Challenges and opportunities for the flexible electronics industry

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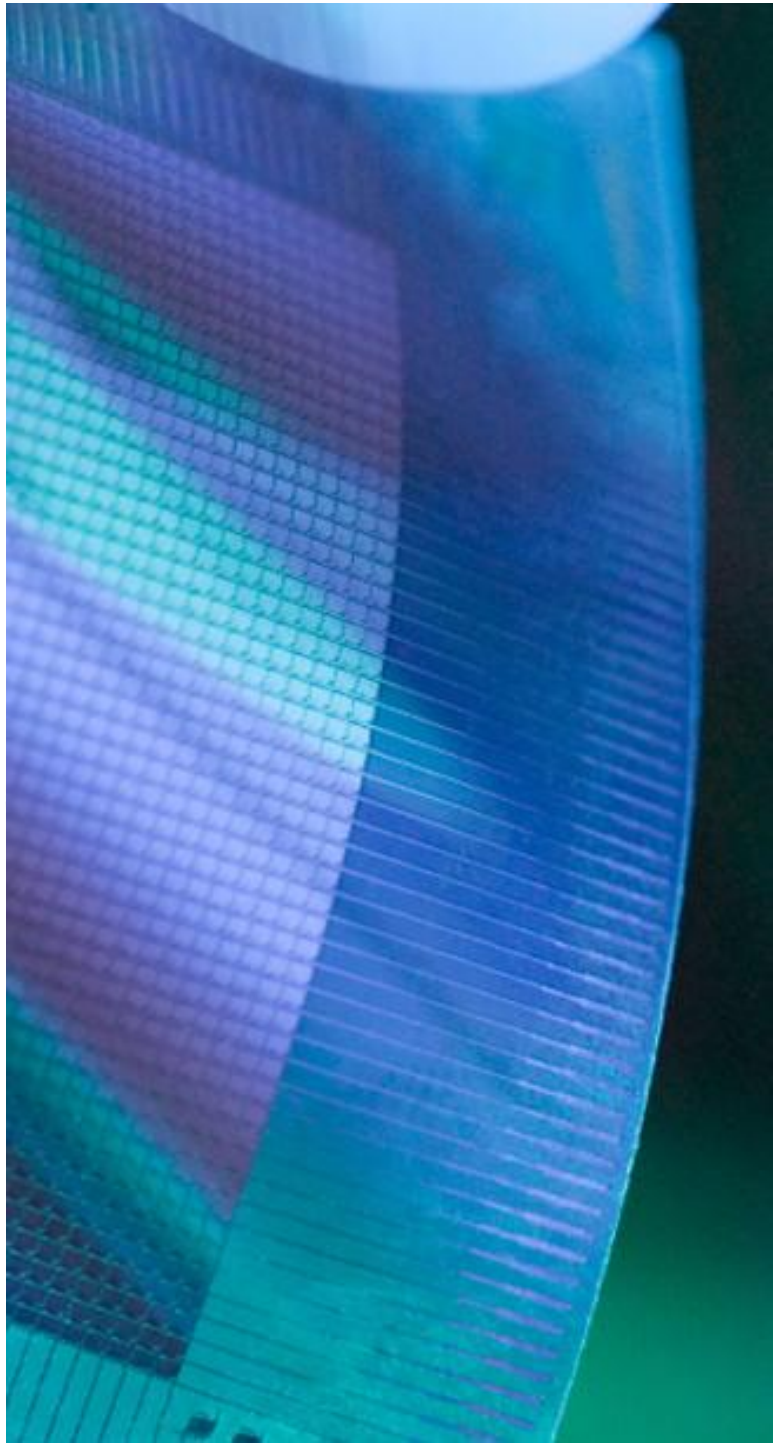

about PARC

Palo Alto Research Center
– incorporated in 2002 (formerly Xerox PARC)

- **4 Divisions**
  - Computer Science
  - Intelligent Systems
  - Hardware Systems
  - Electronic Materials & Devices

Large Area Electronics, MEMS, Optoelectronics, Printing Systems, Biomedical Systems, Clean Technology, ...

