

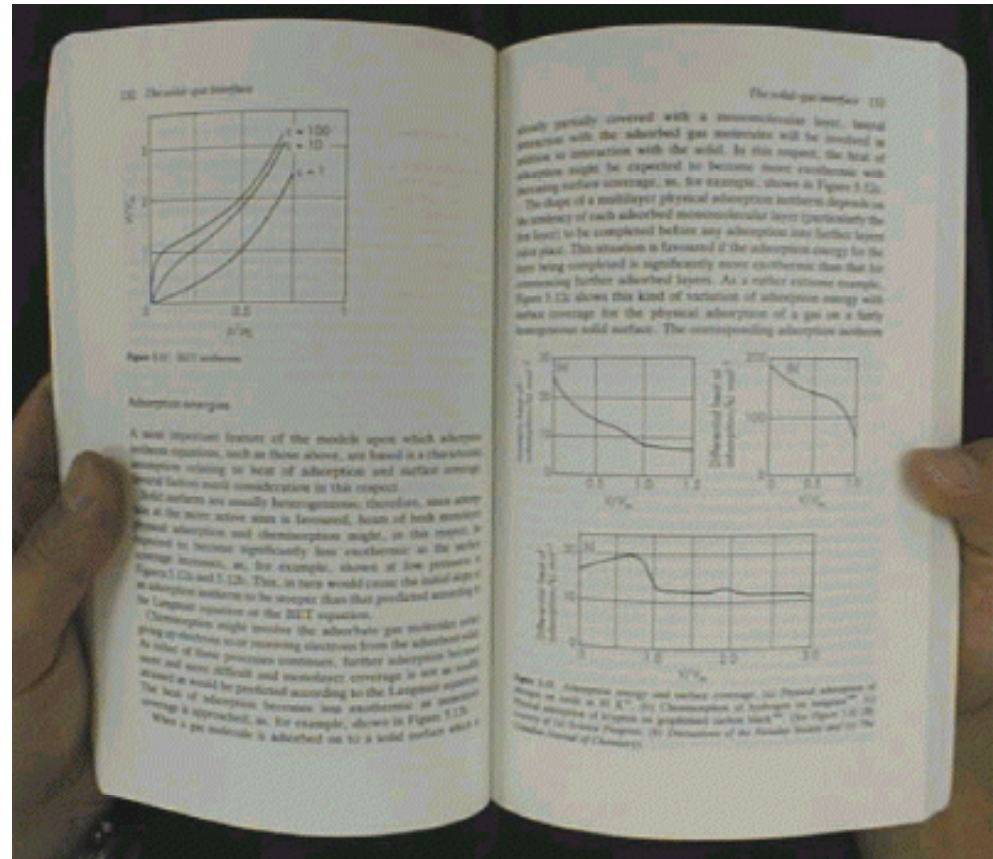
## Electronic Paper Comes of Age Dr. Michael McCreary VP Research and Advanced Development E Ink Corporation

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

September 22, 2009

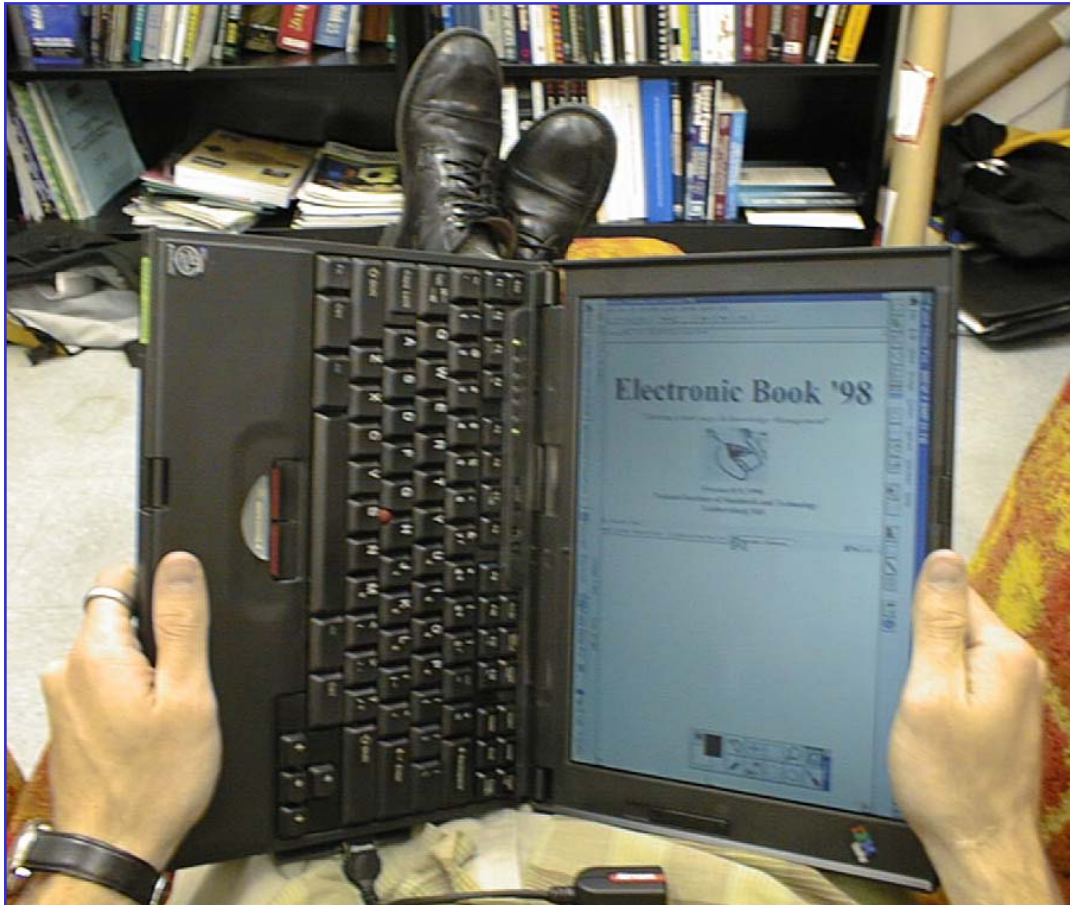
# Paper, the Historical Favorite

- 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.*

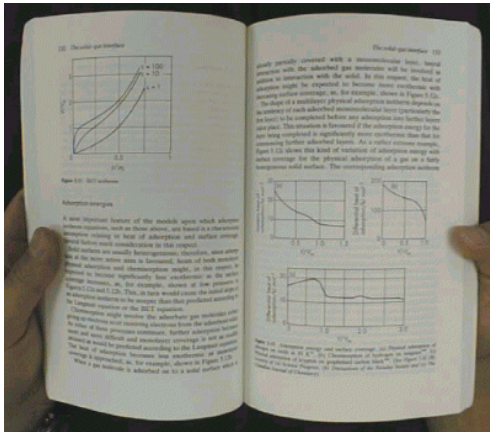
## *LCD/Computers are not “Electronic Books”*



- 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

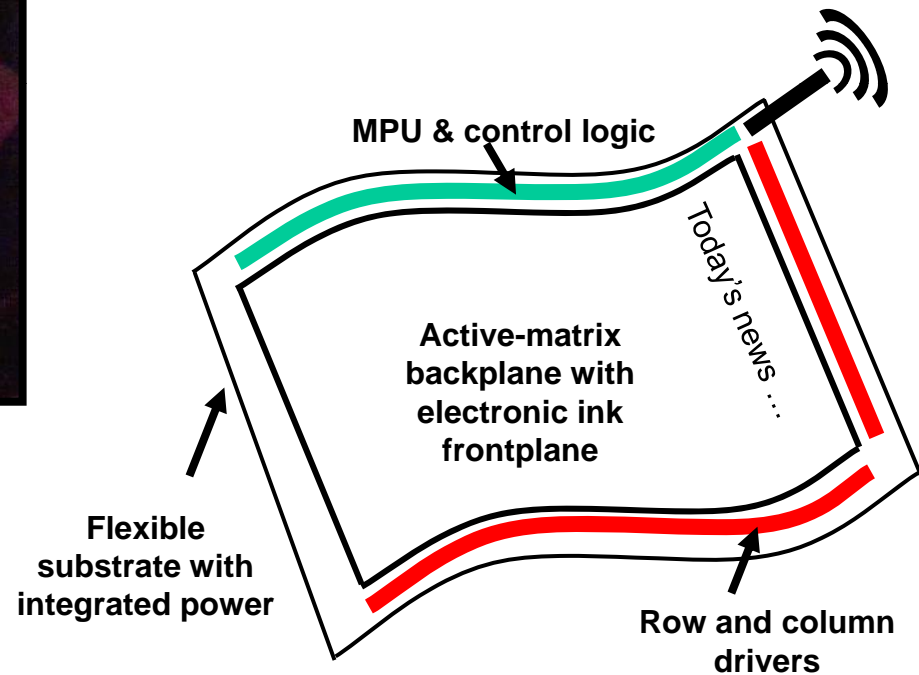


# *The Vision: Radio Paper™*



Photo from IBM

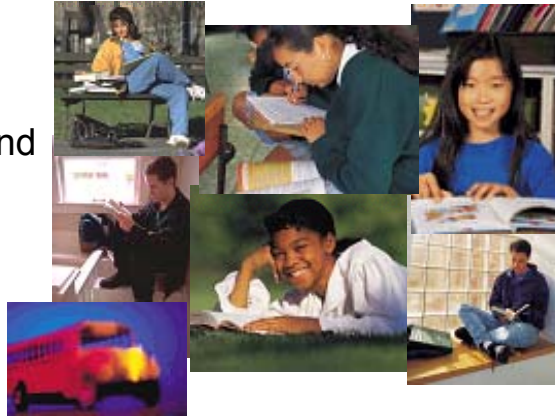
- Flexible
- Large format
- Wireless updates



