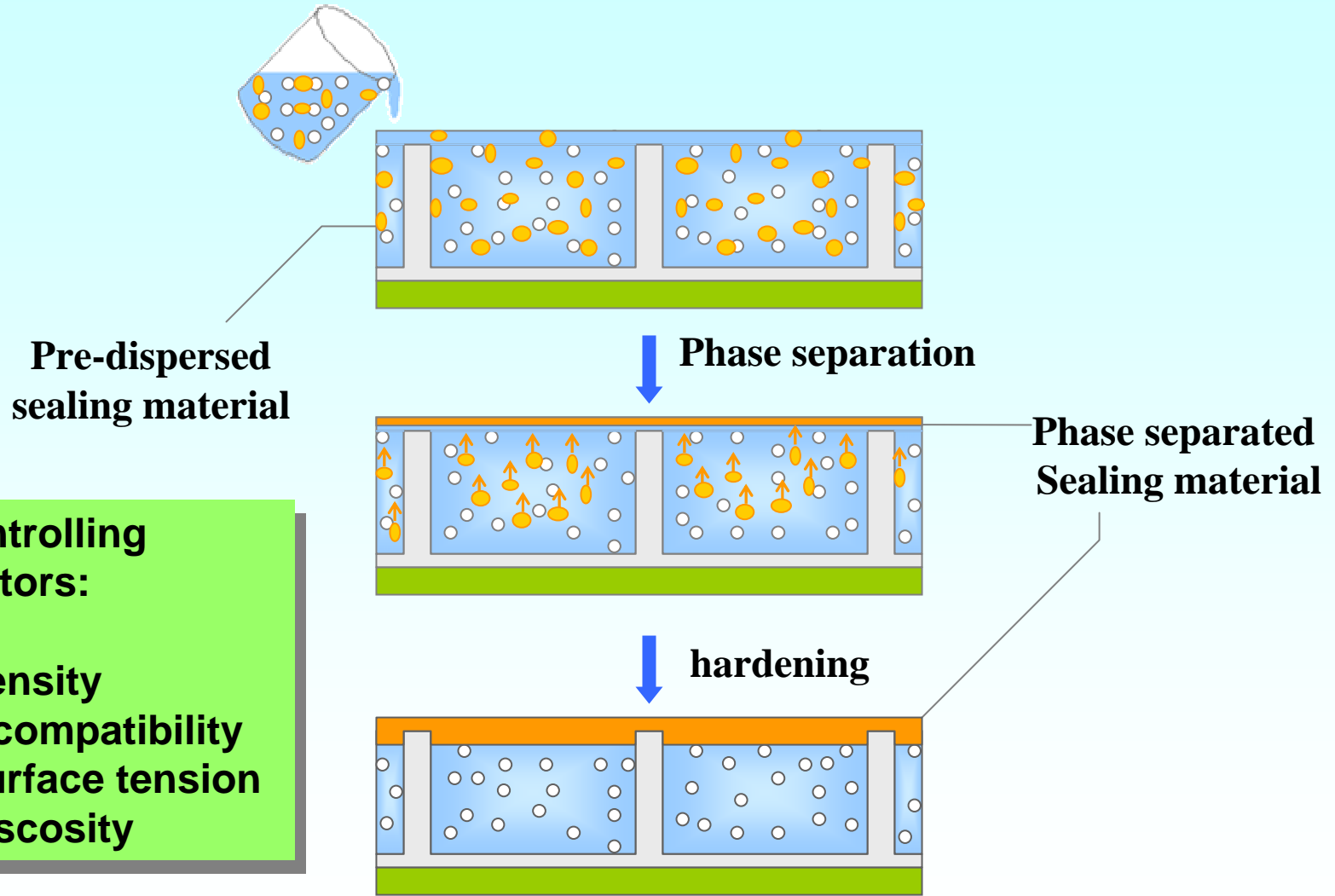
Conventional LCD injection

—— not applicable in microcup EPD display



Time consuming batch process

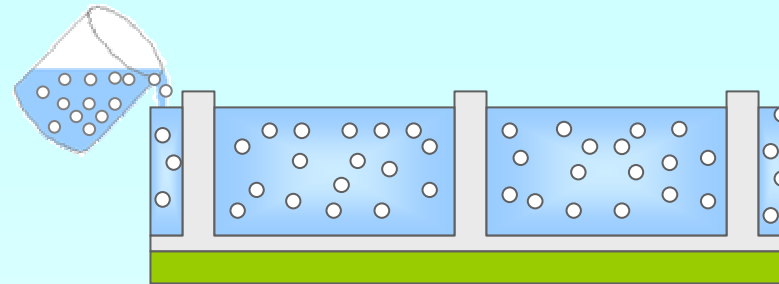
SiPix One-Pass Filling & Sealing



- Controlling Factors:**
- Density
 - Incompatibility
 - Surface tension
 - Viscosity

Seamless sealing may be accomplished in seconds.

