

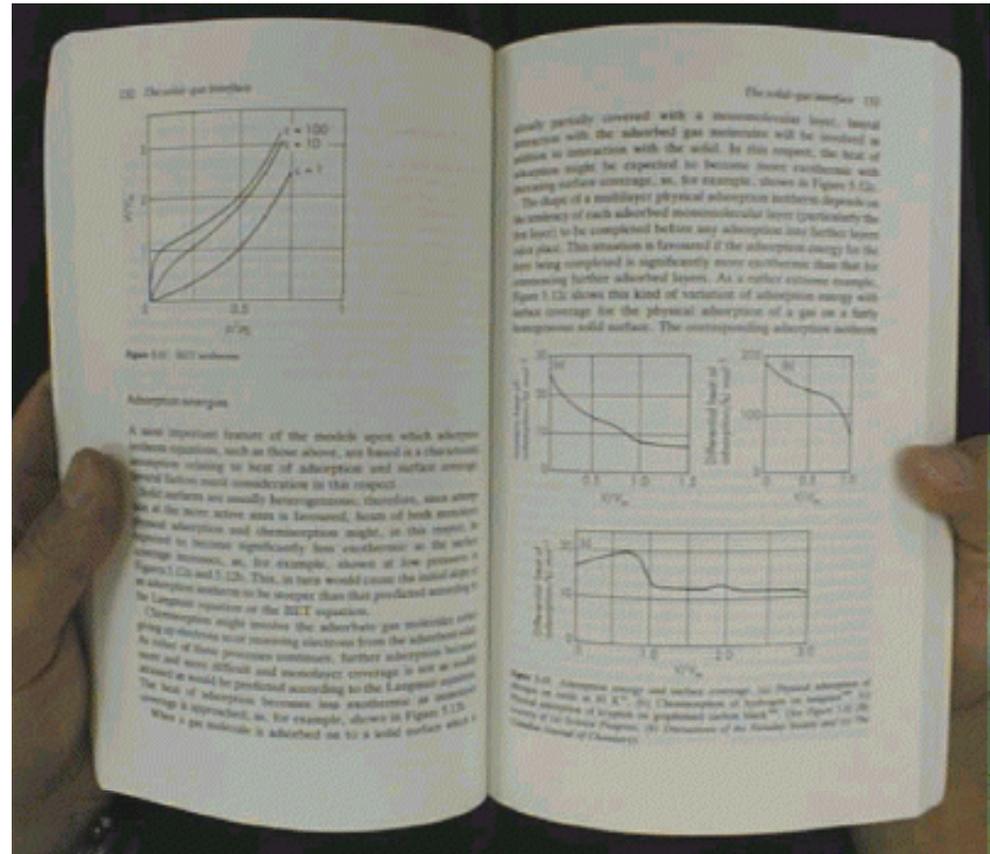
Electronic Paper Comes of Age Dr. Michael McCreary VP Research and Advanced Development E Ink Corporation

Digital Fabrication 2009
Louisville, KY
NIP 25 / Digital Fabrication 2009
Society for Imaging Science and Technology

September 22, 2009

Paper, the Historical Favorite

- High reflectivity (~65%)
- Good contrast ratio (~20:1)
- Ambient light viewable
- Full viewing and illumination angles
- Lightweight and rugged
- No power required



... but you can't change the content.

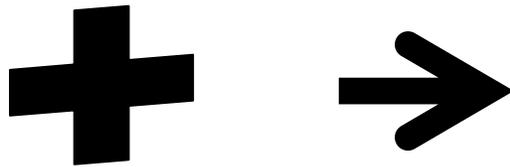
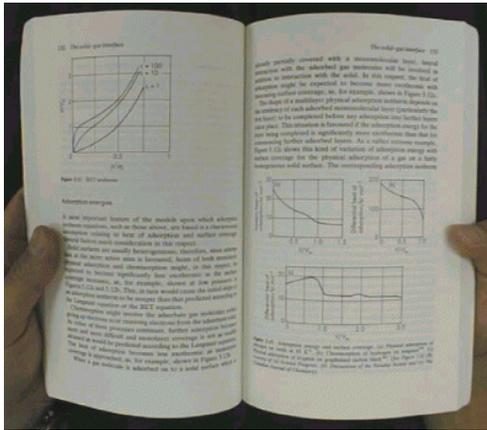
LCD/Computers are not “Electronic Books”



- Trans-reflective backlit STN- or TN-LCDs
- Poor viewing in most lighting conditions
- All glass construction
- Moderate viewing angle (60°)
- Continuously powered with back light.

... but they're not paper-like.

Electronic Paper Displays: Desirable Attributes



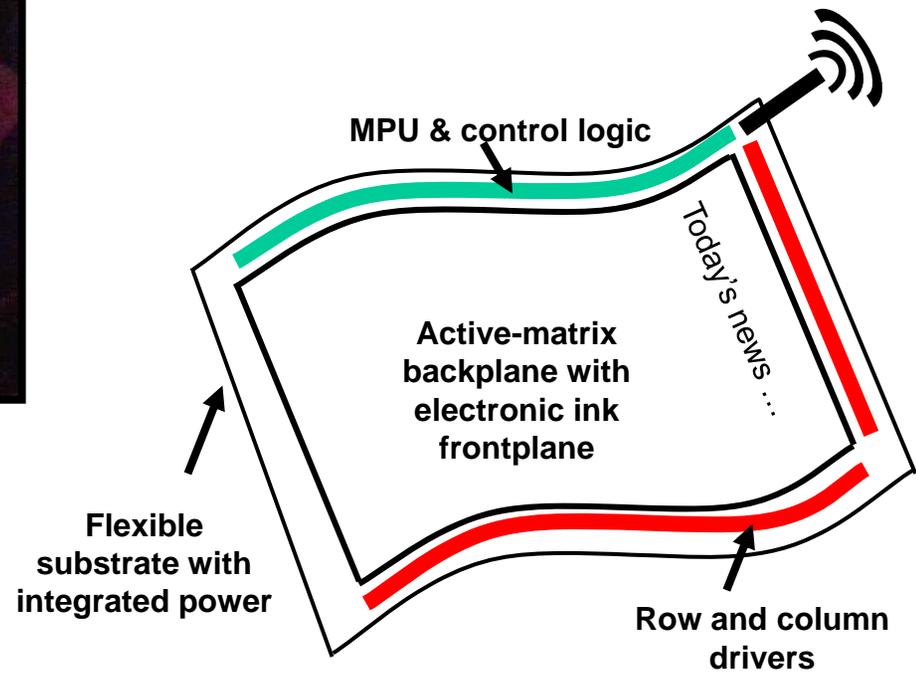
- high contrast and reflectivity
- wide viewing angle
- flexible
- lightweight
- robust and durable
- large area capable
- low power
- bi/multi stable

The Vision: Radio Paper™



Photo from IBM

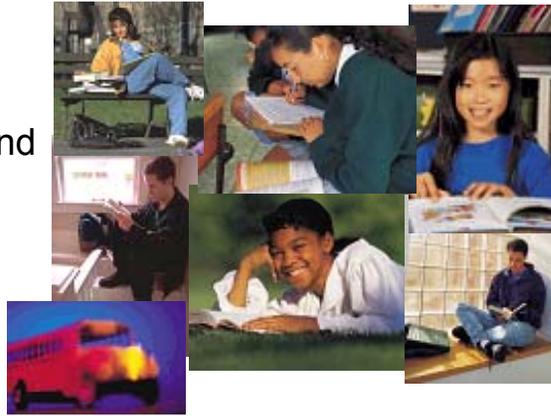
- Flexible
- Large format
- Wireless updates



Market for Electronic Readers

Education

- Text Books
- Class notes articles and reference materials
- Organizer



Consumer

- News & Information
- Novels
- Magazines
- Entertainment
- Book Clubs
- Travel / Field Guides



Professional

- News & Information
- Trade Publications
- Manuals / Reference
- Medical
- Legal
- Accounting
- eMail / Messaging
- Office Communication



Other

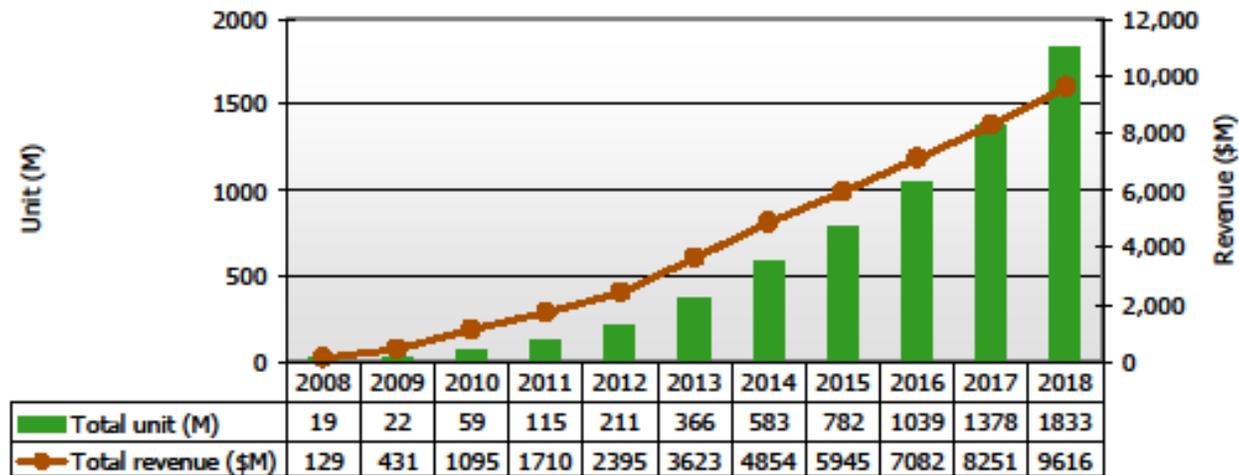
- Gov't
- Military
- Mapping
- Religious