# *Market for Electronic Readers*

## **Education**

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



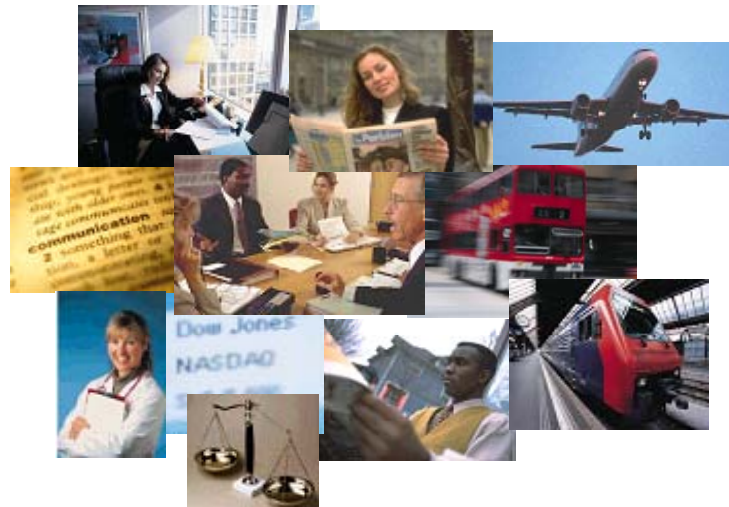
## **Consumer**

- 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**

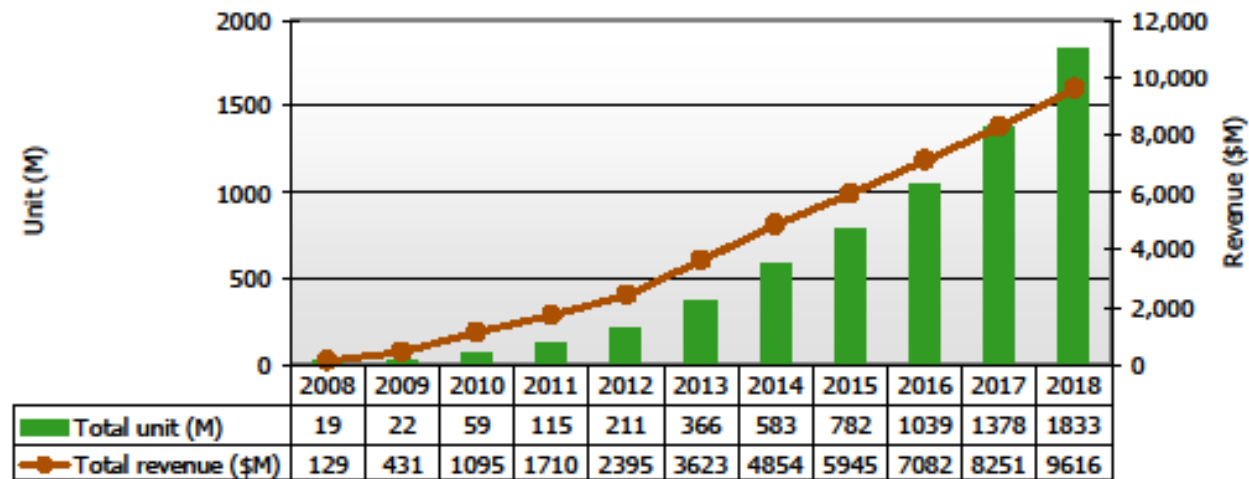
- Gov't
- Military
- Mapping
- Religious



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

# Total E-Paper Display Market Forecast

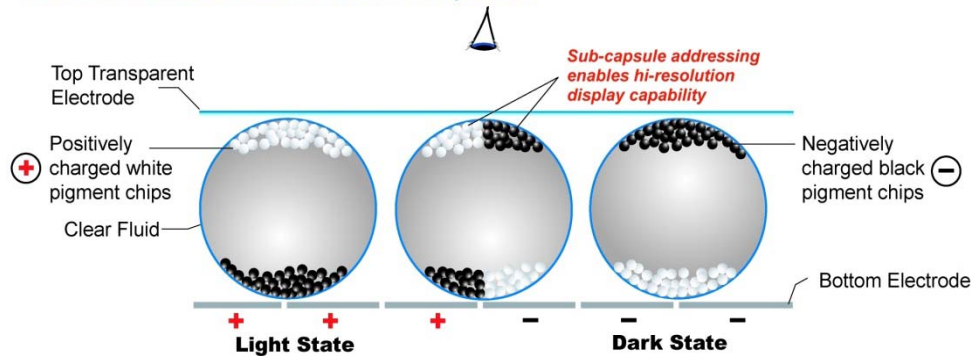
- 22M e-paper displays will be shipped this year; 1.8 billion units forecast in 2018
- Total e-paper displays revenue will reach \$9.6 billion in 2018 from \$431 million in 2009, for a CAGR of 41%.
- Electrophoretic (e-books) will lead revenues
- Electrochromic (smart card and smart label) will lead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



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

# Electrophoretic Ink Enables Electronic Paper

Cross-Section of Electronic-Ink Microcapsules

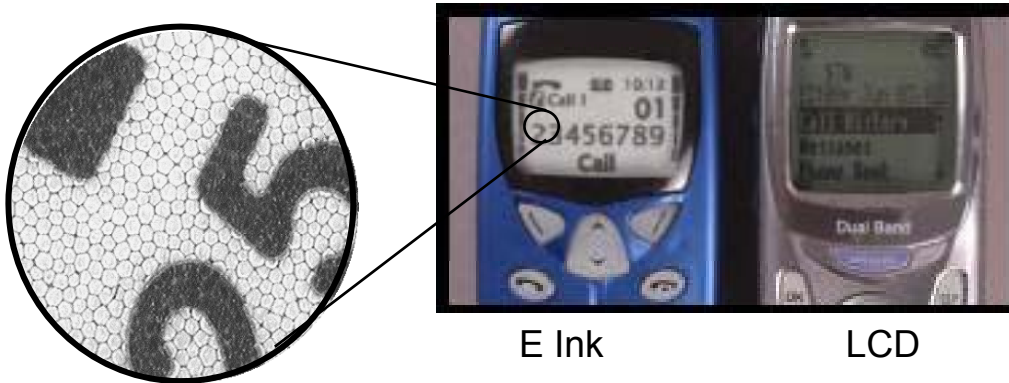


Note: For illustration purposes only - not drawn to scale. Copyright E Ink, 2003.

E INK

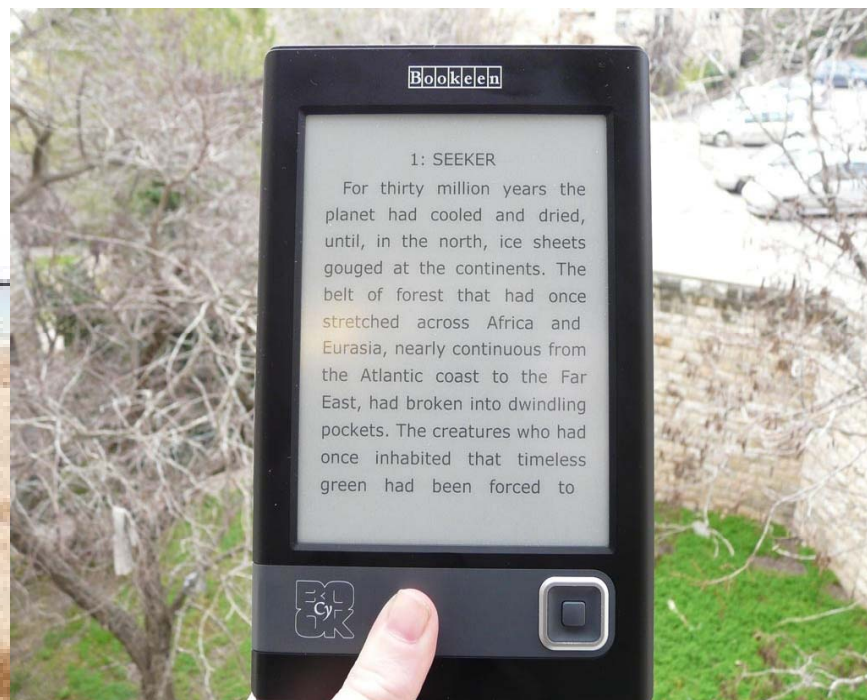
E Ink display technology is based on microencapsulated oppositely charged colored particles that move in an electric field