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about PARC

Palo Alto Research Center
– incorporated in 2002 (formerly Xerox PARC)

- **Research as a business**
  - Research with client companies and the Government
  - Partnerships with new ventures
  - New business creation
  - Licensing and technology transfer

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The Vision for Flexible Electronics

Electronic Patch Network

Nokia

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The Vision for Flexible Electronics

- **There will be new applications that <u>utilize</u> flexibility**
- **And new applications that <u>benefit from</u> flexibility**
  - Lighter, more robust,…..
  - Lowered cost of manufacturing
  - Custom devices and systems
- **A destabilizing technology will be created**
  - There are likely to be new winners
    - Will they be in Asia, Europe or USA?

Electronic Patch Network

Nokia

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Applications that need flexibility

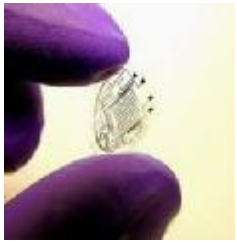
- **Displays**
  - Placed on curved surfaces, wearable
  - Roll-able
  - Robust

Sony

- **Photovoltaics**
  - Placed on curved surfaces
  - Aesthetics as well as function

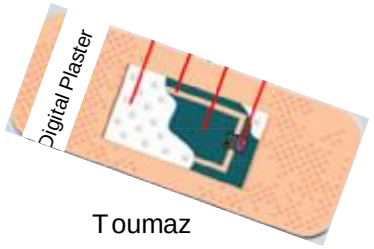
Flexcell

- **Digital X-ray imagers**
  - Conformal – surrounding the object
  - Robust



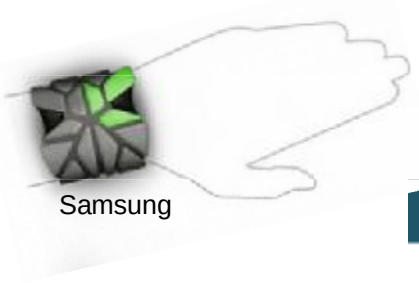
U. Washington

- **Medical devices**
  - Electronic patch
  - Implantables



Toumaz

- **Systems on a foil**
  - Wearable devices
  - Designed for people, not imposed on them



Samsung

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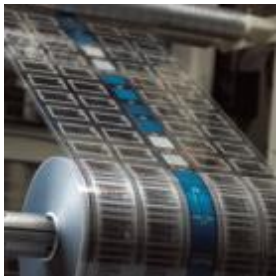
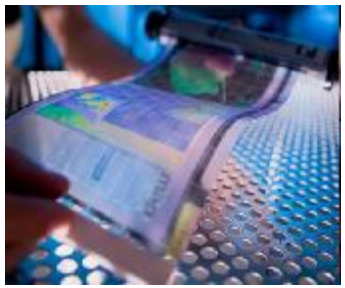
Benefits to industry from flexible substrates

- **Roll-roll manufacturing**
  - Exists in many areas: newspapers, packages…..
  - Low cost at high volume
- **Thin, light substrates**
  - Ultra-light systems
  - Stackable
- **Robustness**
  - No brittle devices
- **Examples**
  - RFID
  - Photovoltaics
  - Smart labels
  - Lighting
  - Smart phones
  - Tablets…….

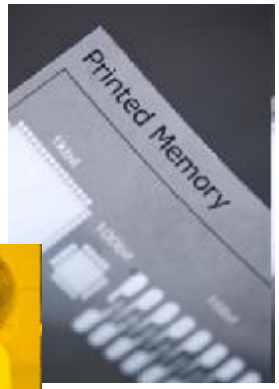


Soligie



HP / FDC at ASU

ECD Ovonics



Thin Film

CAMM

PolyIC

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Our perspective:

- **Flexible Electronics is an exciting opportunity**
  - New technology capabilities
  - New business opportunities

- **And – it is happening**
  - Particularly in Europe

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- **Flexible Electronics is an exciting opportunity**
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- **Applications will drive the technology**
  - People want solutions – not technology
  - And they want convergence of functions

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Our perspective:

- **Flexible Electronics is an exciting opportunity**
  - New technology capabilities
  - New business opportunities
- **And – it is happening**
  - Particularly in Europe
- **Applications will drive the technology**
  - People want solutions – not technology
  - And they want convergence of functions
- **Challenges**
  - Commercial: How can we launch the industry?
  - Government: Where is the best leverage?