A significant amount of today's information is still read on paper

Total E-Paper Display Market Forecast

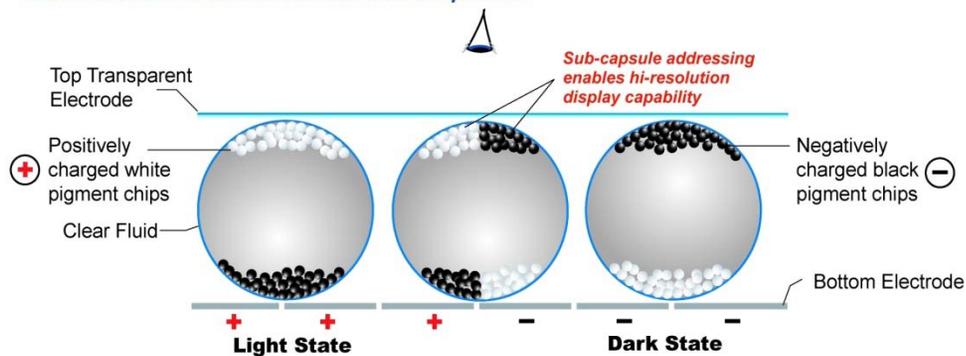
- 22M e-paper displays will be shipped this year; 1.8 billion units forecast in 2018
- Total e-paper displays revenue will reach \$9.6 billion in 2018 from \$431 million in 2009, for a CAGR of 41%.
- Electrophoretic (e-books) will lead revenues
- Electrochromic (smart card and smart label) will lead units



Source: [e-Paper Display 2009 Report](#) by DisplaySearch

Electrophoretic Ink Enables Electronic Paper

Cross-Section of Electronic-Ink Microcapsules

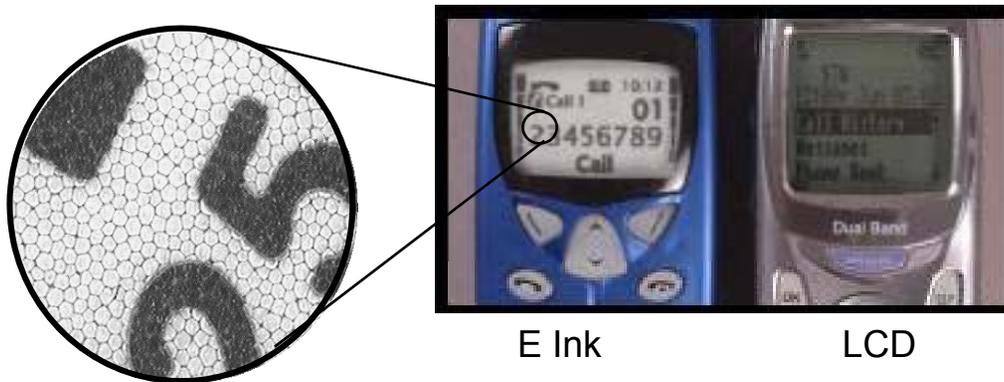


Note: For illustration purposes only - not drawn to scale. Copyright E Ink, 2003.

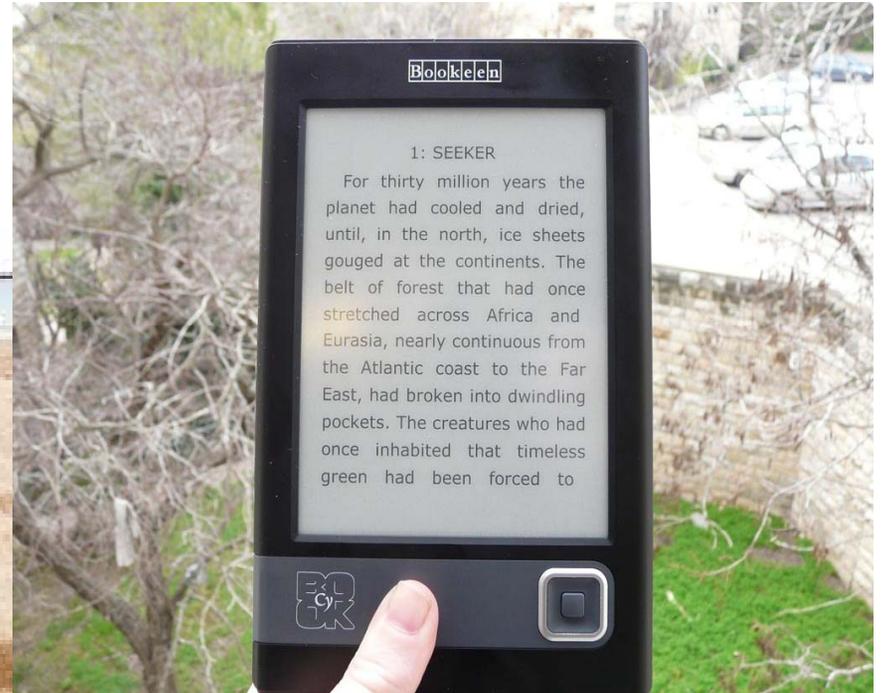
E·INK

E Ink display technology is based on microencapsulated oppositely charged colored particles that move in an electric field

- Paper-like look
 - sunlight and room light readable
 - viewing / lighting angle independent
- Ultra low power
 - no power to maintain image
- Scalable to large area
- Ideal for flexible/bendable displays
 - ink is supplied on flex substrate
 - low TFT mobility requirements
 - no backlight
 - barriers easier than OLEDs



Sunlight Readable



..... no shade required

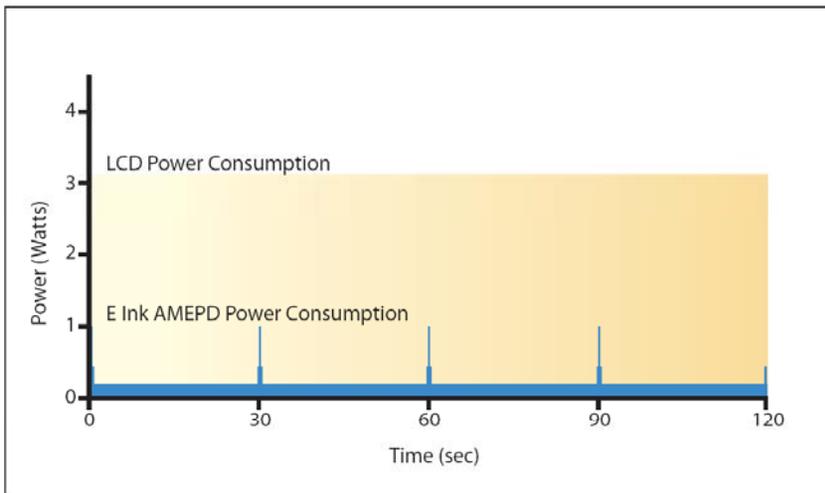
Low Power

12" LCD for 20 hrs = 36



2.5 pounds

LCD vs E Ink Active Matrix Display System
Power Consumption Comparison



E Ink = 1

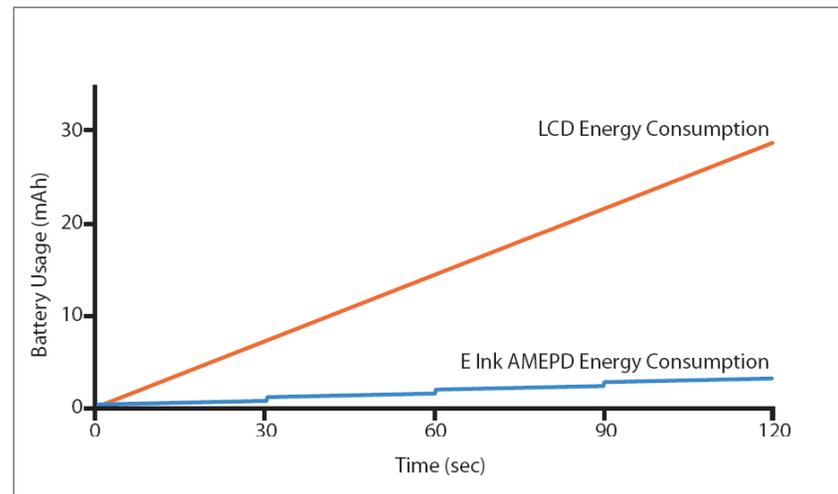


1 ounce!