- Paper-like look
  - sunlight and room light readable
  - viewing / lighting angle independent
- Ultra low power
  - no power to maintain image
- Scaleable 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

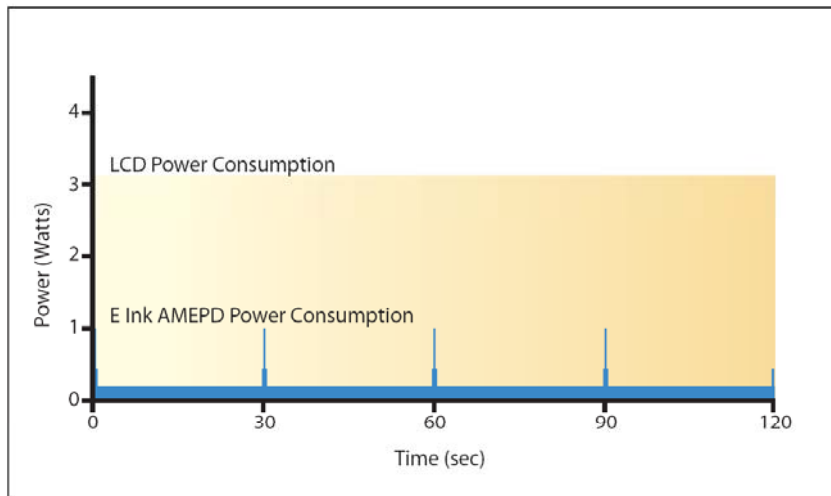
# Low Power

12" LCD for 20 hrs = 36



2.5 pounds

LCD vs E Ink Active Matrix Display System  
Power Consumption Comparison



E Ink = 1

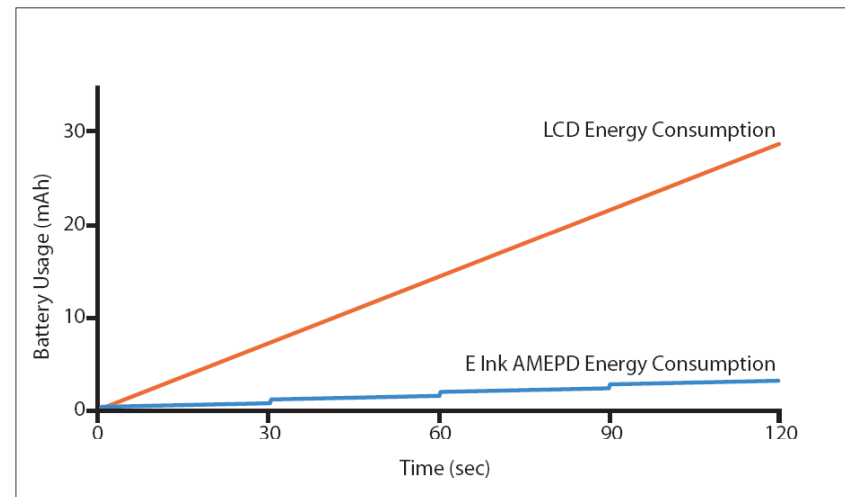


1 ounce!

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

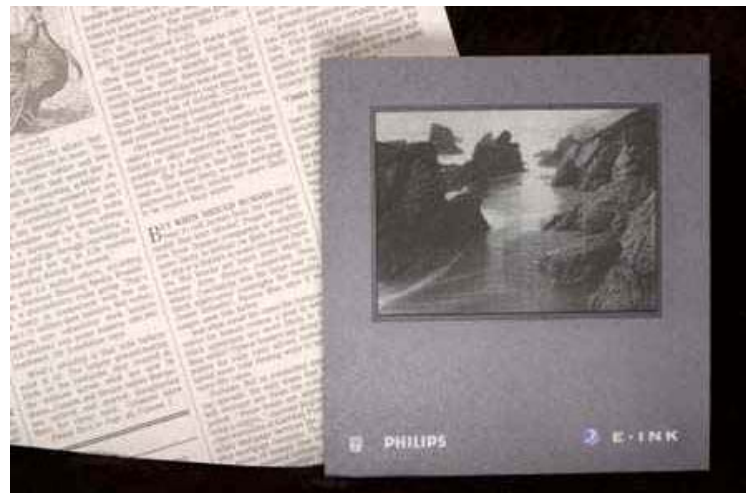


LCD vs E Ink Active Matrix Display System  
Cumulative Current Consumption Comparison

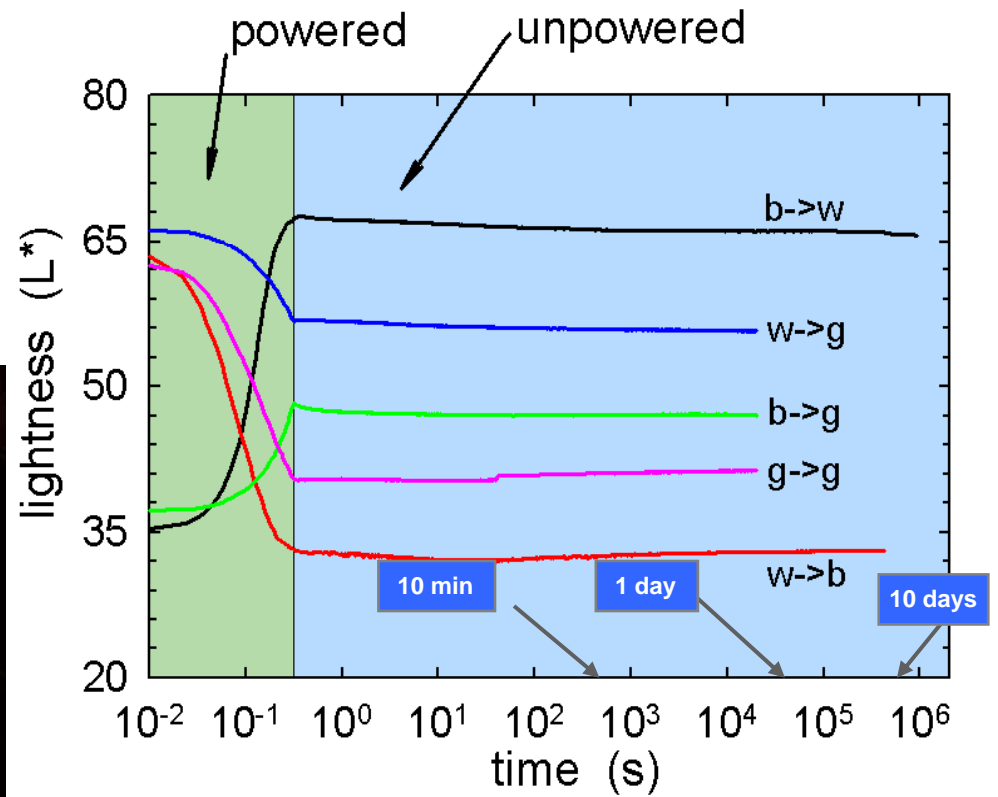


Assuming single cell Li-Ion battery at 3.8v.