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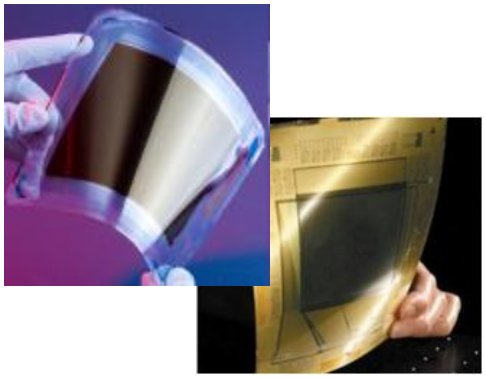
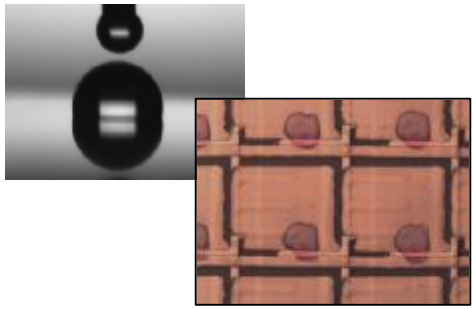
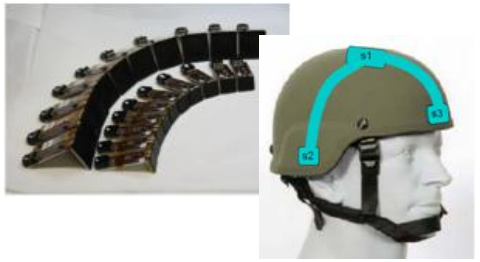
PARC's approach



- **Make "standard" technologies flexible**
  - Amorphous and poly-crystalline Si
- **Exploit printing technology**
  - Inkjet
  - Gravure



- **Develop organic electronics**
- **Demonstrate with applications**
  - Displays
  - Sensors
  - Systems



- **Develop hybrid approaches**

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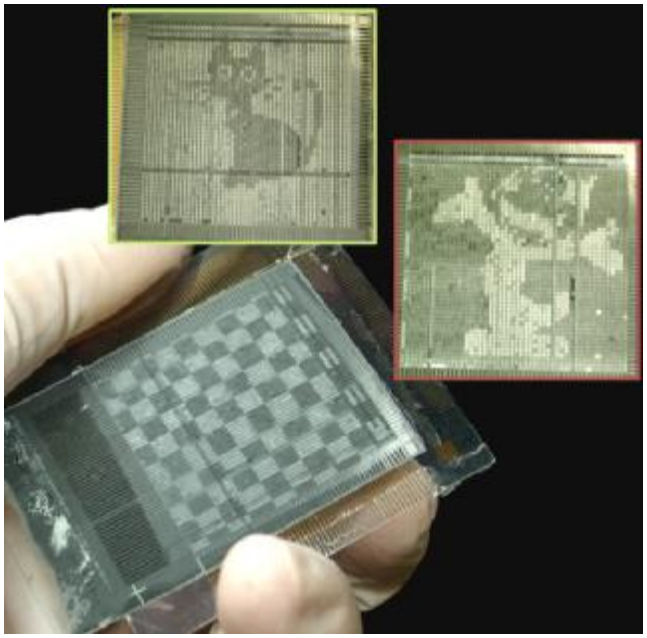
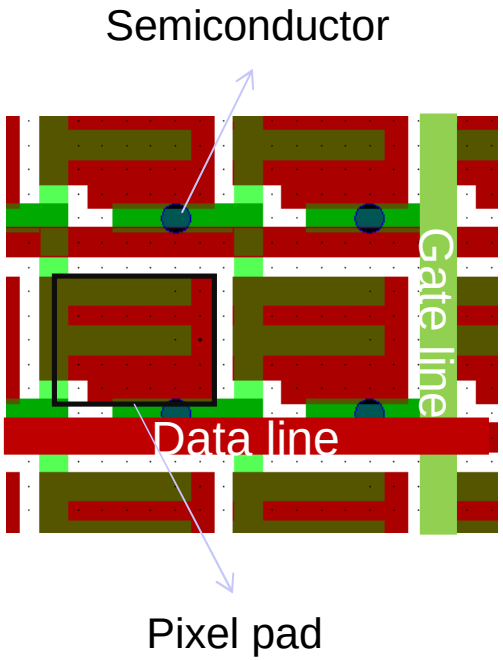
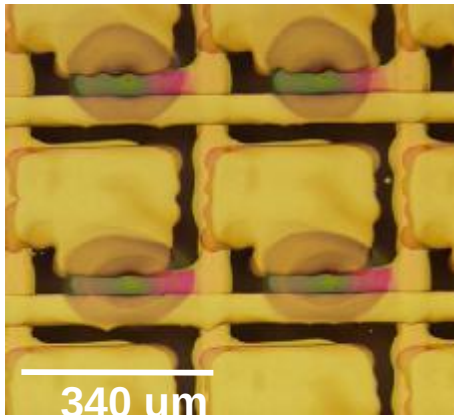
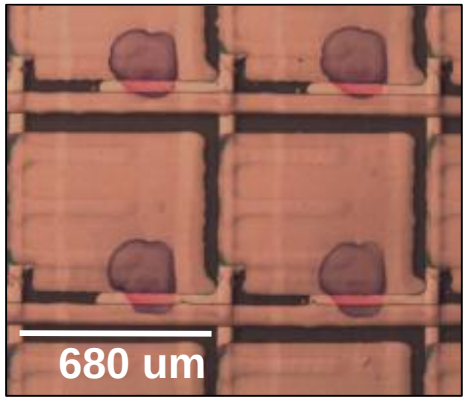
Example 1:
All-additive printed arrays