- ✓ No backlight
- ✓ Bi-stable image
- ✓ Better industrial design

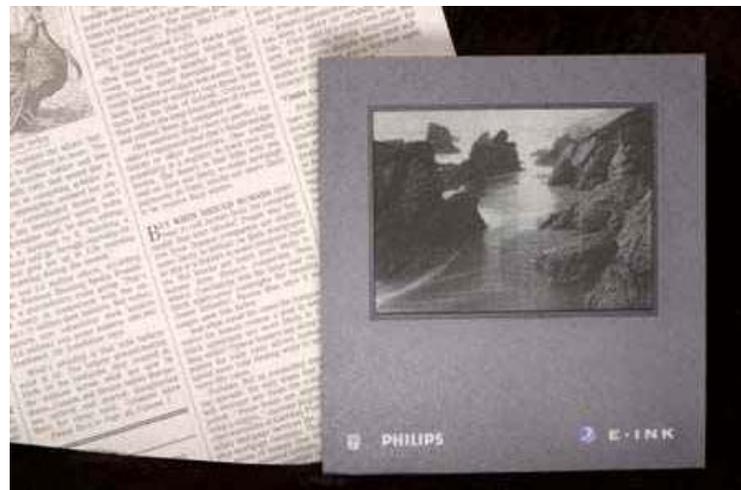


LCD vs E Ink Active Matrix Display System
Cumulative Current Consumption Comparison

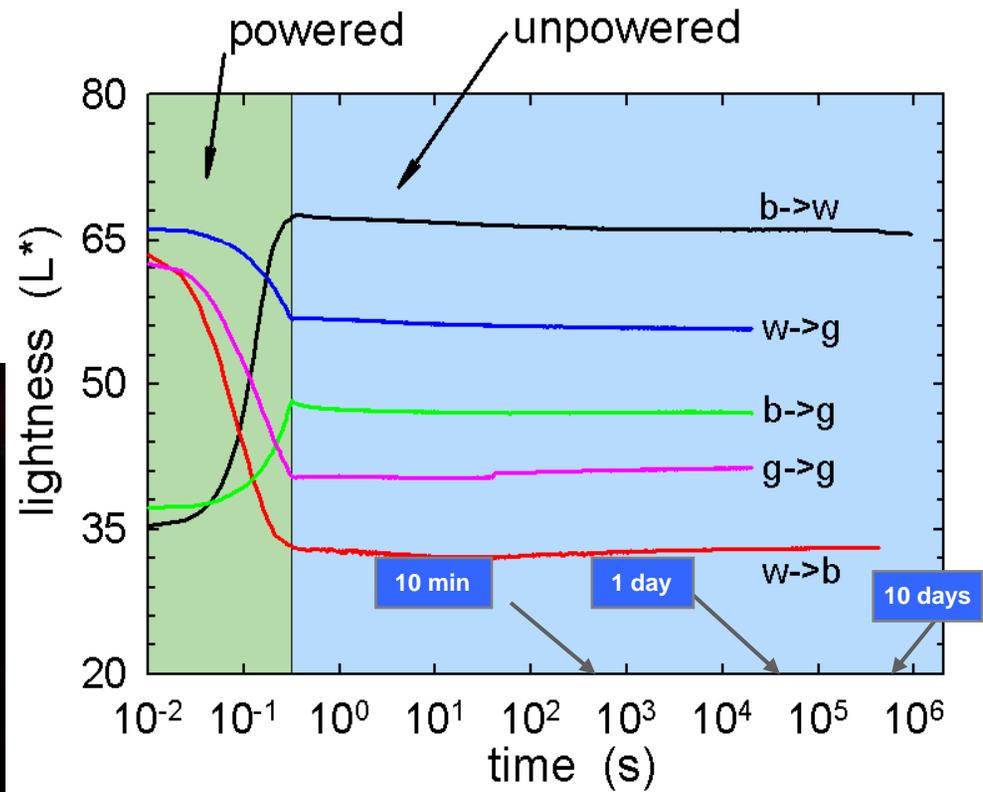


Assuming single cell Li-Ion battery at 3.8V.

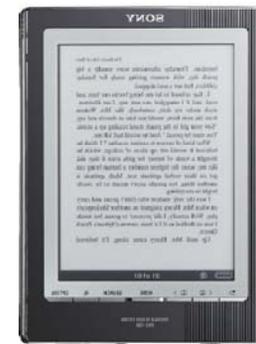
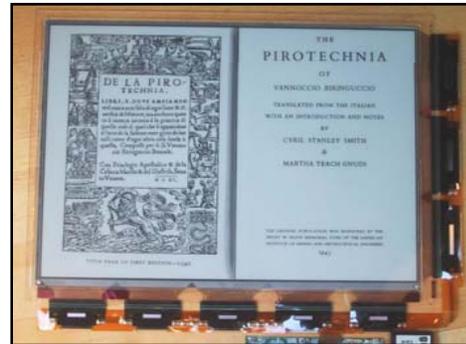
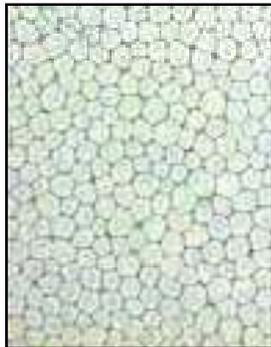
Grayscale Active-Matrix Displays



electronic ink on active matrix panels

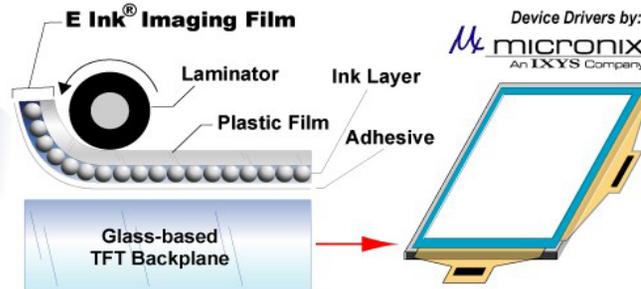
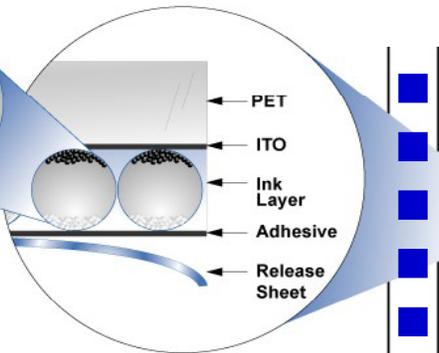


Typical Active Matrix Supply Chain



(-) Black Pigment
Clear fluid
(+) White Pigment

Electronic Ink



Device Drivers by:
micronix
An LXYS Company

Display Cell

Display Module

Ink

Coat/Convert

Cell Assembly

Module Assembly

Set/Device Integration



PRIME VIEW INTERNATIONAL
(or Other TFT Display Manufacturers)



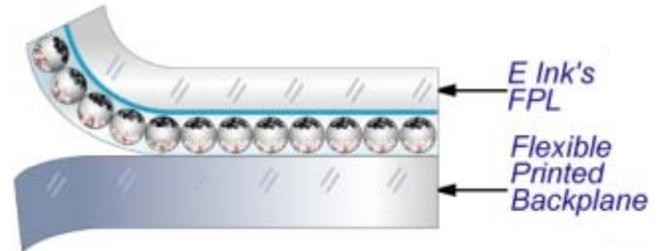
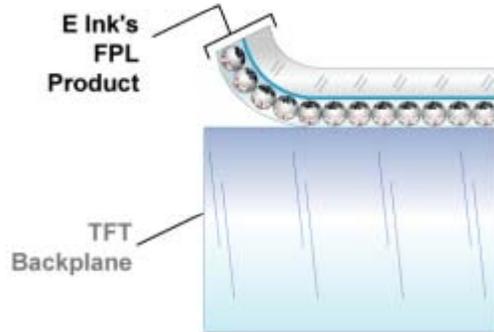
E Ink Imaging Film™ Product