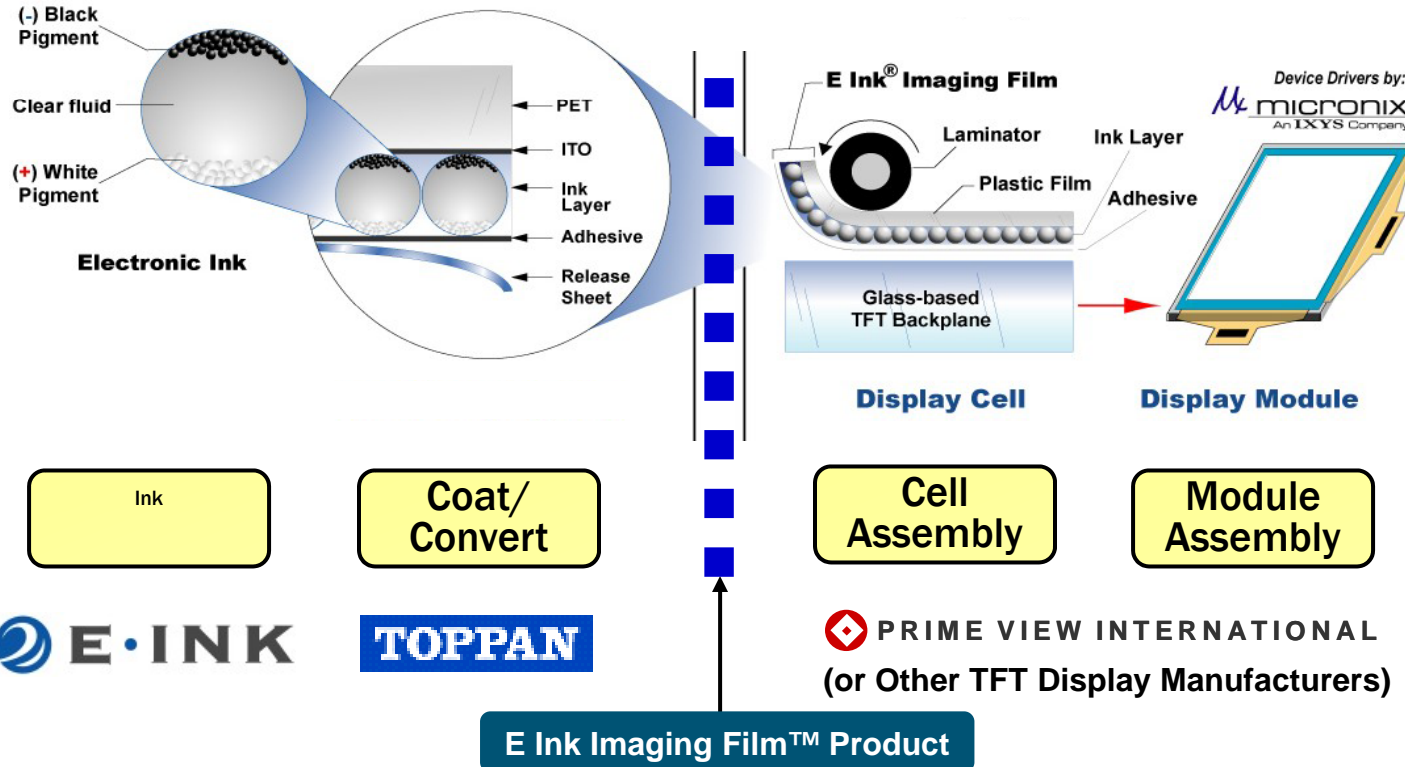
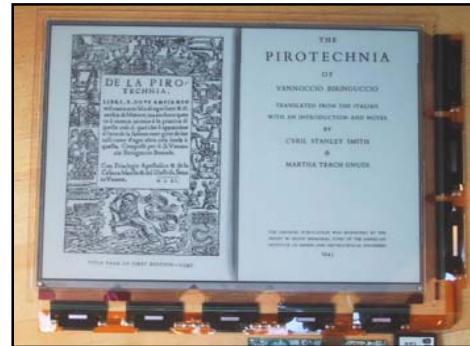
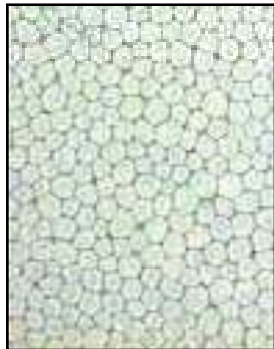
# Grayscale Active-Matrix Displays



*electronic ink on active matrix panels*



# Typical Active Matrix Supply Chain





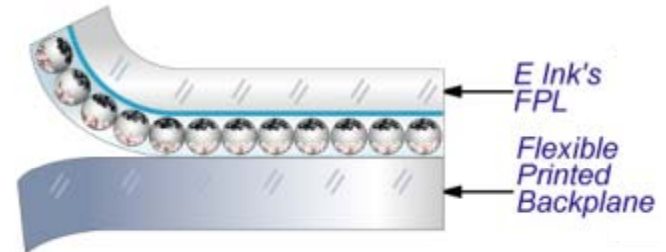
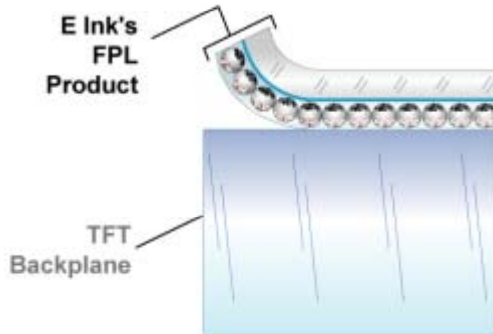
# Two Product Lines



**High-Resolution  
Active Matrix Displays**

**Low-Resolution  
Segmented Displays**

**E·INK**  
**VIZPLEX**  
IMAGING FILM



Display modules supplied by:  
**PRIME VIEW INTERNATIONAL**



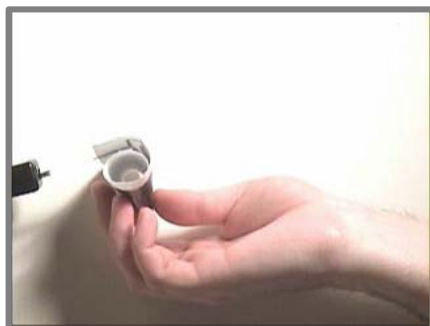
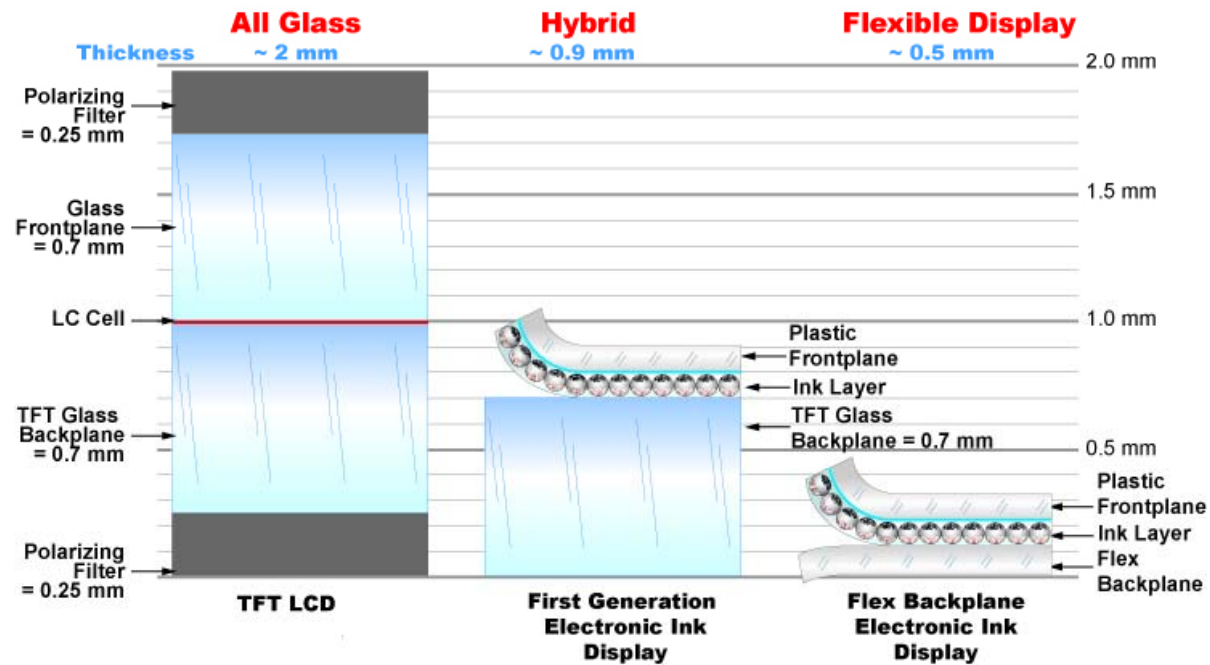
**LG Display**