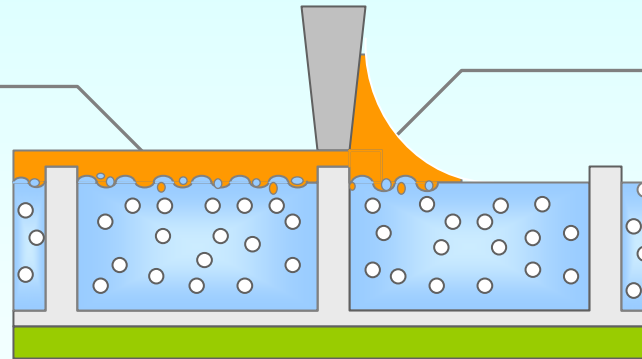
SiPix Two-Pass Filling & Sealing



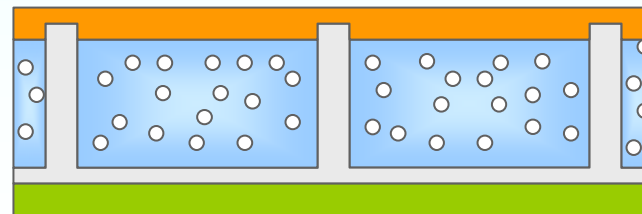
↓ Overcoat sealing layer

Two-phase
Inter-mixing

Sealant material



↓ Phase separation and hardening

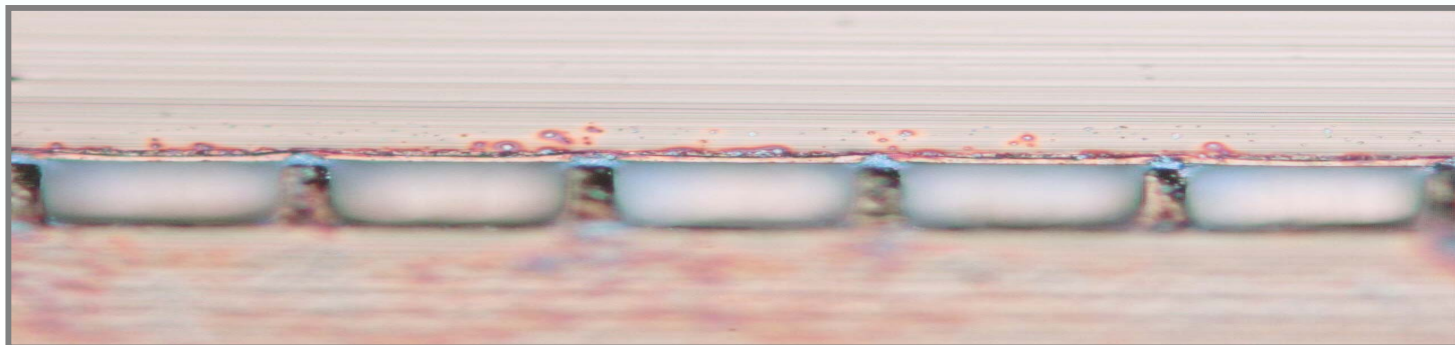
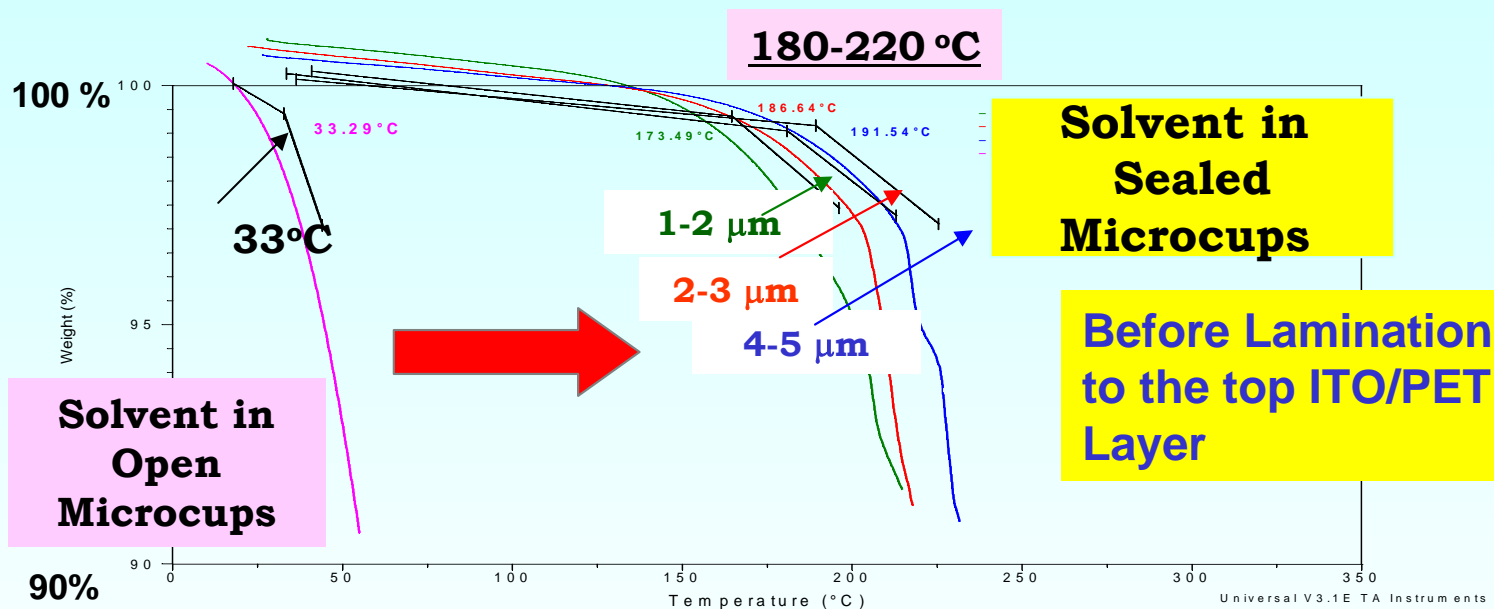


**Controlling
Factors:**

- Density
- Incompatibility
- Surface tension
- Viscosity

Seamless sealing may be accomplished in seconds.

Barrier Property of the SiPix Seamless Sealing Layer



Roll-to-Roll Manufacturing facility

Fremont, CA



Roll-to-Roll Sputtering

Fremont, CA



Current capacity in Fremont, CA:

- > 3.6 MM ft² per shift per year**
 - Up to 14" in width
 - May be unlimited length

Equivalent to about:

345 MM cell phones

100 MM PDAs

14 MM 5"x7" e-Books

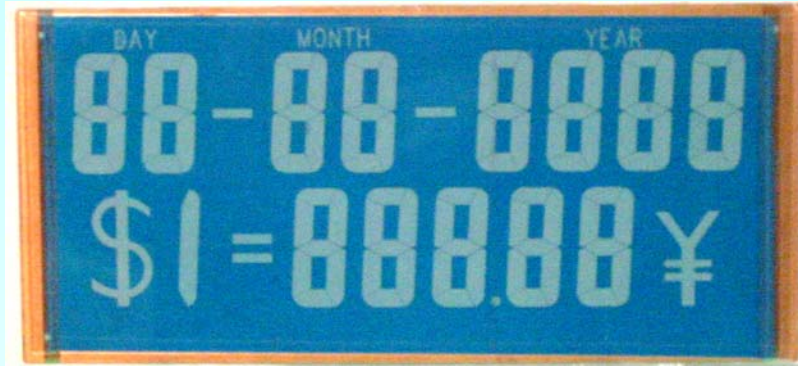
or

4.7 MM 15" Notebooks

@ Less than 20% of the LCD material cost and negligible labor

SiPix Microcup[®] EPDs

SiPix



Bias angle of 0° from the normal plane



Bias angle of 30°



Bias angle of 45°



Bias angle of 60°

Nearly 180° Viewing Angle (horizontal, vertical)

SiPix Reflective Microcup[®] EPDs SiPix



Good visual effect under $\left\{ \begin{array}{l} \text{strong light} \\ \text{non-uniform light} \end{array} \right.$