Two Product Lines



High-Resolution
Active Matrix Displays

Low-Resolution
Segmented Displays

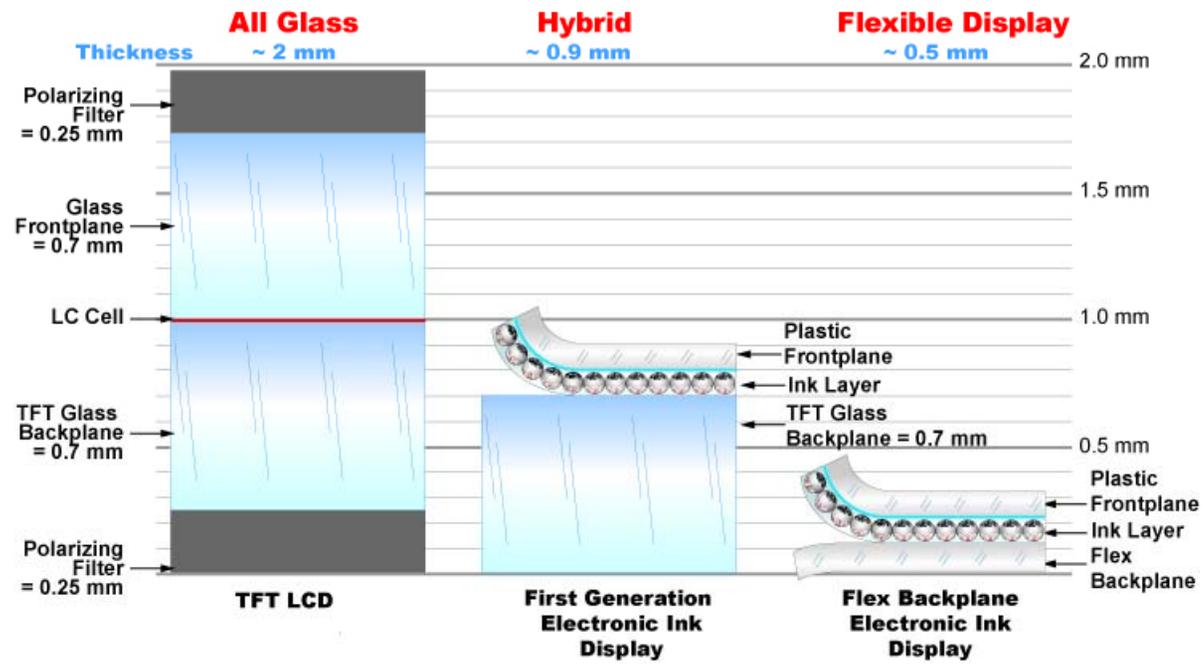


Display modules supplied by:
PRIME VIEW INTERNATIONAL

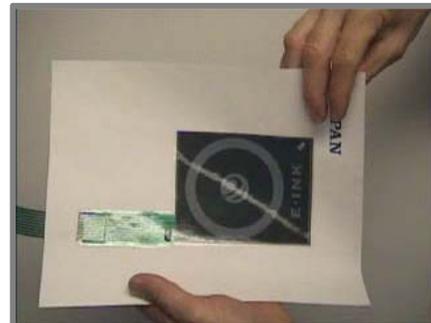
LG Display



Electronic Ink Front Plane Laminate



Cloth



Paper



Tyvek®



Thin Plastic

Millions of Products With E Ink Plastic Displays Have Been Sold

Cellphones



Indicators



Watches



Labels



Signage



E Ink Electrophoretic Displays on Cellphones



Samsung Alias II
E Ink Keyboard Display



Hitachi Fashion Phone
w/ E Ink Case Art



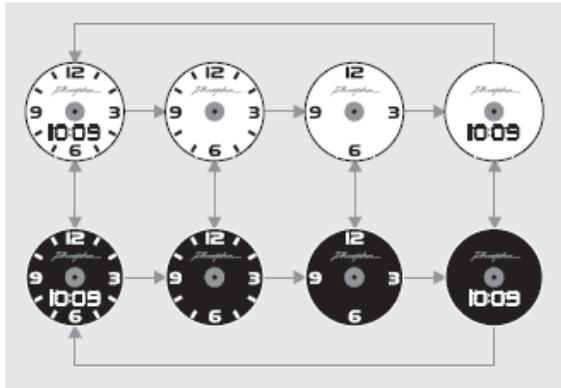
Casio Ruggedized Phone
w/ E Ink Secondary Display

Watches

phosphor™



SEIKO



Labels & Signs



Electronic Shelf Labels

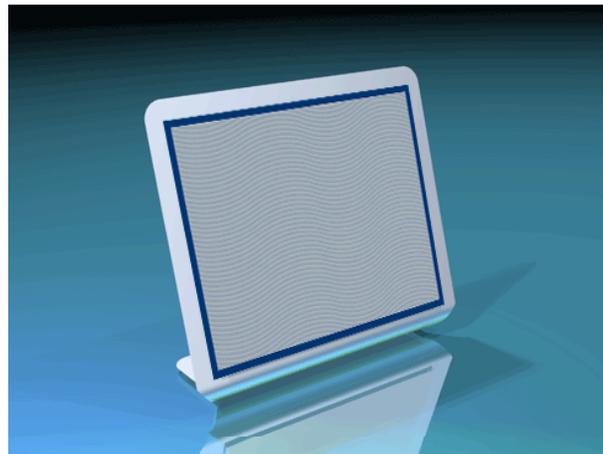
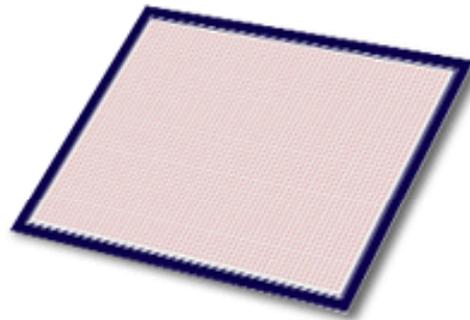
Large Area Signs



Advertising/Promotional all-Plastic Displays

NEO LUX

www.neoluxiim.com



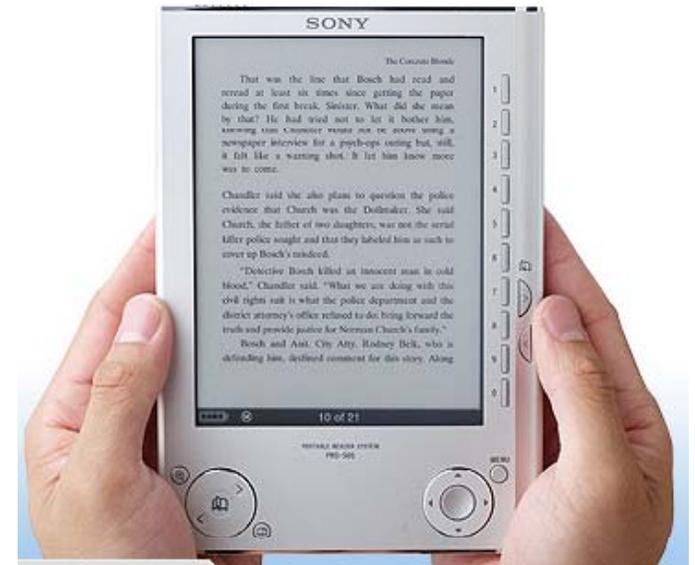
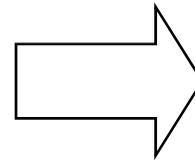
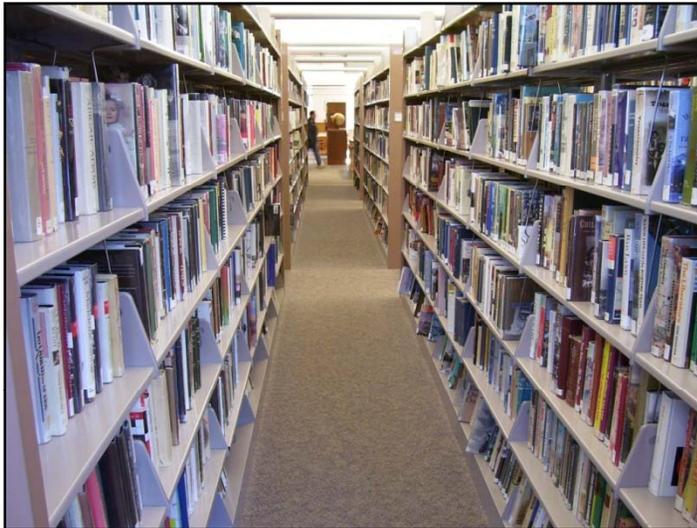
- Stand alone
- Pre-programmed
- Months of operation on 2 AA batteries

Esquire Magazine – 75th Anniversary Issue

- Electrophoretic display on outside / inside of cover
- 100,000 issues on newsstands in Sept. / Oct. 2008
- Combined project with Esquire Magazine, Ford and E Ink
- Symbolizes a “cultural tipping point”
 - physical magazine literally embraces the future by embedding an electronic paper display



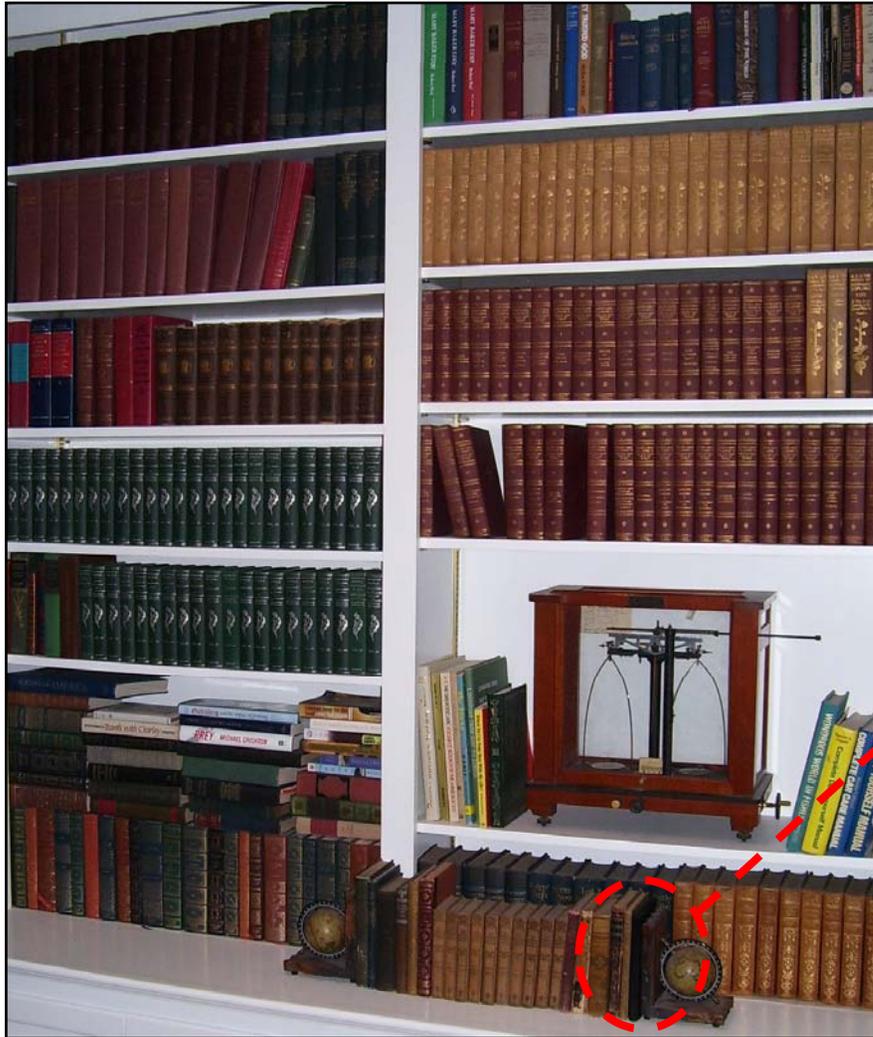
Electronic Publishing is a Multi-\$B Addressable Market