**E·INK**

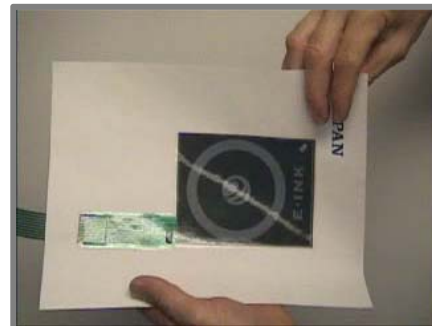


**E·INK**

# Electronic Ink Front Plane Laminate



Cloth



Paper



Tyvek®



Thin Plastic

# Millions of Products With E Ink Plastic Displays Have Been Sold

## Cellphones



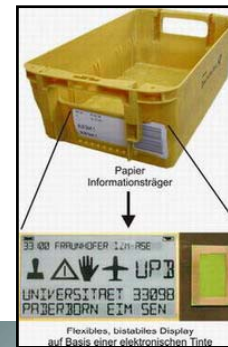
## Indicators



## 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

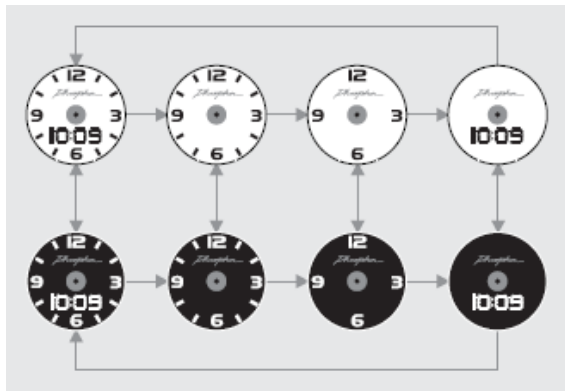


# Watches

phosphor™



SEIKO



# Labels & Signs



Electronic Shelf Labels

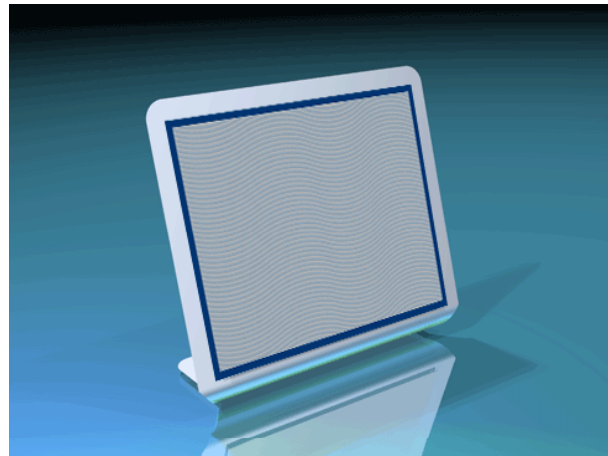
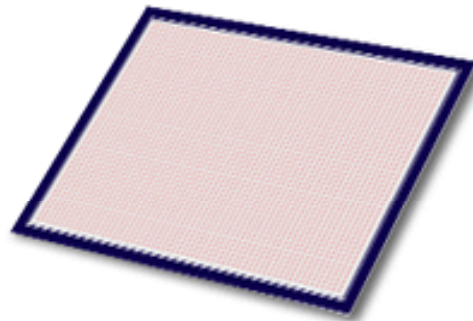
Large Area Signs



# Advertising/Promotional all-Plastic Displays



[www.neoluxiim.com](http://www.neoluxiim.com)



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





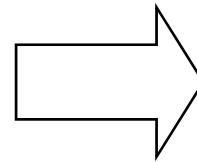
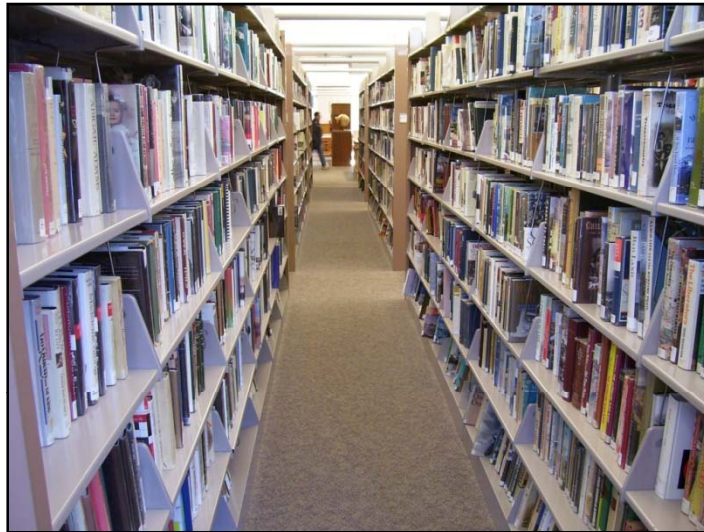
# *Esquire Magazine – 75<sup>th</sup> Anniversary Issue*

- 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





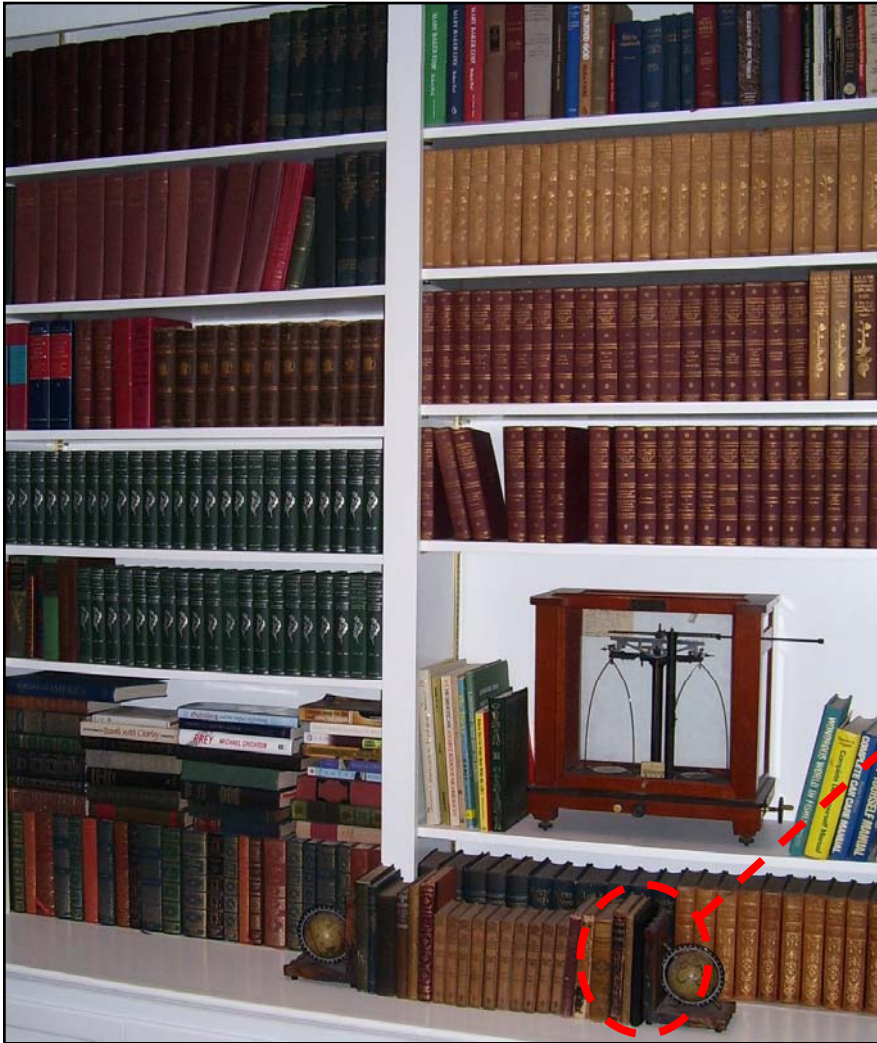
# *Electronic Publishing is a Multi-\$B Addressable Market*



- **\$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**

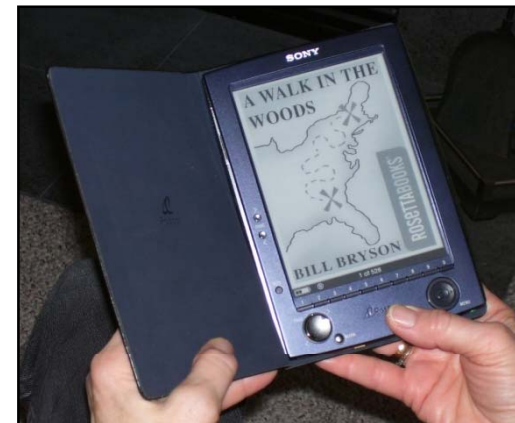
# *Why I Use My Personal E Book*



~300 books



~1000 books  
with 1G SD Card



# *Readers are Getting Bigger*

amazon.com.