PARC has demonstrated all-printed TFT backplanes for displays

J. Soc. Info. Display 2007, 7, 485-490

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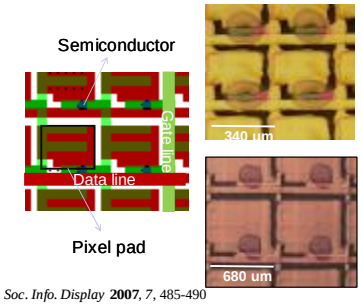
Why this is important

- **Fewer steps**
  - Printed:
    - 4 layers = 4 steps
  - Traditional:
    - 4 layers = 16-20 steps

- **Scalable to simpler applications**
  - custom applications
  - Smart labels etc.

Example 1:
All-additive printed arrays



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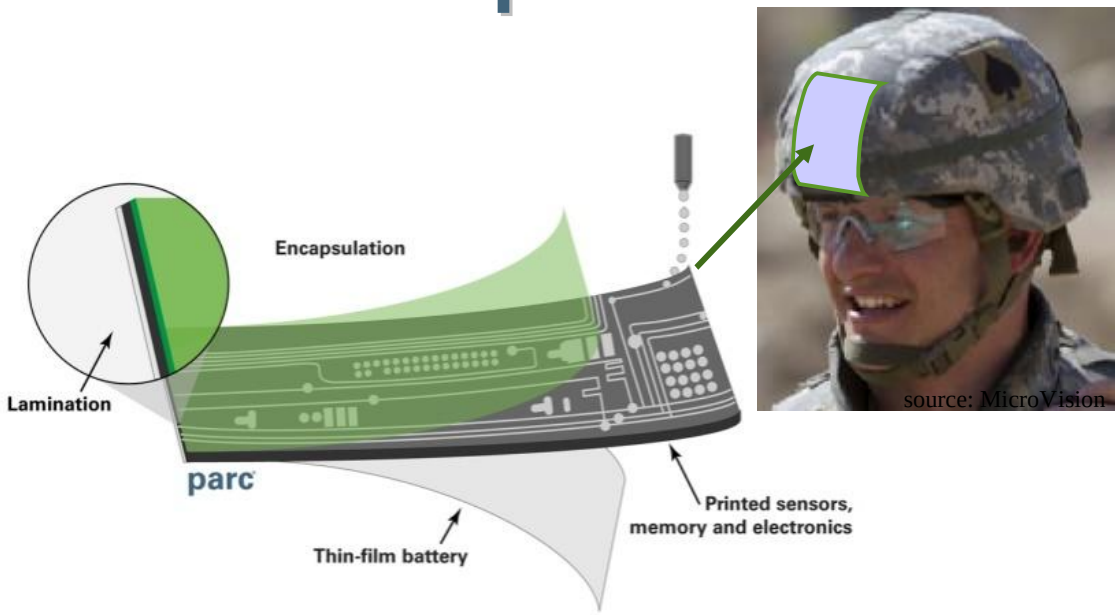
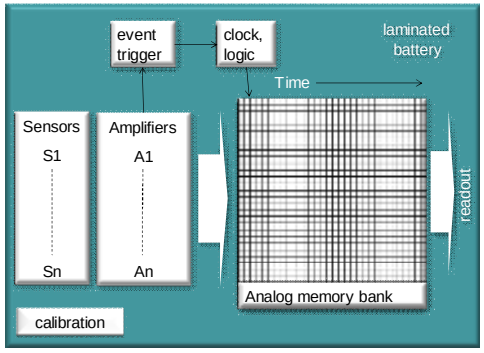
Example 2:
Printed Sensor Tape