- **\$100B- \$300B annual publishing industry today, is bigger than the entire electronic display industry**
- **Mobile electronic books has not previously succeeded since traditional displays are fatiguing to read and drain batteries too quickly**

**A library in
your hands**

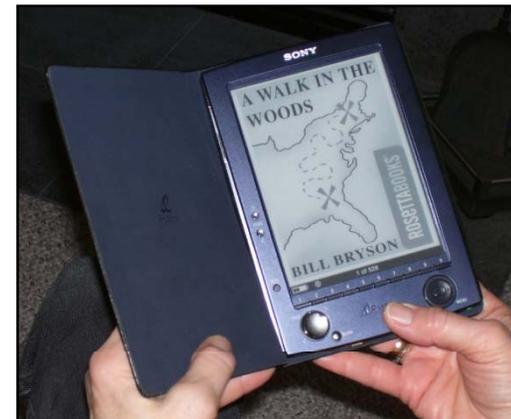
Why I Use My Personal E Book



~300 books



~1000 books
with 1G SD Card



Readers are Getting Bigger

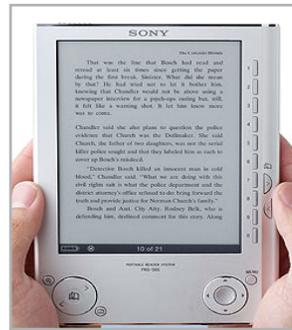
amazon.com.



Almost 40 Electronic Readers Now In Production



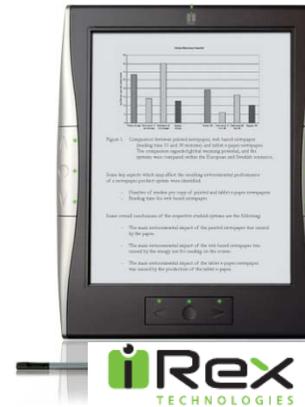
amazon.com



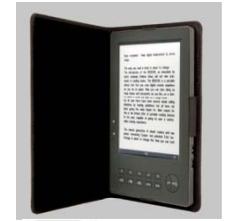
SONY



ASTAK



iRex
TECHNOLOGIES



EE BOOK



eSlick Reader
save money to buy more e-books

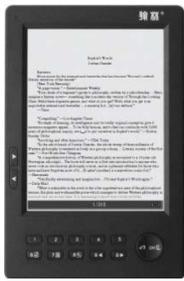


STARBOOKSTORE
www.starbookstore.com.cn

• Broad availability now (hardware and language content) in US, Europe, Japan, Korea, Taiwan, and China.



Les Echos
Newspaper



Jinke Hanlin
南開津科
CREATIVE & WEALTHY



CYBOOK
the neverending book

Bookeen

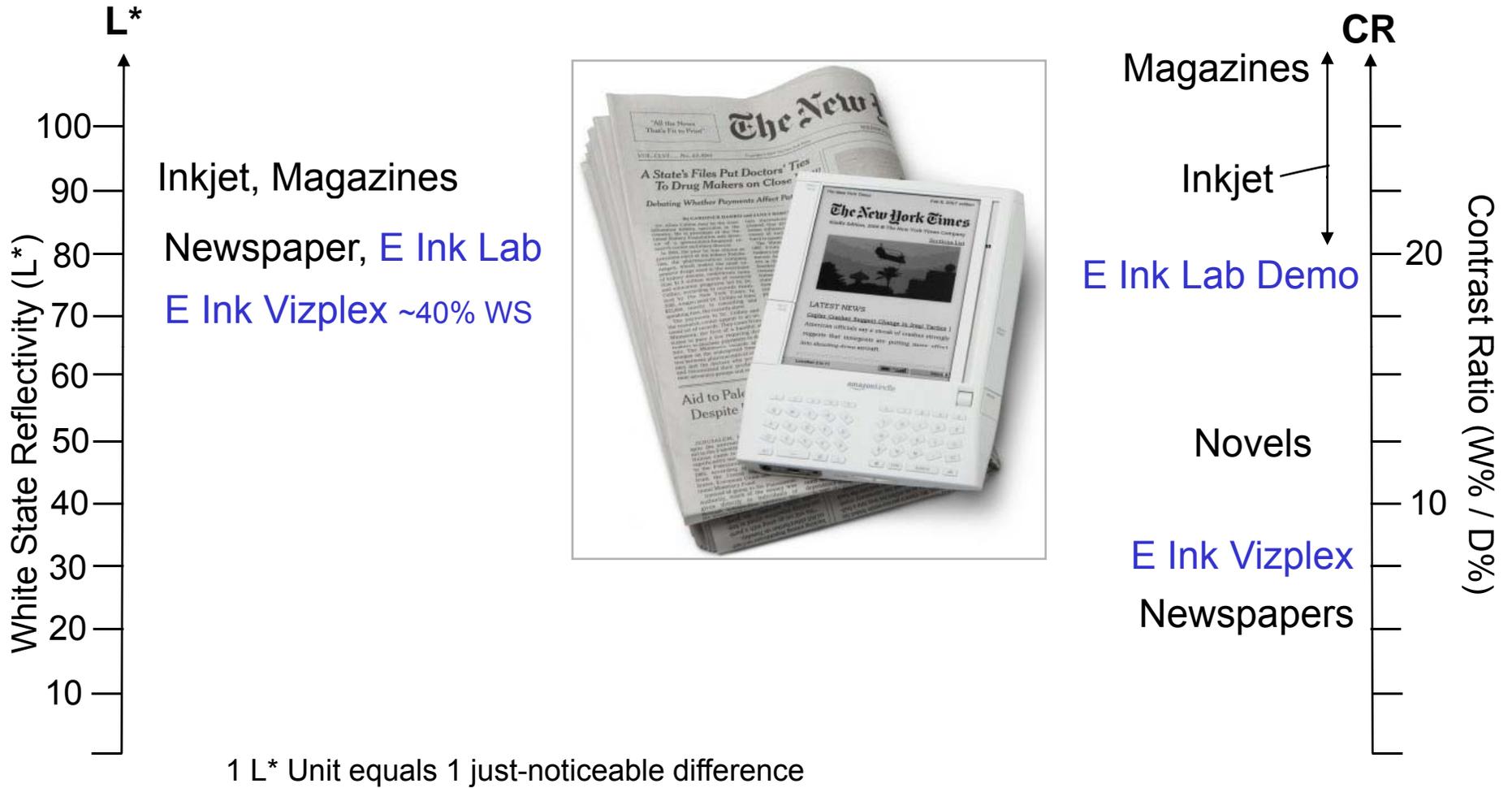


INTERREAD

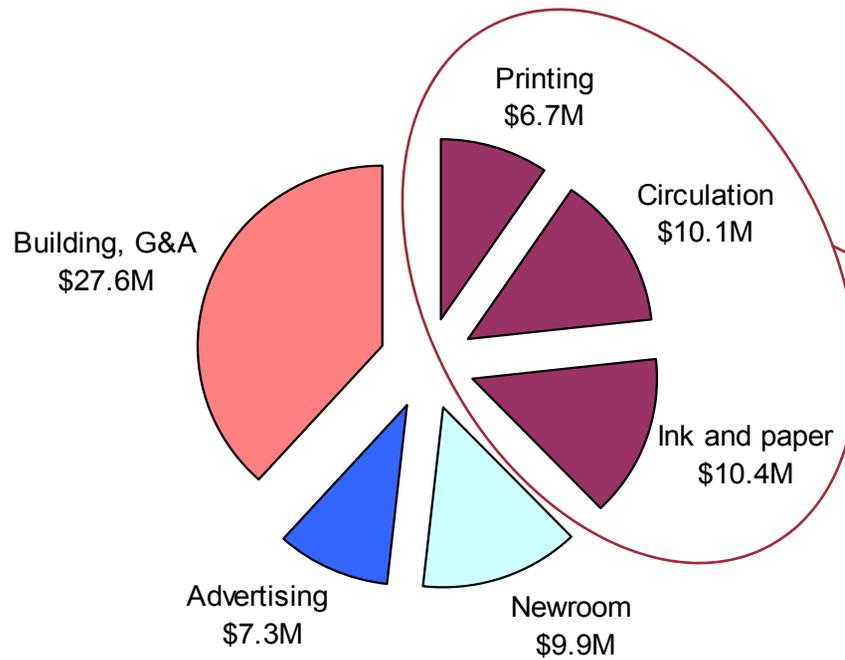


Neolux

E Ink Vizplex Has Better Contrast than Newspapers



Economic Reasons to Move From Paper Newspapers



- Newspapers could eliminate \$27M (~38%) from its variable budget by moving away from printed newspapers
- But it will be critical to keep subscriptions and advertising rates high with electronic newspapers

Composite Newspaper Business Profile*

100,000 Circulation
\$83.9M Revenue
\$72.1M Total Cost
~10% Profit

*Published by Bill Richards (former NY Times and Washington Post reporter)