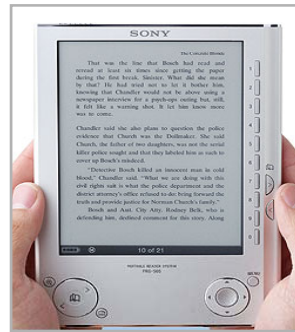




# Almost 40 Electronic Readers Now In Production



amazon.com



SONY



ASTAK



BE BOOK



eSlick Reader  
save money to buy more e-books



STARBOOKSTORE  
www.star-bookstore.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



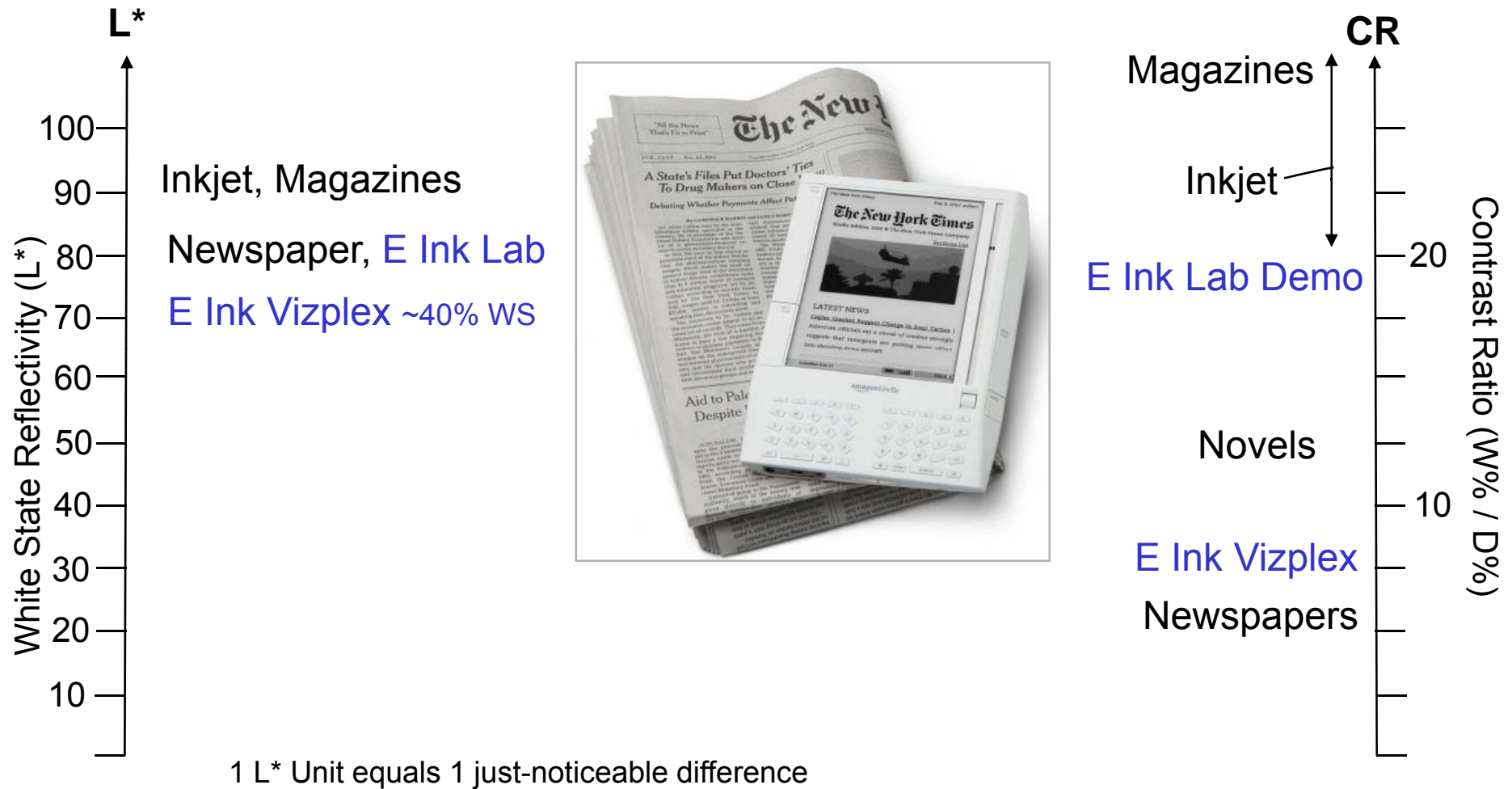
INTERREAD



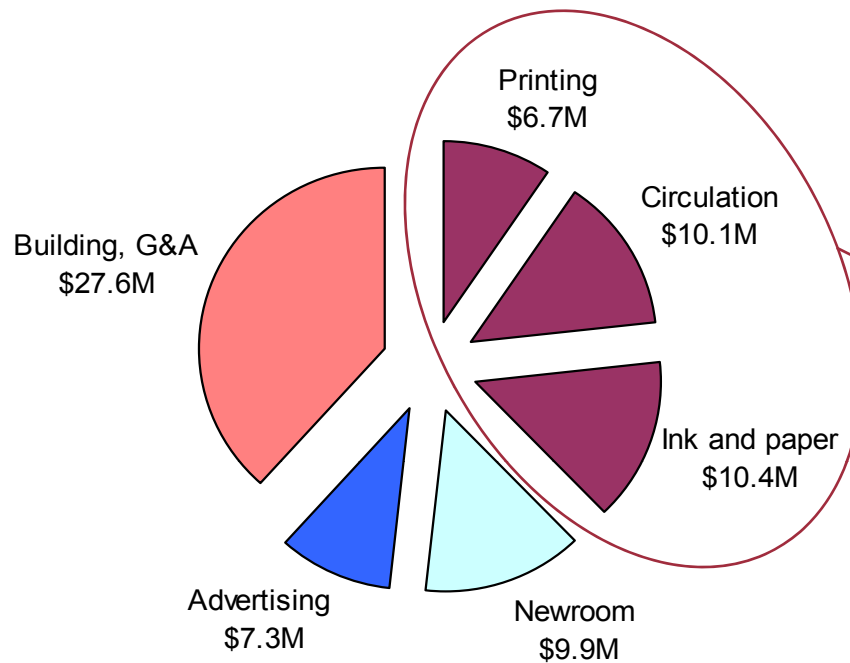
Neolux



# *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

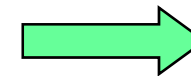
## **Composite Newspaper Business Profile\***

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

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

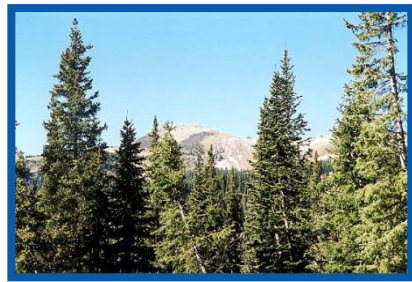


# ***"Electronic Newspapers" are Green***





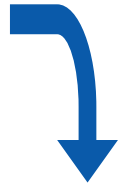
# Paper Newspapers Are Resource Intensive



95 million trees



49M pounds of greenhouse gases



8.7 million tons of paper



126 billion gallons of wastewater



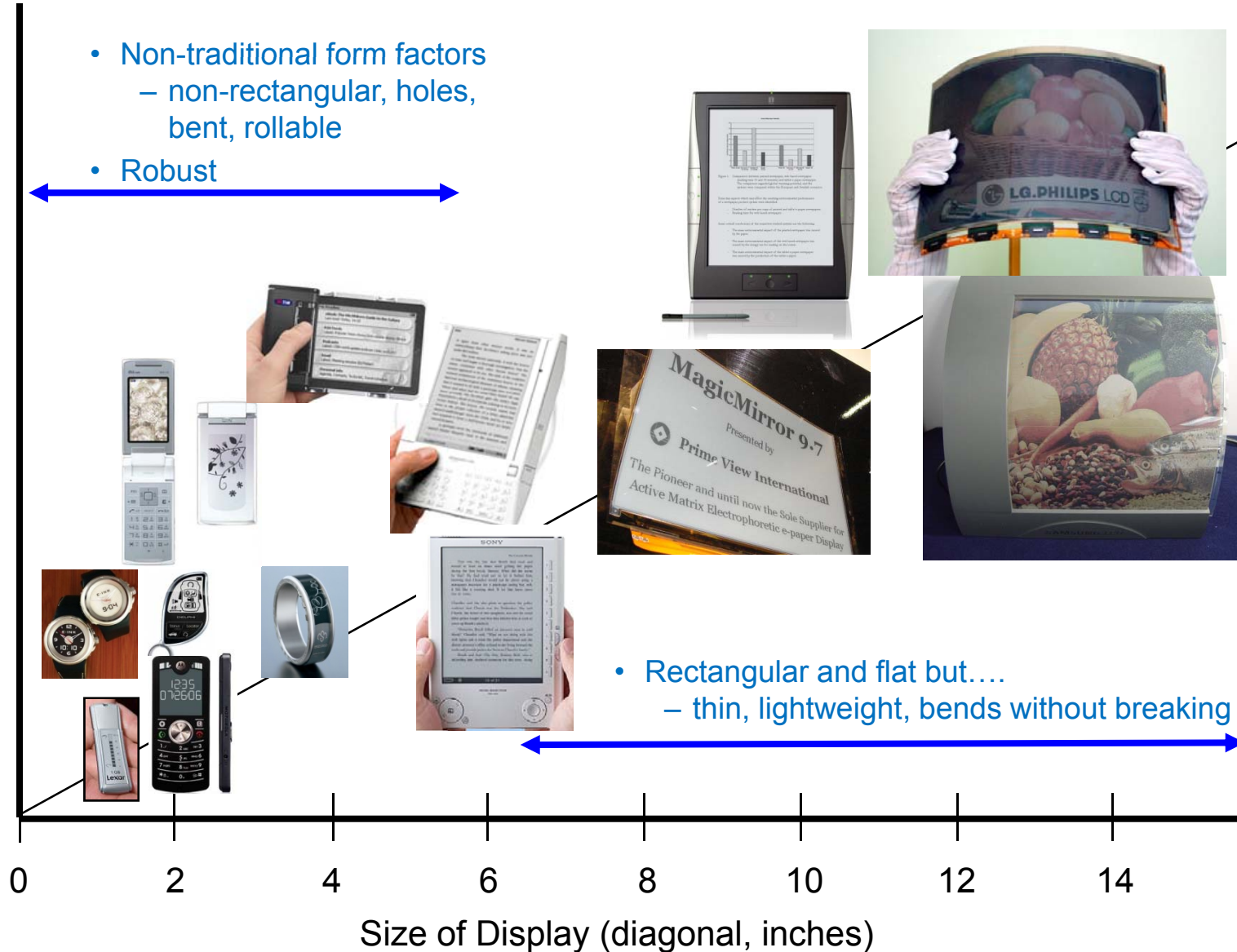
1/5 ton waste per subscription





# 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*


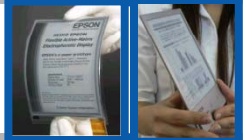
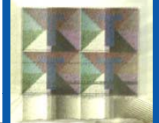