SiPix Unbreakable Microcup[®] EPDs

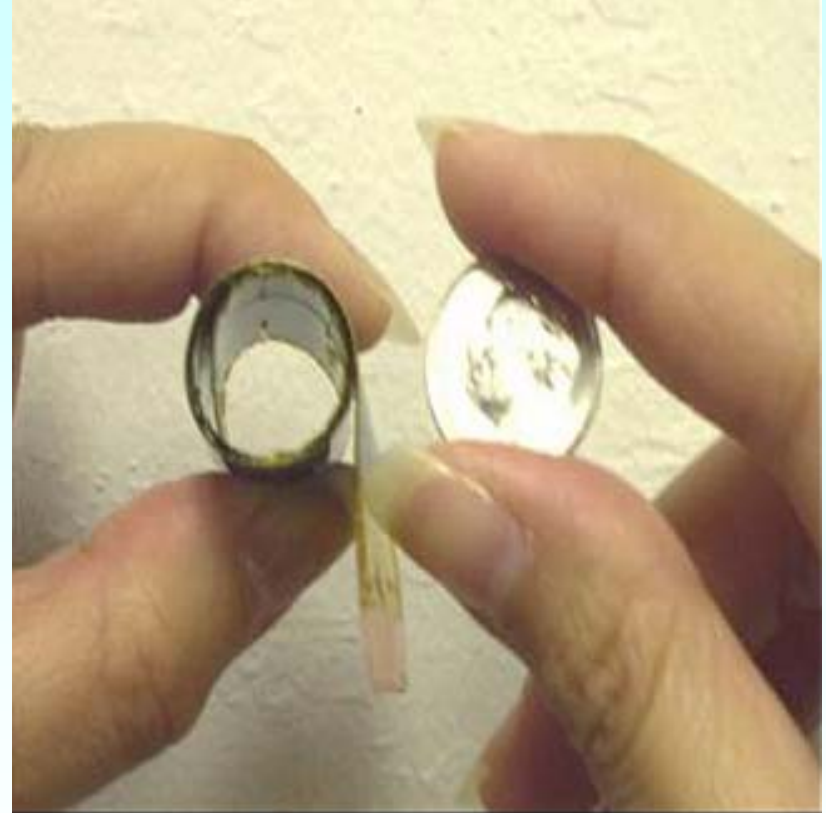
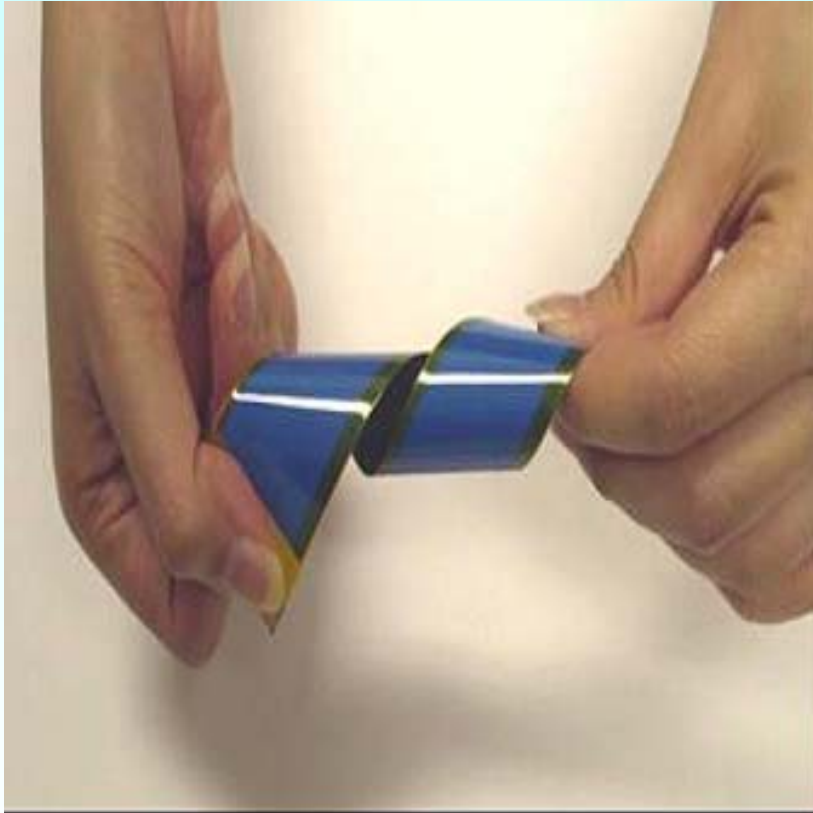


Detail condition of the dropdown test:

- *Dropdown height: 3 meter,*
- *Floor type: cement hard floor with hard coating,*
- *Repetition >50 times,*
- *Result: Panel maintained the same performance.*

SiPix EPDs: Super Flexibility

SiPix



The display can be rolled up to carry, unwind to read.