“Electronic Newspapers” are Green

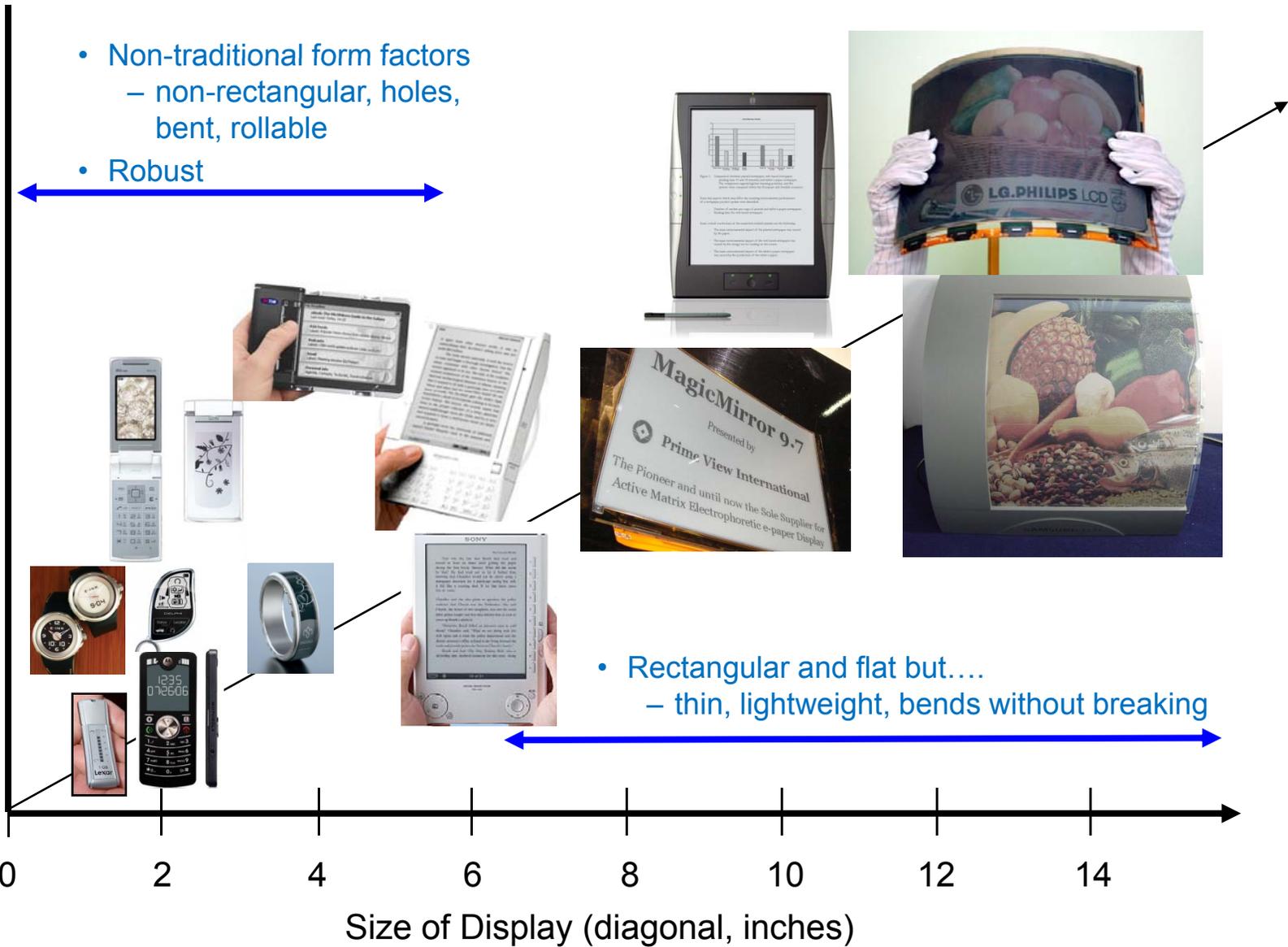


Paper Newspapers Are Resource Intensive



Market Drivers for E Ink Flex Displays

- Non-traditional form factors
 - non-rectangular, holes, bent, rollable
- Robust



EPD Flex Display Robustness



Flexible Display Center at
Arizona State University

- Robust EPD TFT displays utilize flexible stainless steel backplanes with plastic E Ink frontplane



General Dynamics Mission
Briefing Demonstrator



In Hand Ruggedized PDA
for Future Force Warrior

Flexible E Ink Demonstrators

	Substrate	TFT	Patterning	Year
Lucent	Plastic	Polymer	Printed	2000
E Ink	Steel	a-Si	Photolith	2002
PolymerVision	Plastic	Polymer	Photolith	2004
Plastic Logic	Plastic	Polymer	Printed	2004
Seiko Epson	Plastic	LTPS	Photolith	2005
LG Displays	Steel	a-Si	Photolith	2005
Toppan	Plastic	Oxide	Photolith	2006
Samsung	Plastic	a-Si	Photolith	2007
PVI	Plastic	a-Si	Photolith	2007
HP/ASU	Plastic	a-Si	Printing	2008

Nearer Term Flex Technology

Category/Company	Diag (in.)	Pixels (color subpix)	Substrate	AMTFT	Image
Spin on Plastic Substrate					
PVI (EPLAR)	6	768 x 1280	Plastic	a-Si	
(B&W + Color)	9.7		Plastic	a-Si	
Large Area					
LGD (B&W + Color)	14	1600 x 2650	Metal (SS)	a-Si	
Printed-TFT Large Area Displays					
Plastic Logic	10	900 x 1200	Plastic	Organic	
Rollable Display Prod. Shown					
Polymer Vision (B&W + Color)	5	240 x 320	Plastic	Organic	

Longer Term Flex Research Partnerships

Category/Company	Diag (in.)	Pixels (color subpix)	Substrate	AMTFT	Image
Large Area Samsung Electronics (B&W + Color)	14.3	1500 x 2120	Plastic	Organic a-Si	
High Resolution Display (SUFTLA) Seiko Epson (397 ppi, drivers, color)	6.4 6.7	1536 x 2048 1200 x 1600	Plastic Plastic	Poly-Si Poly-Si	
Printed Inorganic Electronics Toppan (B&W + Color)	1.0	60 x 80	Plastic	a-InGaZnO	
Roll to Roll Backplanes Hewlett Packard	1.8	24 x 38	Plastic	a-Si	
Solution Process on Plastic	3.5	120 x 160	Plastic	Organic	
Additive Printed Org Electronics Xerox PARC	6	480 x 480	Plastic	Organic	
Low Temp Process Electronics ASU FDC (B&W + Color)	3.7	240 x 320	(Metal SS)	a-Si	

PVI Flex Displays: EPLaR Process



- Multiple Sizes, 9.7 in. Shown here

LG Philips Flexible 14 in. Si TFT on Stainless Steel

- Flexible AM EPD (A4, 14 in. active area)
- Conventional a-Si:H processes on stainless steel substrate were used to fabricate the display
 - Mono and Color 1280 X 800 Pixels (WXGA)
 - 235.5 μ m Pixels (108 ppi)
 - 301.4 mm X 188.5 mm
 - Monochrome (4 bits, 16 Gray Levels)



Plastic Logic Factory in Dresden

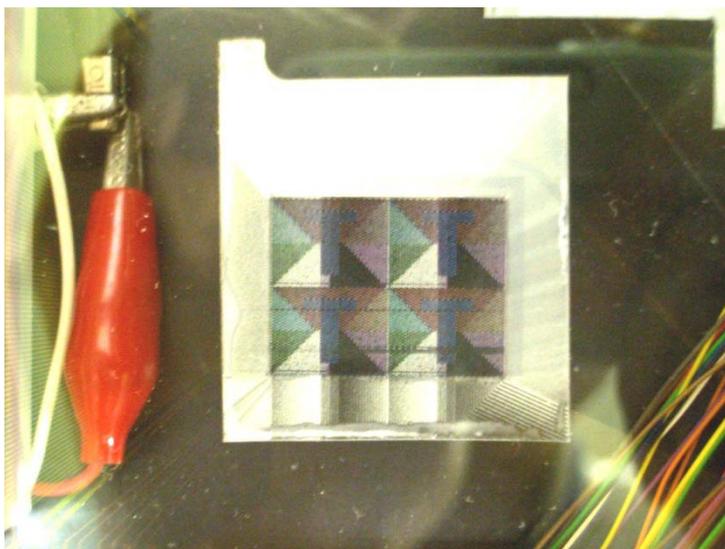


- 8.5" x 11" size and ultra-thin profile
- Mass production 2009
- Printed, organic TFT, plastic backplane



Toppan Printing: Flexible Inorganic TFT on Plastic

- Amorphous Oxide TFT Array: α -InGaZnO 2" display, 80x60 pixels, fabricated at room temperature
 - Mobility $> 5 \text{ cm}^2/\text{V sec}$, On-off ratio $> 10^6$
- World's first Color Electronic Paper driven by amorphous Oxide TFT α -InGaZnO 1" display, 80x60 pixels (IDW 2006)
 - Novel Structure: Color filter upon transparent TFT array
- Applying printing techniques for efficient fabrication