	Substrate	TFT	Patterning	Year
Lucent	Plastic	Polymer	Printed	2000
E Ink	Steel	a-Si	Photolith	2002
PolymerVision	Plastic	Polymer	Photolith	2004
Plastic Logic	Plastic	Polymer	Printed	2004
Seiko Epson	Plastic	LTPS	Photolith	2005
LG Displays	Steel	a-Si	Photolith	2005
Toppan	Plastic	Oxide	Photolith	2006
Samsung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

# Nearer Term Flex Technology

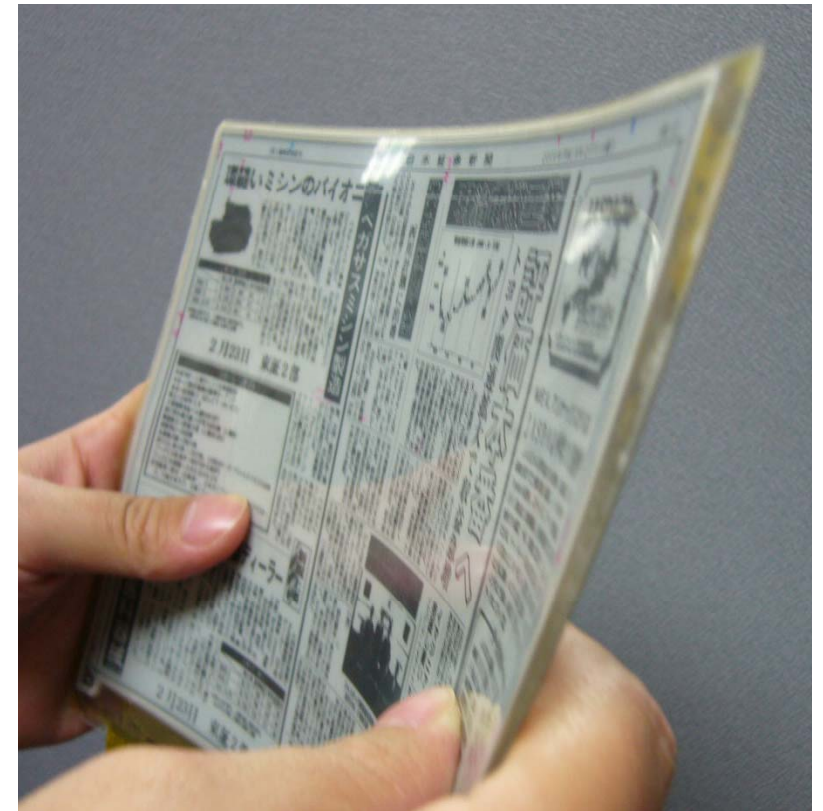
Category/Company	Diag (in.)	Pixels (color subpix)	Substrate	AMTFT	Image
Spin on Plastic Substrate					
PVI (EPLAR)	6	768 x 1280	Plastic	a-Si	
(B&W + Color)	9.7		Plastic	a-Si	
Large Area					
LGD (B&W + Color)	14	1600 x 2650	Metal (SS)	a-Si	
Printed-TFT Large Area Displays					
Plastic Logic	10	900 x 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
<b>Large Area</b> Samsung Electronics (B&W + Color)	14.3	1500 x 2120	Plastic	Organic a-Si	
<b>High Resolution Display (SUFTLA)</b> Seiko Epson (397 ppi, drivers, color)	6.4 6.7	1536 x 2048 1200 x 1600	Plastic Plastic	Poly-Si Poly-Si	
<b>Printed Inorganic Electronics</b> Toppan (B&W + Color)	1.0	60 x 80	Plastic	a-InGaZnO	
<b>Roll to Roll Backplanes</b> Hewlett Packard	1.8	24 x 38	Plastic	a-Si	
<b>Solution Process on Plastic</b>	3.5	120 x 160	Plastic	Organic	
<b>Additive Printed Org Electronics</b> Xerox PARC	6	480 x 480	Plastic	Organic	
<b>Low Temp Process Electronics</b> 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 $\mu$ m Pixels (108 ppi)
  - 301.4 mm X 188.5 mm
  - Monochrome (4 bits, 16 Gray Levels)



# *Plastic Logic Factory in Dresden*



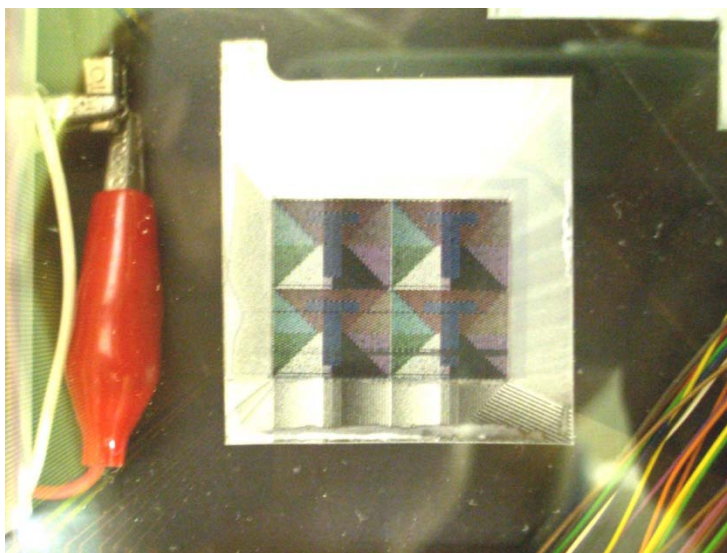
- 8.5" x 11" size and ultra-thin profile
- Mass production 2009
- Printed, organic TFT, plastic backplane