source: MicroVision



- Monitor pressure, acceleration, sound, light
- Signals recognized, processed, sent to memory
- Non-volatile memory holds data for one week
- Off-board readout system

Monitoring environment to prevent traumatic brain injury. (DARPA)

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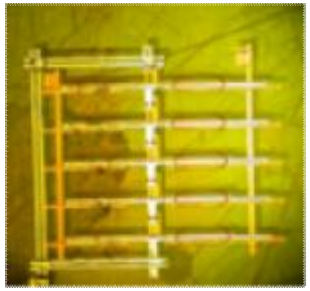
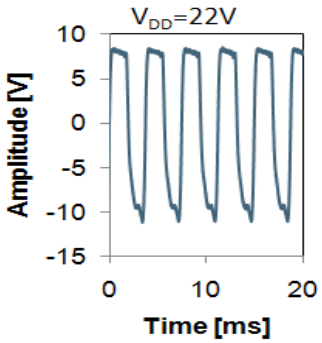
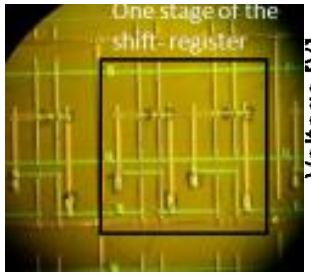
Sensor Tape: Printed Electronics