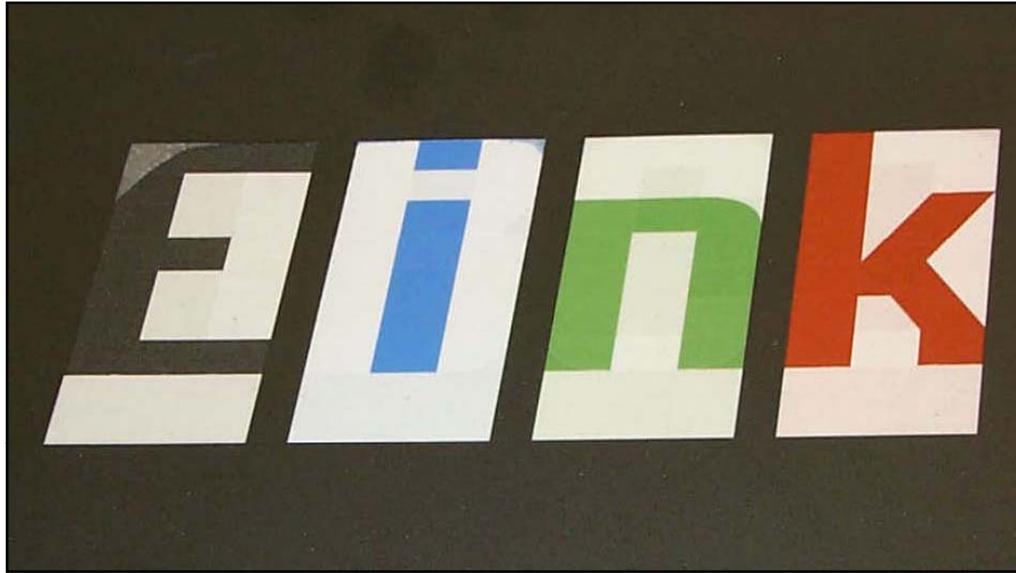


Electronic Paper Prototype



Color Electronic Paper Prototype

Color Without CFA (colored pigments)



- Black / white pigments
- blue / white pigments
- green / white pigments
- red / white pigments

Full Color Displays Have Been Demonstrated



- RGBW Color filter array is placed over a high contrast B&W ink
- Reflective, no front light or backlight
- 18:1 CR
- 12 bit color (4096 colors)
- SVGA glass TFT (600X800 total pixels)
- 2 frames per second



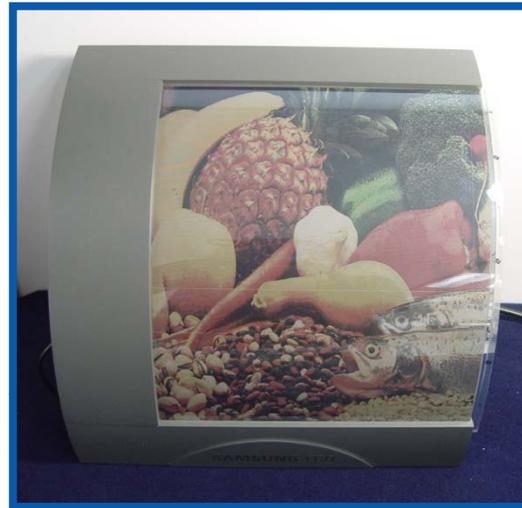
Color E Ink EP Flex Displays

LG Display



- 14.3 in.
- 1600 x 2560 subpixels
- a-Si Stainless steel backplane

Samsung



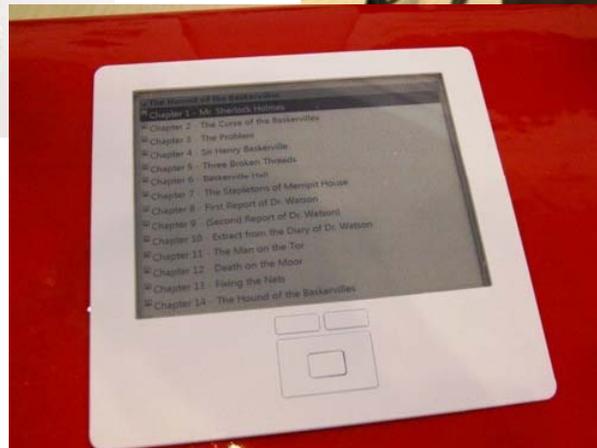
- 14.3 in.
- 1500 x 2120 subpixels
- Plastic backplane

Polymer Vision

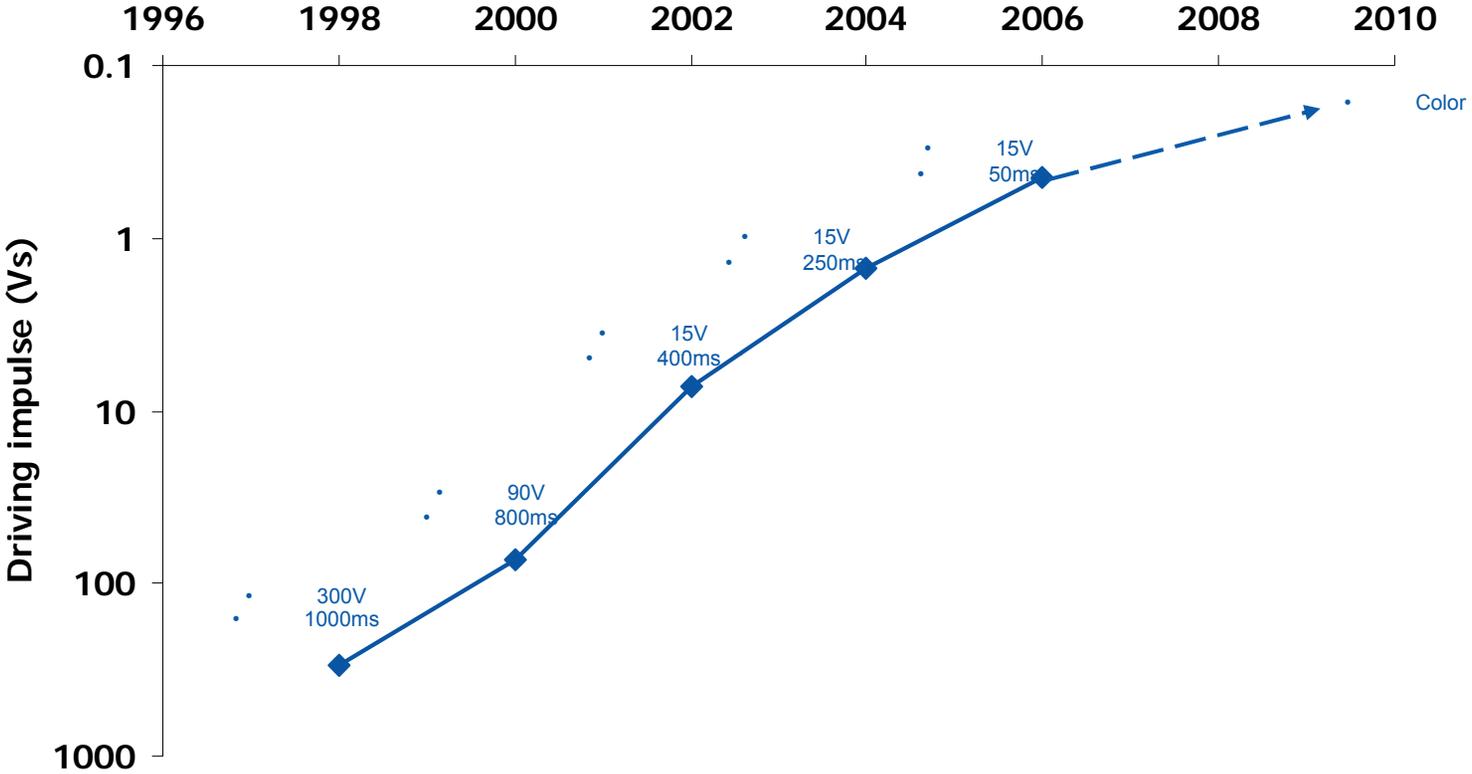
- World's first rollable color display
- 3.5 in.
- 400 x 1000 subpixels
- 127 ppi color resolution (264 ppi TFT resolution)



Intel Developers Forum Beijing, WinHEC Taiwan: Vista SideShow Notebook (Intel, Microsoft)