# *Toppan Printing: Flexible Inorganic TFT on Plastic*

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

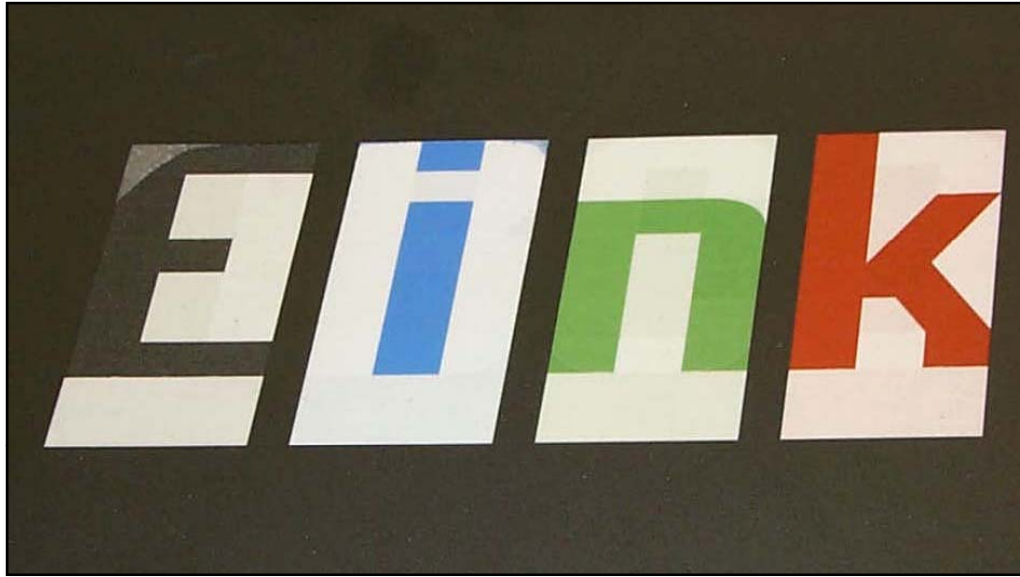


**Electronic Paper Prototype**



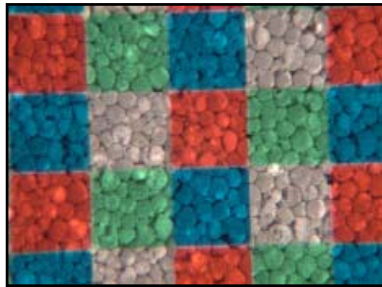
**Color Electronic Paper Prototype**

## *Color Without CFA (colored pigments)*



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

# *Full Color Displays Have Been Demonstrated*



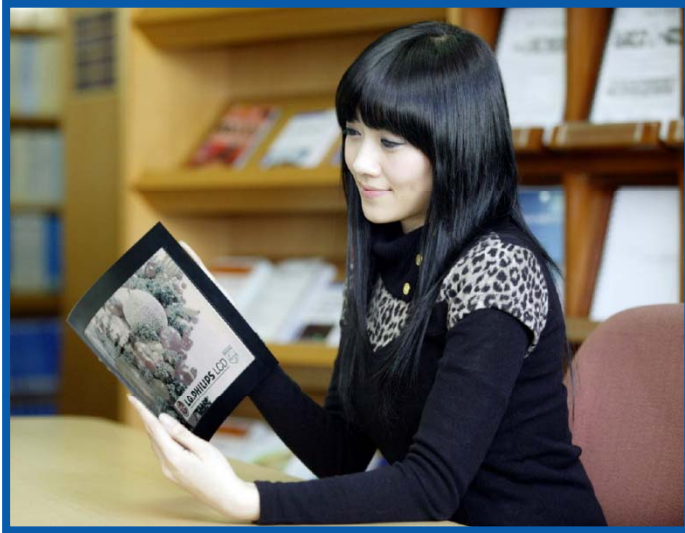
- RGBW Color filter array is placed over a high contrast B&W ink
- Reflective, no front light or backlight
- 18:1 CR
- 12 bit color (4096 colors)
- SVGA glass TFT (600X800 total pixels)
- 2 frames per second





# 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

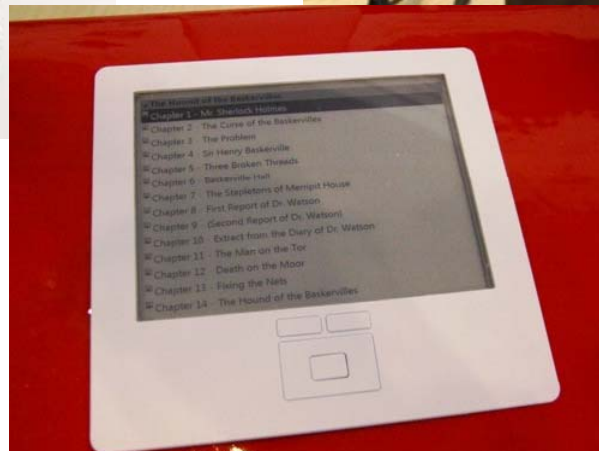
## Polymer Vision

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

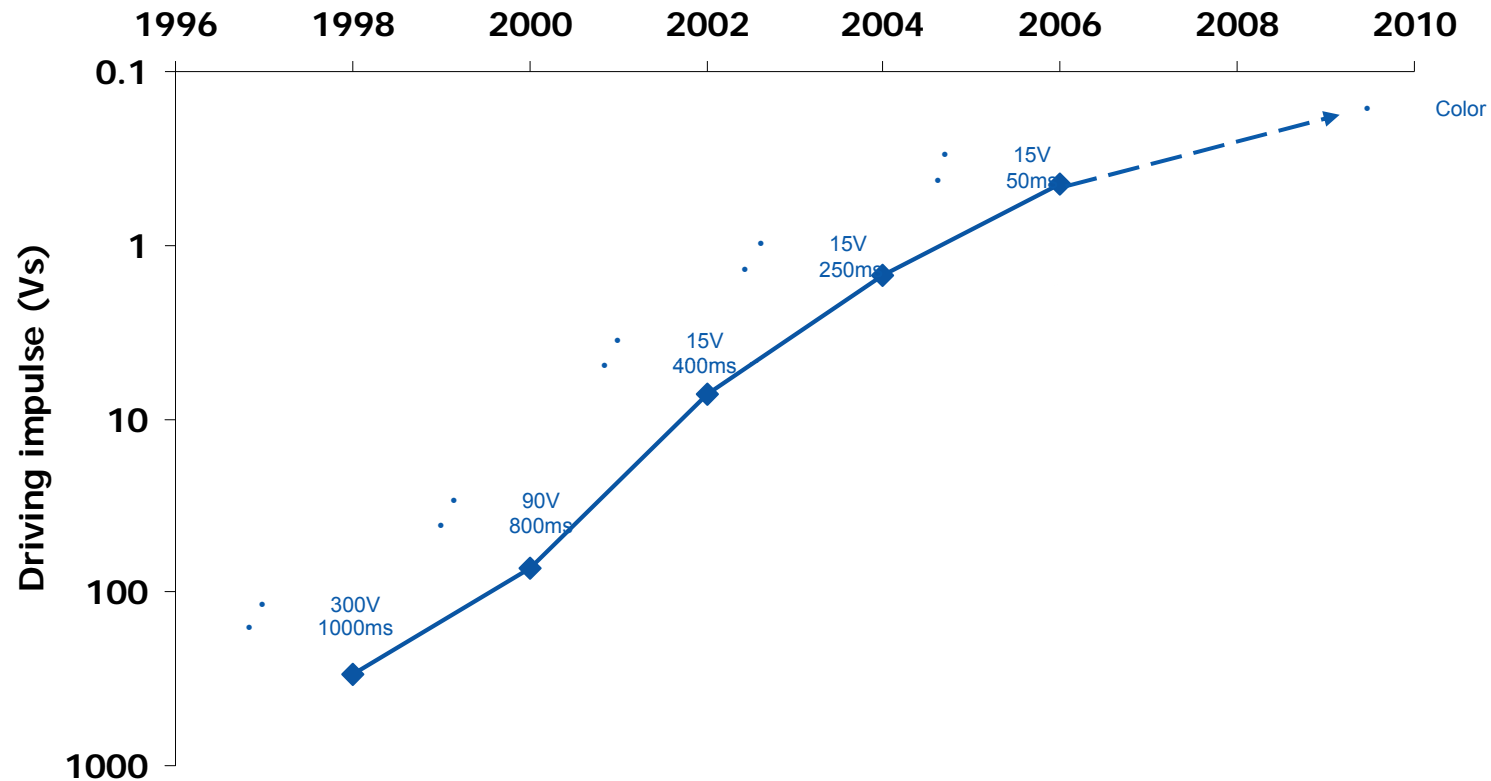




## *Intel Developers Forum Beijing, WinHEC Taiwan: Vista SideShow Notebook (Intel, Microsoft)*

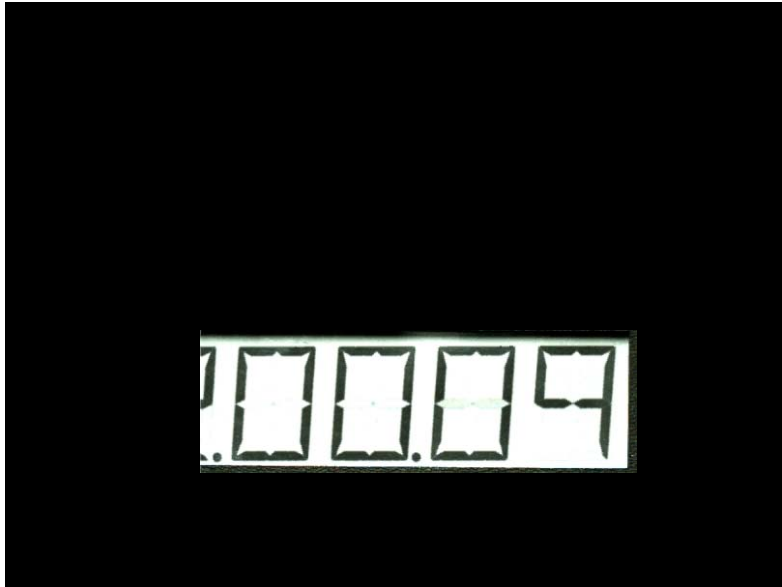


# *Advanced Ink Research Demonstrations*



•Doubling Speed/Volt Every 18 Months

# *Faster Inks Demonstrated*



Filmed Real Time

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

Clock is shown down to  
hundredth of second intervals



Filmed in Slow Motion  
~ 1/30 speed

- 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**

**AIR  
PRODUCTS**



Midori Mark

**iRex**  
TECHNOLOGIES

amazon.com.

**SmartDisplayer™**

**NEOLUX**

**南開津科**  
CREATIVE & WEALTHY

**PHILIPS**



**Lexar™**

**Actel**

**DELPHI**

UPM

**intel®**

**Dialog**  
Semiconductor

**Plastic Logic**

**NEC**



**ALPS®**



**SEIKO**



eFlyBook  
by **ARINC**



**CITIZEN.**

**STARBOOKSTORE**  
www.star-bookstore.com.cn

# *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