SiPix EPDs: Super Water Resistance

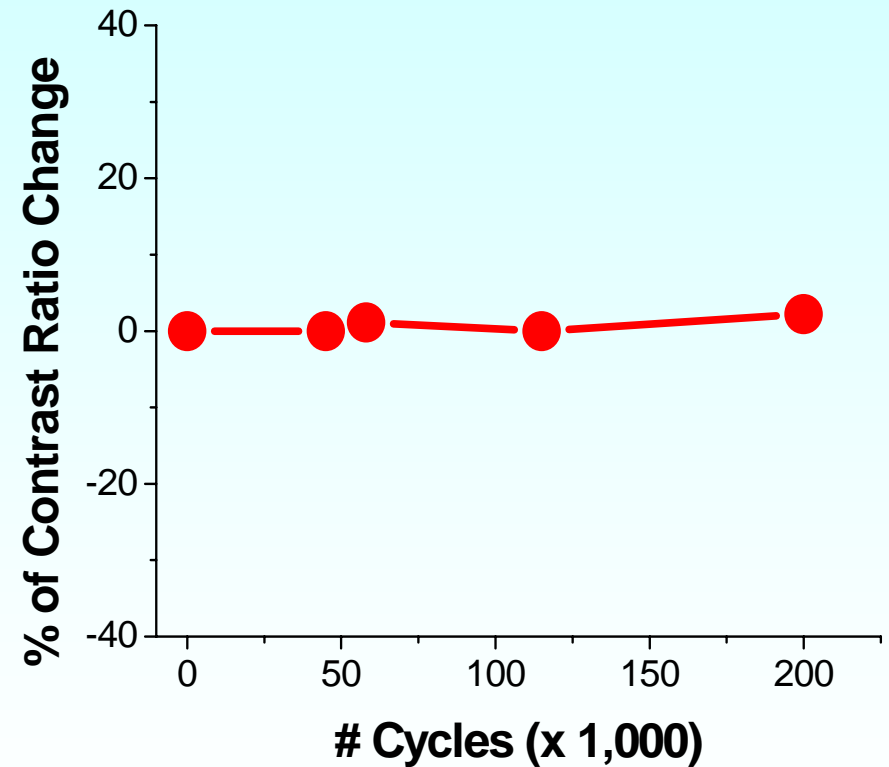
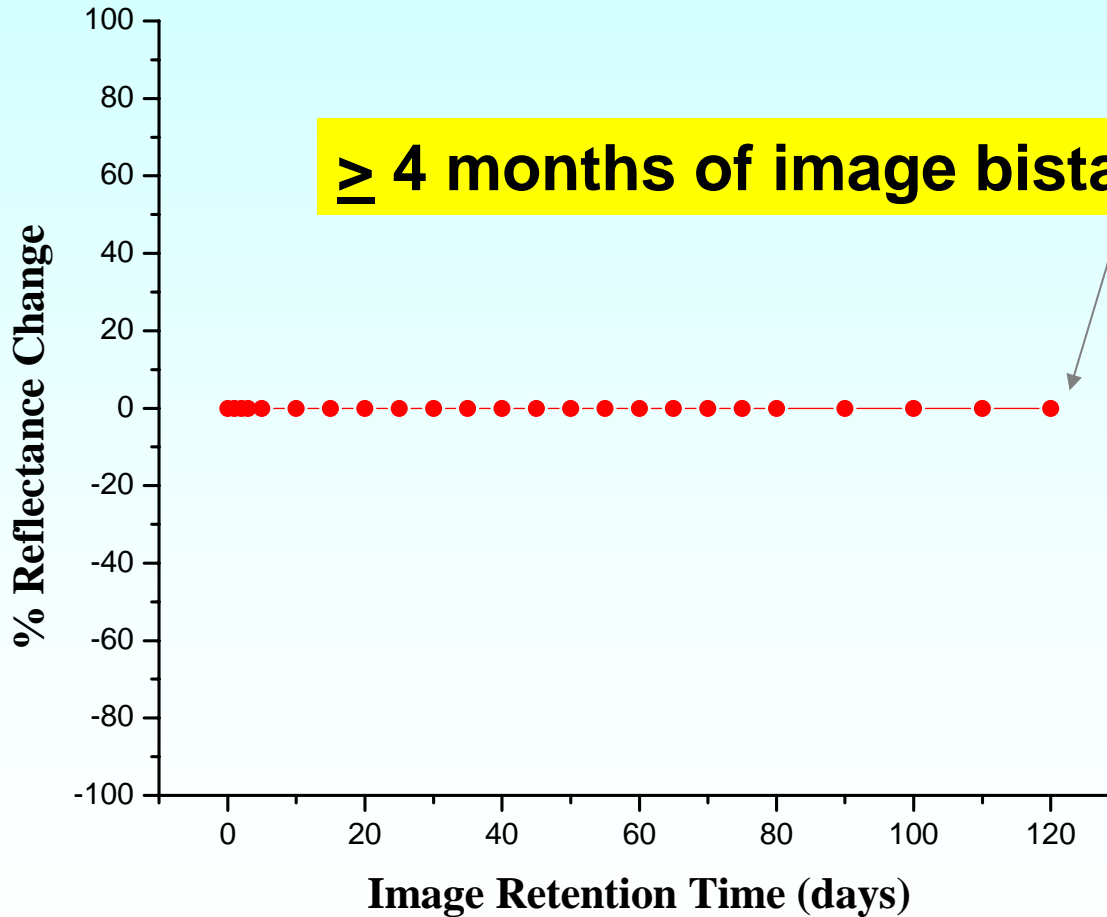