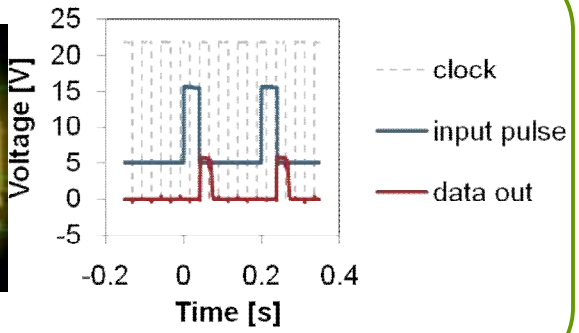
Ring oscillator



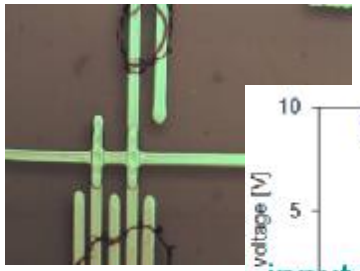


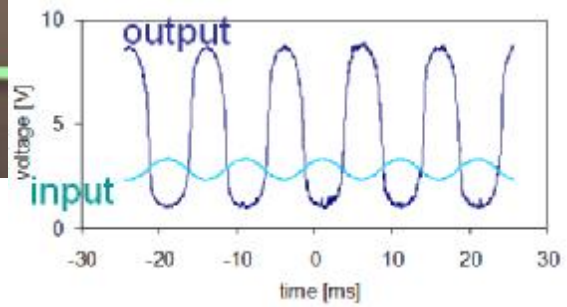
Shift Register



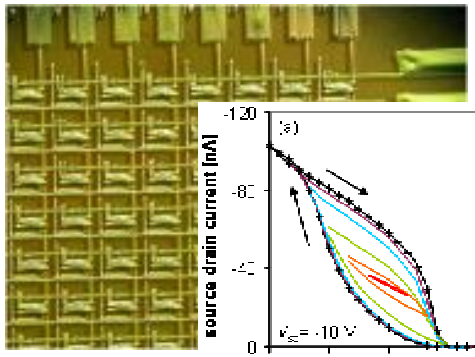


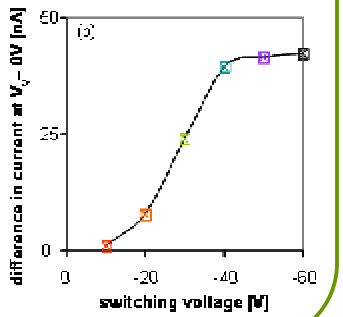
Amplifier





Memory





APL, 94, 233307 2009
JAP, 106, 094504 2009

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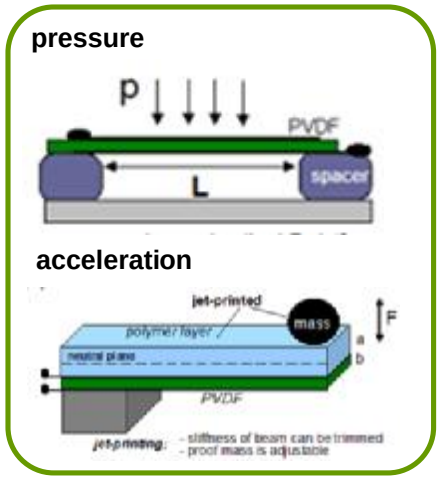
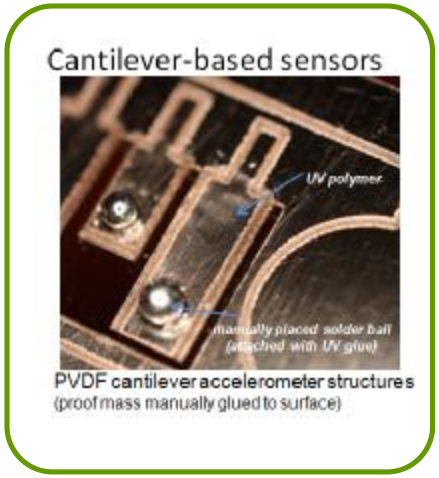
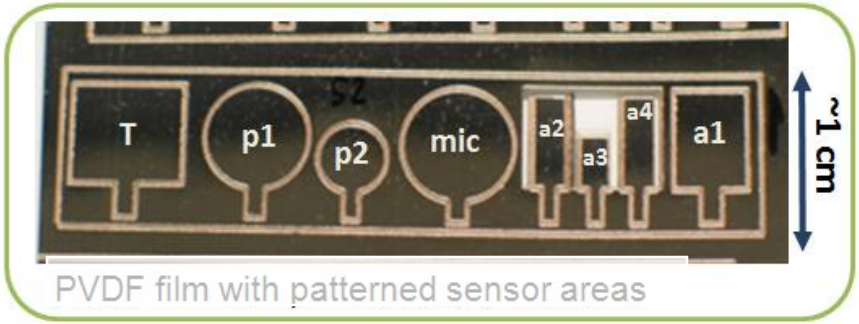
Sensors

- **Piezoelectric sensing**







Laminated PVDF foil or PVDF-TrFE solution

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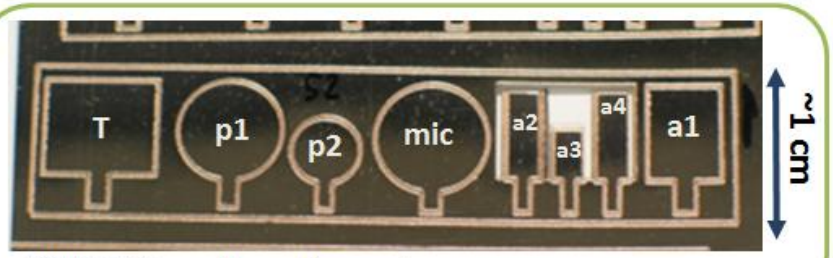
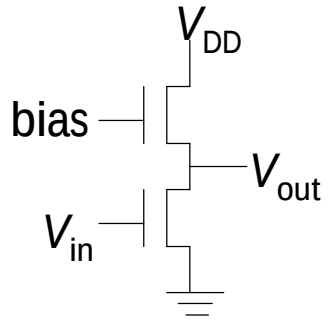
Sensor Tape: Next step: integration