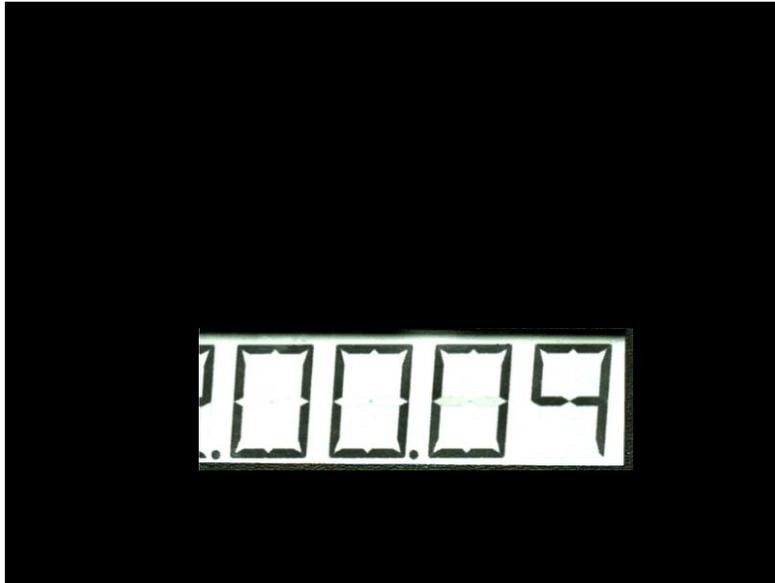


Advanced Ink Research Demonstrations



•Doubling Speed/Volt Every 18 Months

Faster Inks Demonstrated



Filmed Real Time

Clock is shown down to hundredth of second intervals



Filmed in Slow Motion
~ 1/30 speed

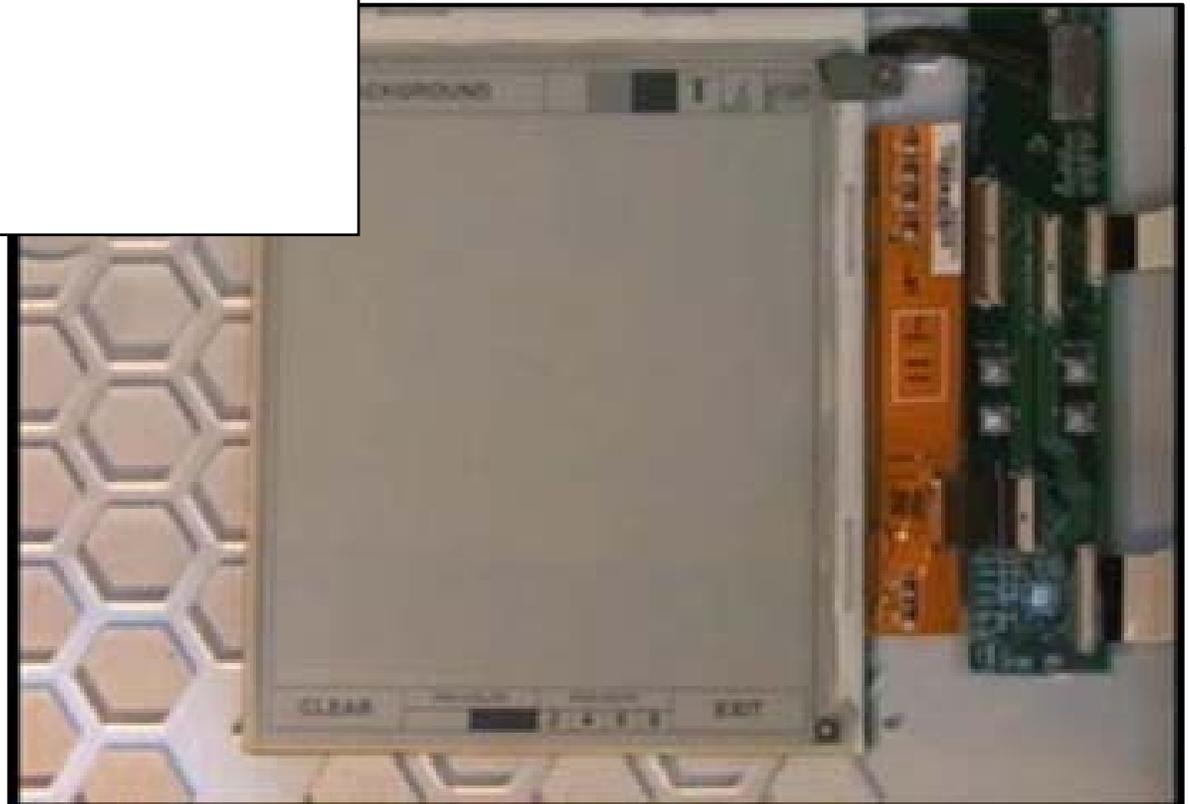
Ink	WS %	CR	Pulse (ms)
Control	36	5.6 :1	500
Research Ink	47	10.2 :1	250
Research Ink	38	9.4 :1	50

- Pulse length is 33 ms (~30 fps), $\pm 15V$
- Image stable, microencapsulated electrophoretic ink — segmented display
- 1 bit only, current multibit gray scale waveforms would take 2x longer

Touchscreen Capability

Broadsheet controller chip from Epson – E Ink collaboration enables new EPD capabilities

- **Independent addressing of multiple defined display areas**
- **Rapid text input**
- **Rapid menuing**
- **Touchscreen and pen input**



"Video" Rate E Ink Color Display



- Glass AMTFT with CFA
- 600 x 800 total pixels
- Image stable, research ink
- Speed is enabled by proprietary driving methods as well as new ink chemistries

Thank You to E Ink's Partners and Customers

TOPPAN



EPSON®

SONY



Midori Mark



amazon.com.

SmartDisplayer™



PHILIPS



Lexar™

Actel

DELPHI

UPM

intel®

Dialog

Plastic Logic

NEC

Semiconductor



SEIKO



ALPS.



eFlyBook
by ARINC

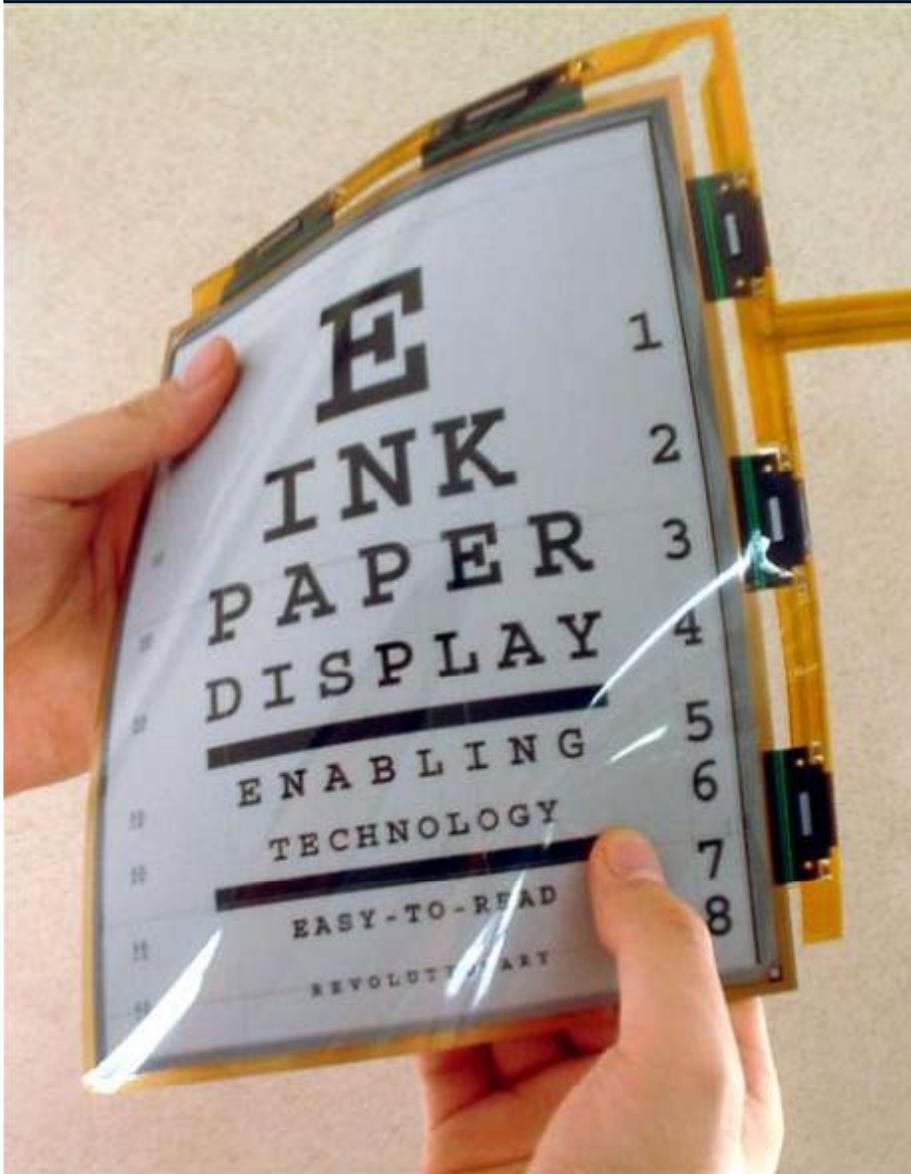


Materials Opportunities For Flexible Displays

- Printable inks for backplanes (inkjet, offset printing, microcontact printing, thermal transfer, etc.)
 - Conductors
 - Dielectrics
 - Semiconductors
- Novel backplane patterning processes/materials
 - Microcontact printing, embossing 3-D patterning, etc.
- Transparent Conductors
 - Organic semiconductors, CNT, nano-ITO, metal “screens”, other
- Flexible CFAs
 - Thermal dye transfer
 - Inkjet printing
 - Photolithography

Summary

- **e-paper is growing quickly to a multi-billion dollar market**
 - Electronic books have gained acceptance and momentum
 - Segmented applications continue to expand
- **Electrophoretic displays are leading the way in this e-paper growth**
 - Daylight readability, low power consumption, excellent viewing angle
- **Electronic publishing utilizing glass TFTs electrophoretic displays will soon have the option of flexible TFT electrophoretic displays for these applications**
 - electronic readers and newspapers will be thinner and lighter as a result
- **Next generation E Ink EPD technology continues to advance**
 - Higher performance inks (reflectivity and contrast ratio)
 - Full color electrophoretic displays
 - Near video rate displays
- **The e-paper “ecosystem” is providing opportunities for multiple companies to share in the materials and hardware business growth**



Thank You



E Ink at a Glance



- Founded in 1997 from the MIT Media Lab
- >150 employees worldwide (*and growing!*)
- ***Industry Leading Supplier of Electronic Paper Displays***
 - Scalable active segmented & matrix electronic paper displays solutions
- ***Multiple High Volume Designs in Production Today***
 - Sony, Motorola, Samsung, Amazon, Lexar, Citizen, Seiko-Epson, Casio-Hitachi
- ***High Profile Investors***
 - Intel, Hearst, Philips, Toppan, Printing, Air Products

E Ink Has Proven Mass Production

- Mass production across the globe



- More than 10 million displays (AM and Segmented) shipped
 - Multiple customers have done more than 500,000 units
- Support for international manufacturing standards
 - RoHS compliance
 - Sony Green
- Manufacturing capability
 - Dual Source: FPL production in US and Asia
 - E Ink University teaches six sigma, SPC, lean manufacturing, Five-S
 - » Over 20% of staff has green belt or black belt training