Image Bistability of Microcup[®] EPDs SiPix



SiPix EPDs: thin & format flexible



First Direct Drive EPD integrated with Smart Card

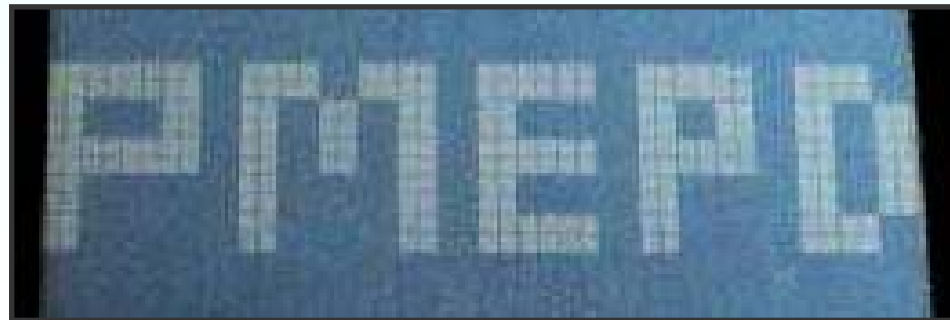
- **Active Matrix EPD (AMEPD):**

Monochrome XVGA has been demonstrated



- **Passive Matrix EPD (PMEPD)**

132X60 has been demonstrated with wide operation temperature latitude

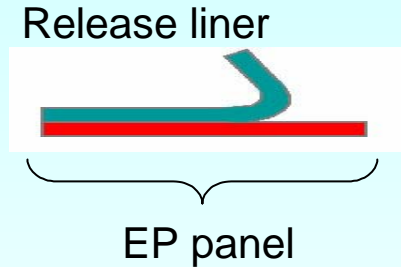


SiPix Microcup[®] AMEPDs

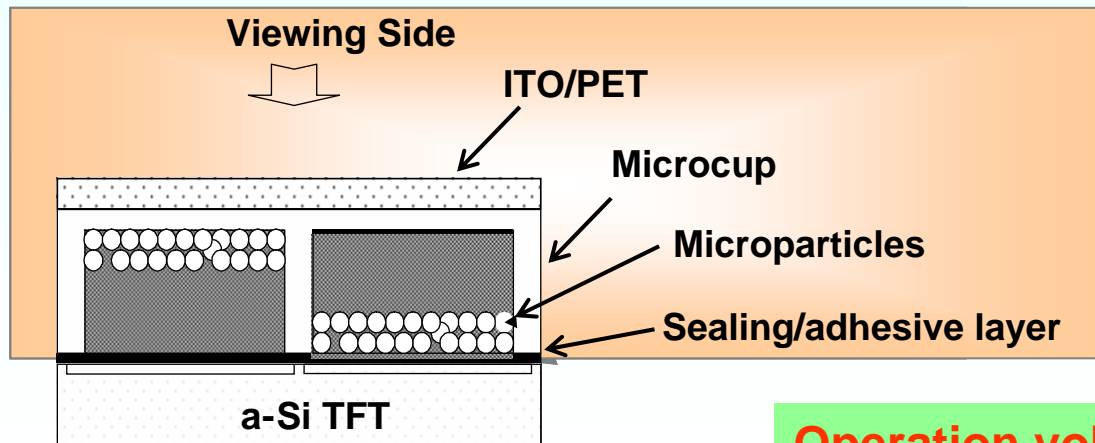


EPD Roll

Remove
Release
→



↓ Lamination to TFT



Operation voltage $\leq \pm 10V$

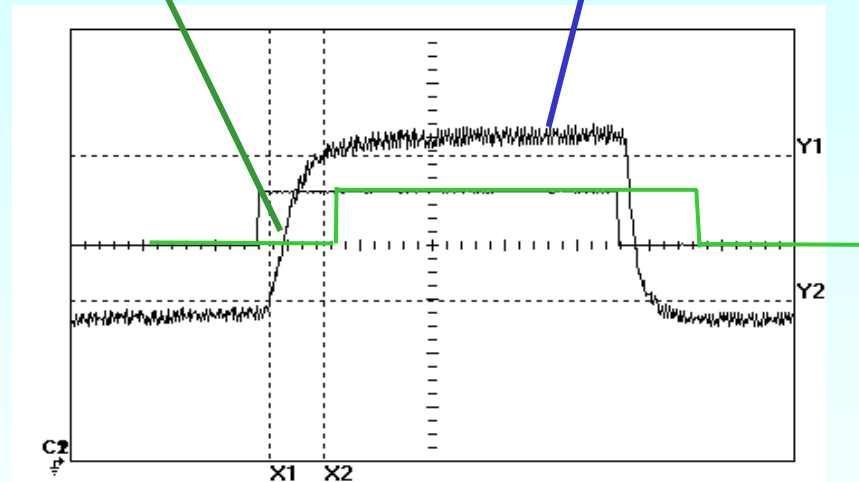
SiPix Microcup[®] AMEPDs

SiPix



Electrical Input

Optical output



Electro-optical response curves of the
1st generation a-Si TFT Microcup[®]

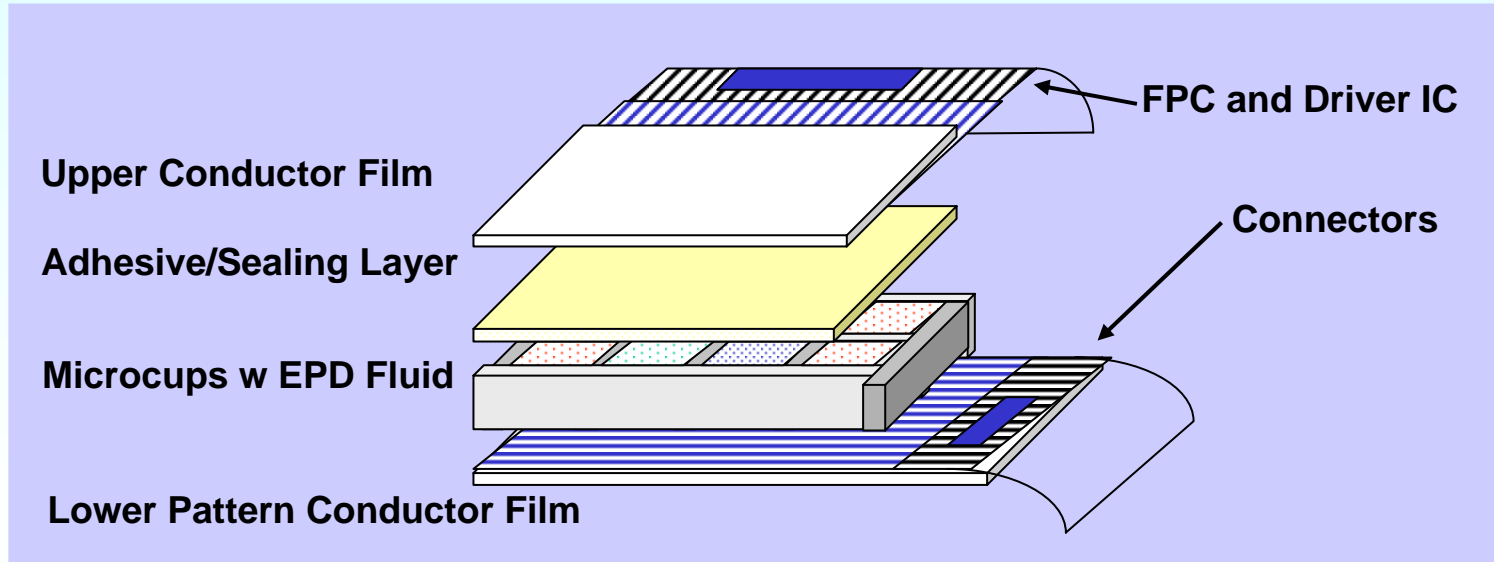
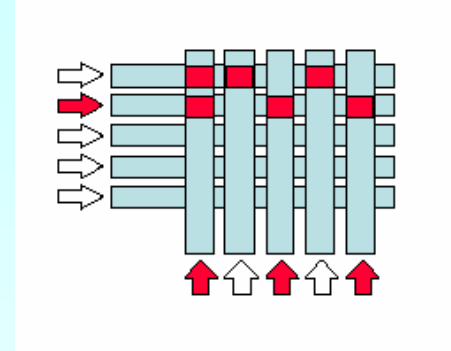
Operation voltage ± 14 V

$t_{on} \sim 150$ ms

CR ~ 10

SiPix Microcup[®] PMEPPDs

EPD Roll

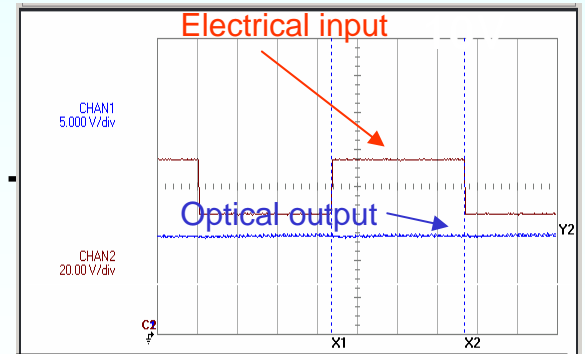
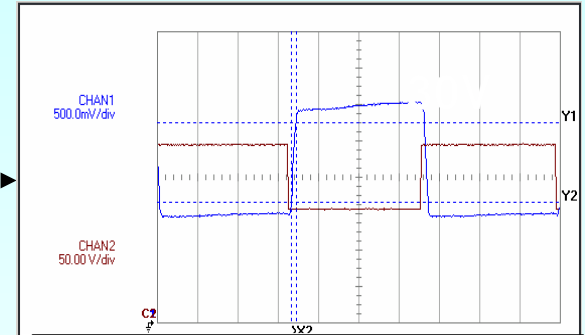
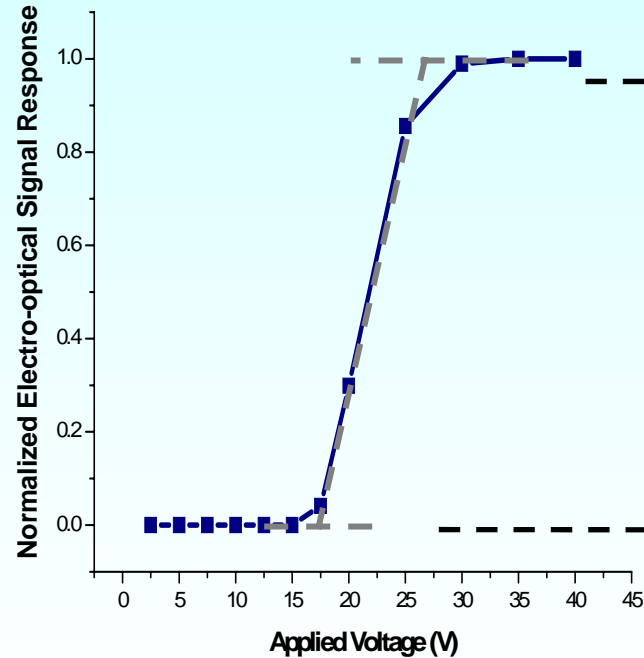
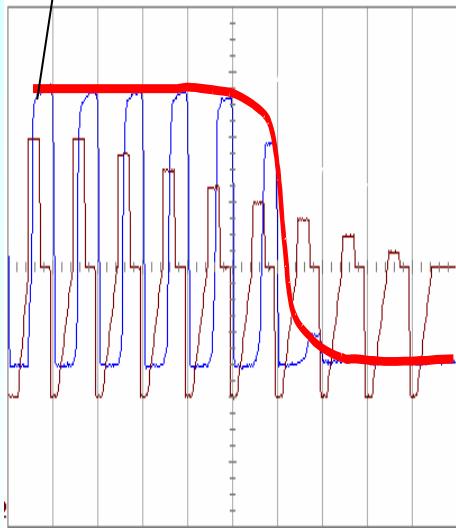