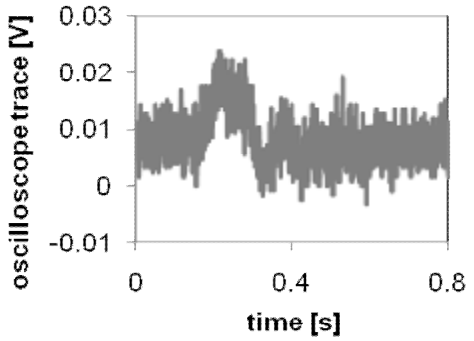
MEMS sensors



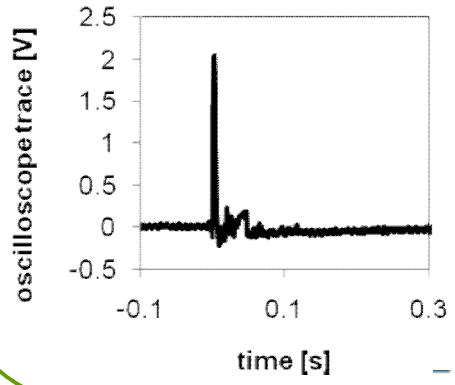
PVDF film with patterned sensor areas

Printed organic amplifiers



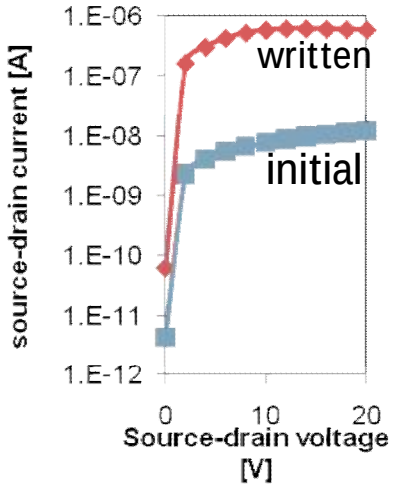


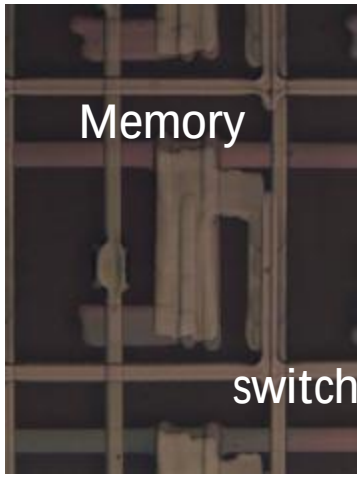
Pressure signal without amplifier



Pressure signal after amplifier

Printed memory cells

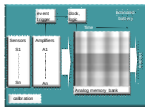




What we have learned

- **Flexible sensor systems will be important**
- **Hybrid devices are very promising**
  - Silicon + organics
  - Printed + traditional manufacturing

Example 2:
Printed Sensor Tape



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Monitoring environment to prevent traumatic brain injury. (DARPA)

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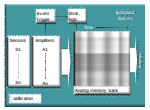
What we have learned

- **Flexible sensor systems will be important**
- **Hybrid devices are very promising**
  - Silicon + organics
  - Printed + traditional manufacturing
- **Integration into a system can be done**
  - but is challenging
- **Taking this to the next level is difficult**

  Applications need volume
  Volume needs applications

Example 2:
Printed Sensor Tape



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Monitoring environment to prevent traumatic brain injury. (DARPA)

  - Does the industry wait for a company with enough money and demand to drive the development of a particular device
    AND the industry itself?

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PARC's view

- **The flexible electronics industry has a huge future**
- **We are active across the industry and work with a wide range of participants**
- **With our clients and partners, we invent, develop and demonstrate**
  - Processes
  - Prototypes
  - Applications
- **We are investing in**
  - Components
  - Partnerships for manufacturing

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What more is needed?