Microcup[®] structure allows format flexibility

SiPix Microcup[®] PMPEDs

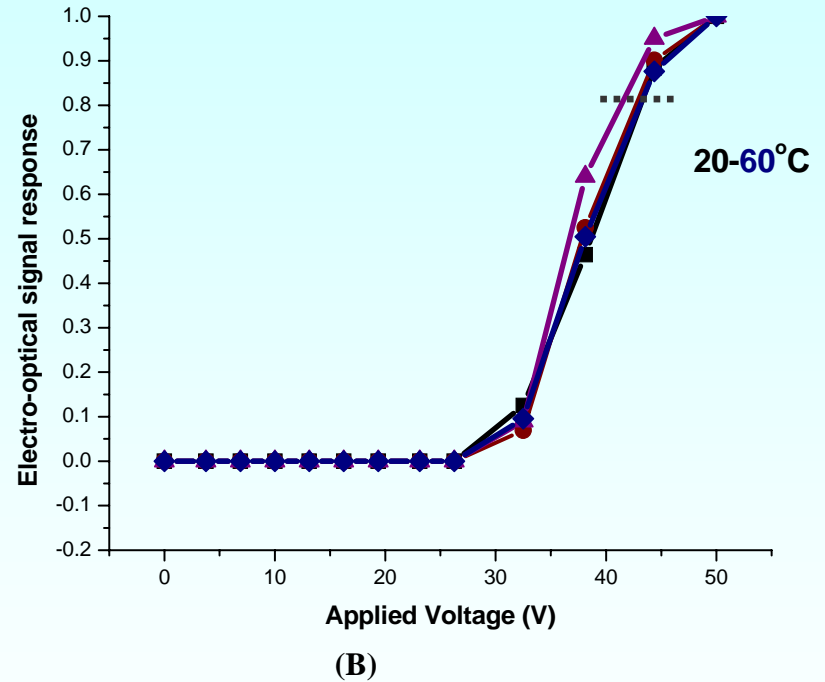
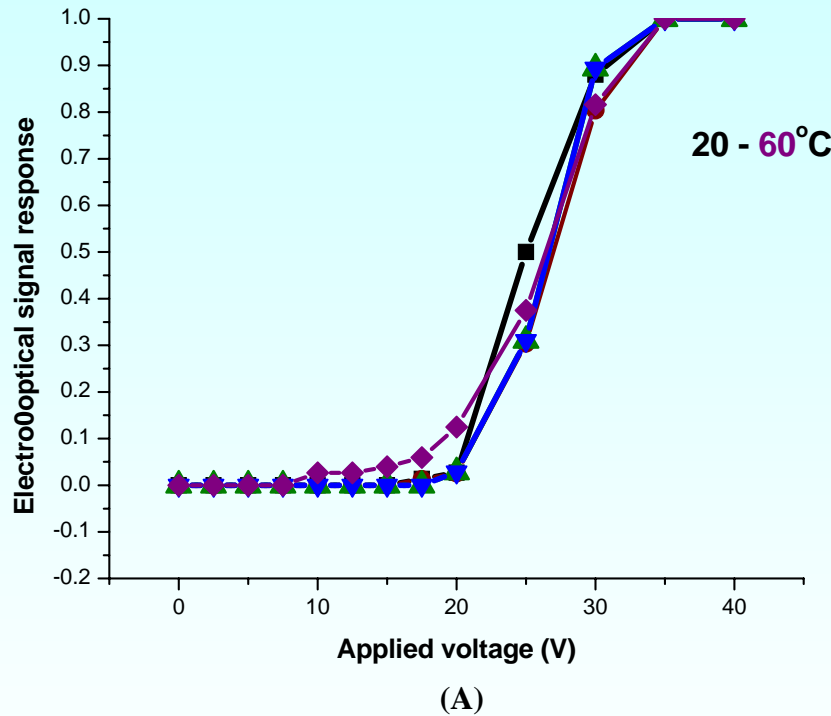
Threshold Voltage $\geq 10V$; Operation: $\geq 25V$;

Sharp Gamma (for e-board applications)



Threshold voltage $> \frac{1}{2}$ of the driving voltage Today $T_{on} = 20$ msec

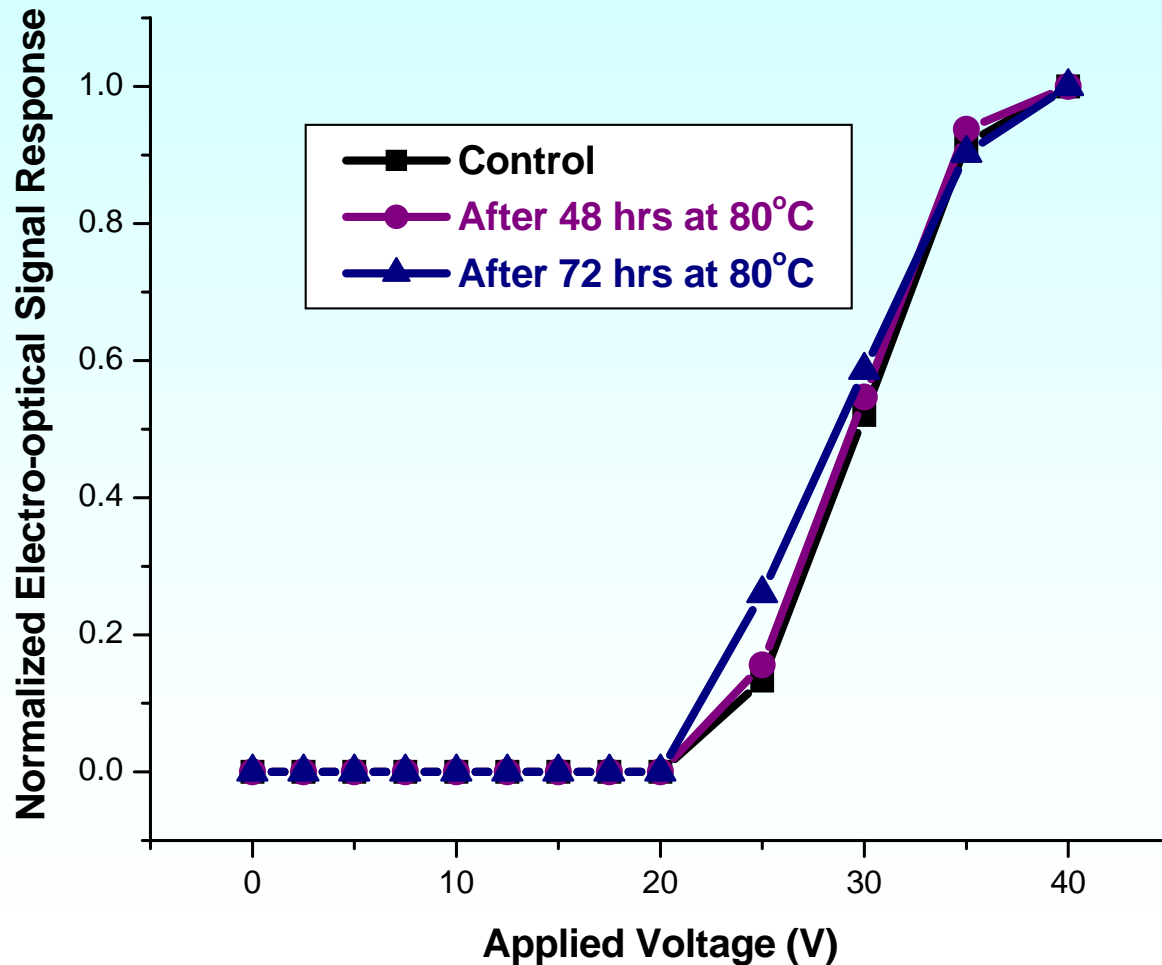
SiPix Microcup[®] PMPDs



**Good temperature latitude (20-60°C)
with different threshold voltage**

SiPix Microcup[®] PMPEDs

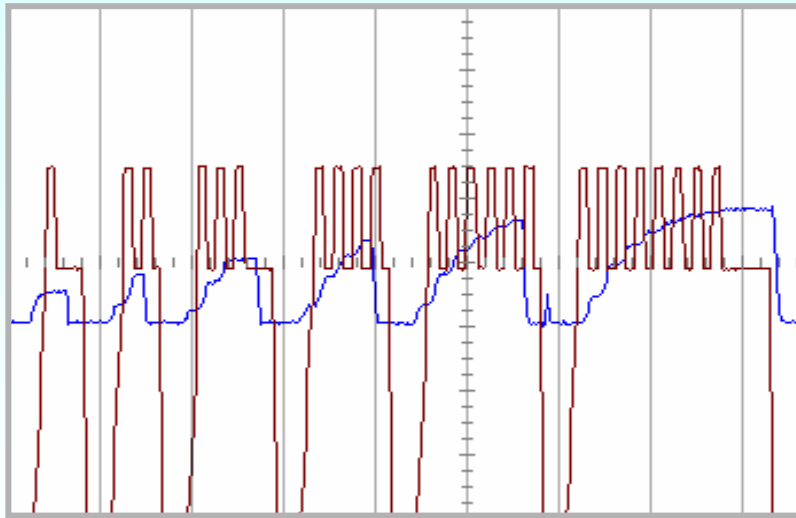
No change in threshold after aging at 80°C



Gray Scale **Microcup**[®] EPDs

In addition to voltage and area modulation mechanisms:

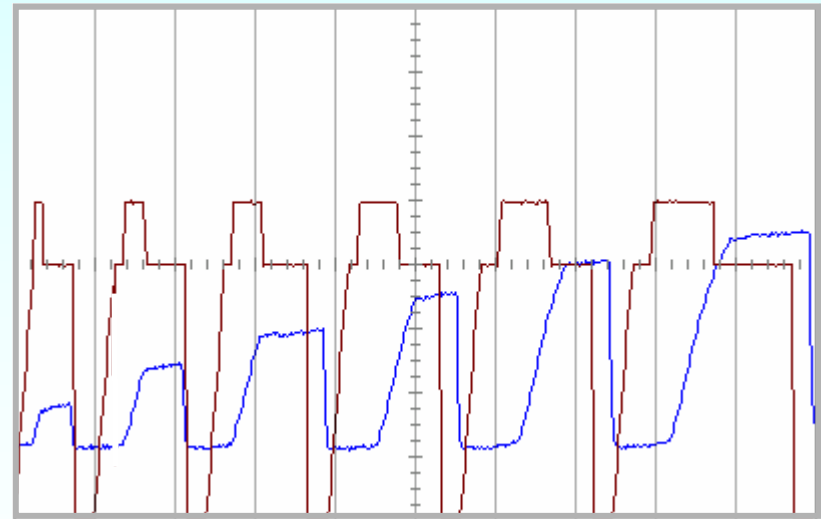
Pulse Frequency Modulation



Pulse Voltage = 20 V

Pulse Width = 15 ms

Pulse Width Modulation

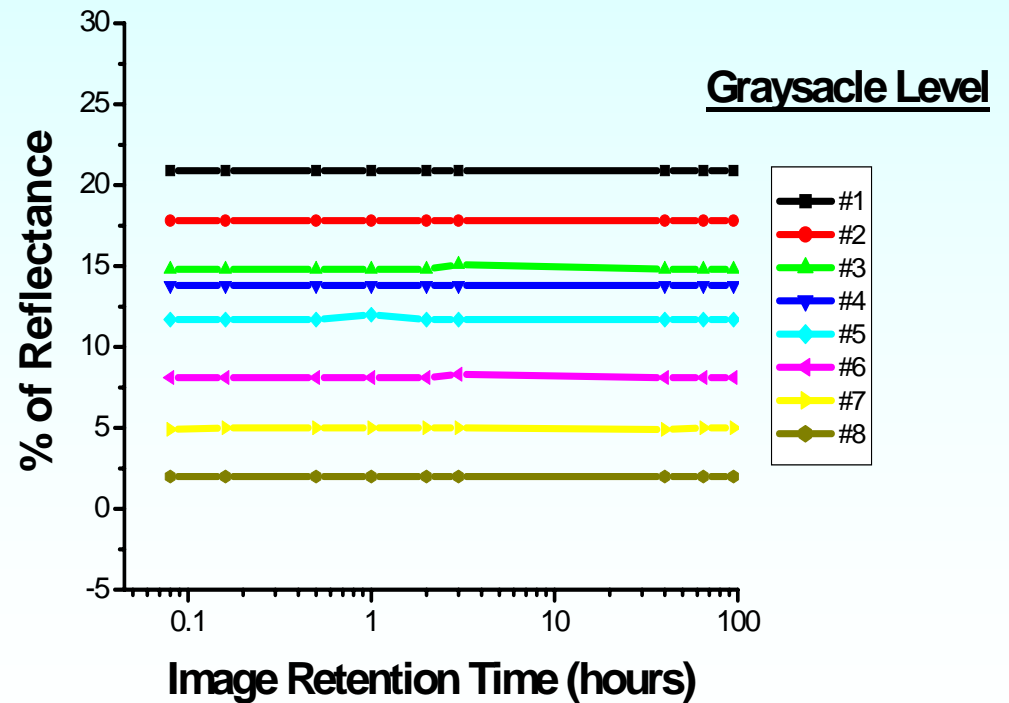


Pulse Voltage = 15 V

Pulse Width = 20ms ~ 120ms

SiPix Microcup[®] PMPEDs

More than 12 grayscale levels have been demonstrated with super bistability





Threshold Voltage: 15V,
• **Contrast ratio of >8,**
• **$t_{\text{on}} \simeq t_{\text{off}} \simeq 45\text{ms}$ at a
driving voltage of 30 V**
• **Resolution: 60x20 lines**
Microcup[®] PMEPPD

SiPix EPD Applications



Summary: Microcup[®] EPDs

- Microcup[®] + Continuous Filling/Sealing Technologies

- ➡ High Throughput & High Yield, Roll-to-Roll Process
- ➡ Superb Physico-mechanical Properties
- ➡ Color Rendition

- Proprietary Electrophoretic Fluid & Microcup[®]

- ➡ Compatible with PM & AM Driving
- ➡ Wide Temperature Latitude of Threshold Characteristics
- ➡ Grayscale Bistability

- Desirable features for Electronic Paper Applications

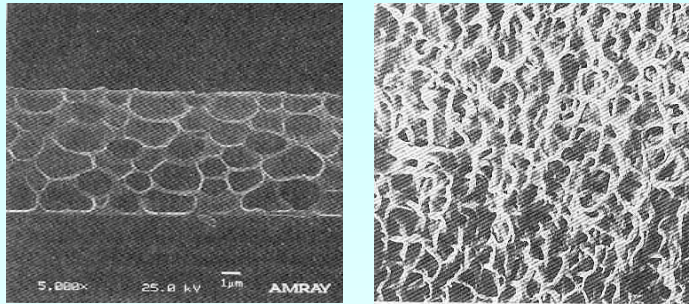
- ➡ Flexible, Rugged, Thin, Light Weight, High Contrast,
- ➡ Low power consumption, Ambient/Sun light readability

- **Dispersed Liquid Crystal Displays**

by

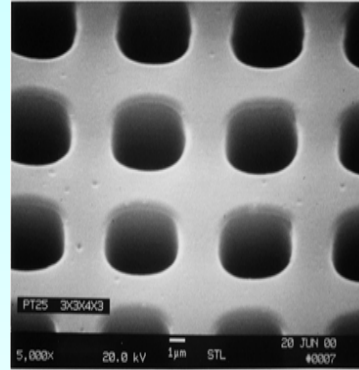
Roll-to-Roll Manufacturing Processes

Monodispersed Microcup[®] LCDs **SiPix**

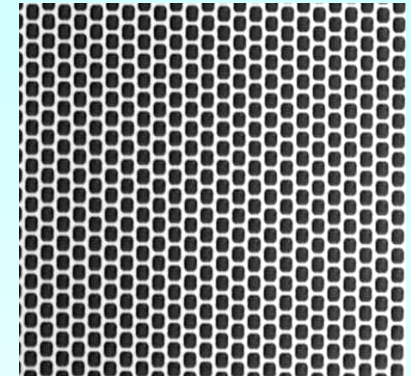


Conventional PDLC

3 μm (l) x 3 μm (w) x 2.5 μm (p)



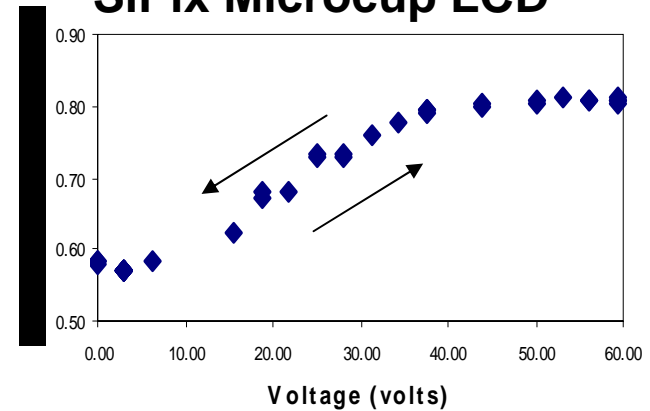
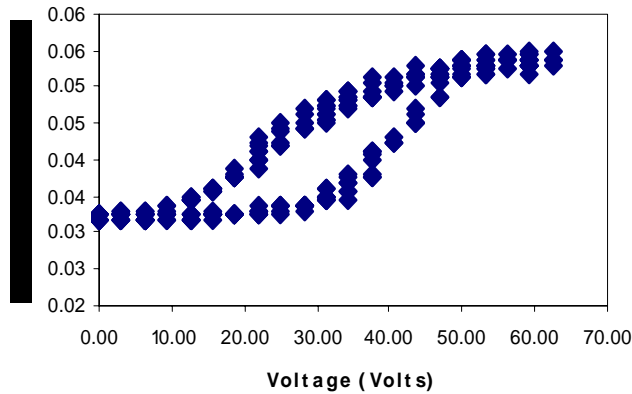
2 μm (l) x 2 μm (w) x 1.5 μm (p)



10 μm

10 μm

SiPix Microcup LCD



Monodispersed Microcup[®] LCDs **SiPix**

Microcup[®] LCDs:

- Wide latitude for the selection of LC, resin, and dyes.
- A reorientation field of about **1V/um**
- A threshold of about 3V.
- **Negligible hysteresis**
- **$t_{on} \sim 0.2$ msec**

Thank you!



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Display the World with **SiPix**