- **Focus on development of applications**
  - There is currently some funding for processes and capabilities
    - This should be enhanced
  - We need to put this together with applications
    - The big missing piece in the US

- **This could kick-start the industry**

…. the relatively low prevalence of actual manufacturing and advanced systems research and development in the United States has led to an incomplete hybrid flexible electronics R&D scenario for this country…… [NSF/ONR Report: www.wtec.org/flex/]

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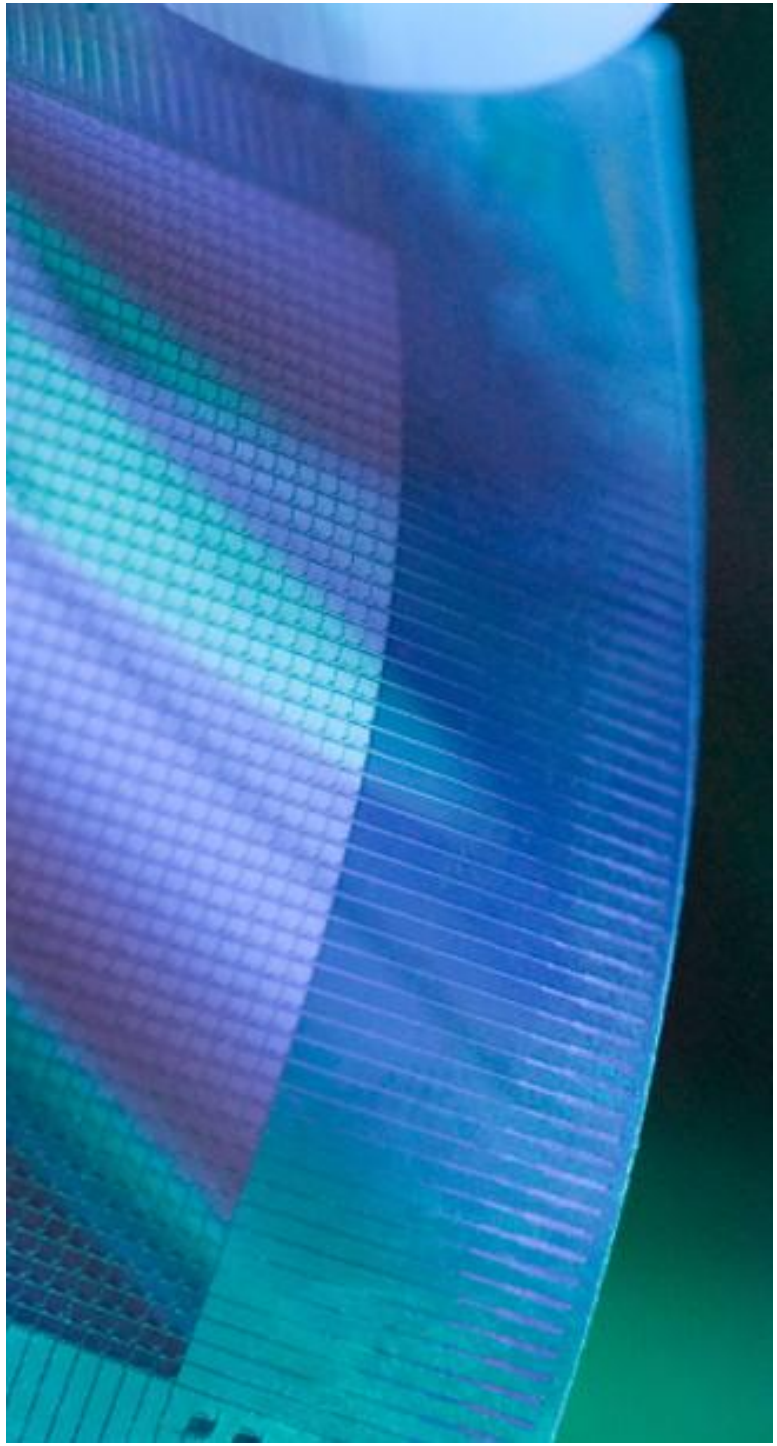
Thank you

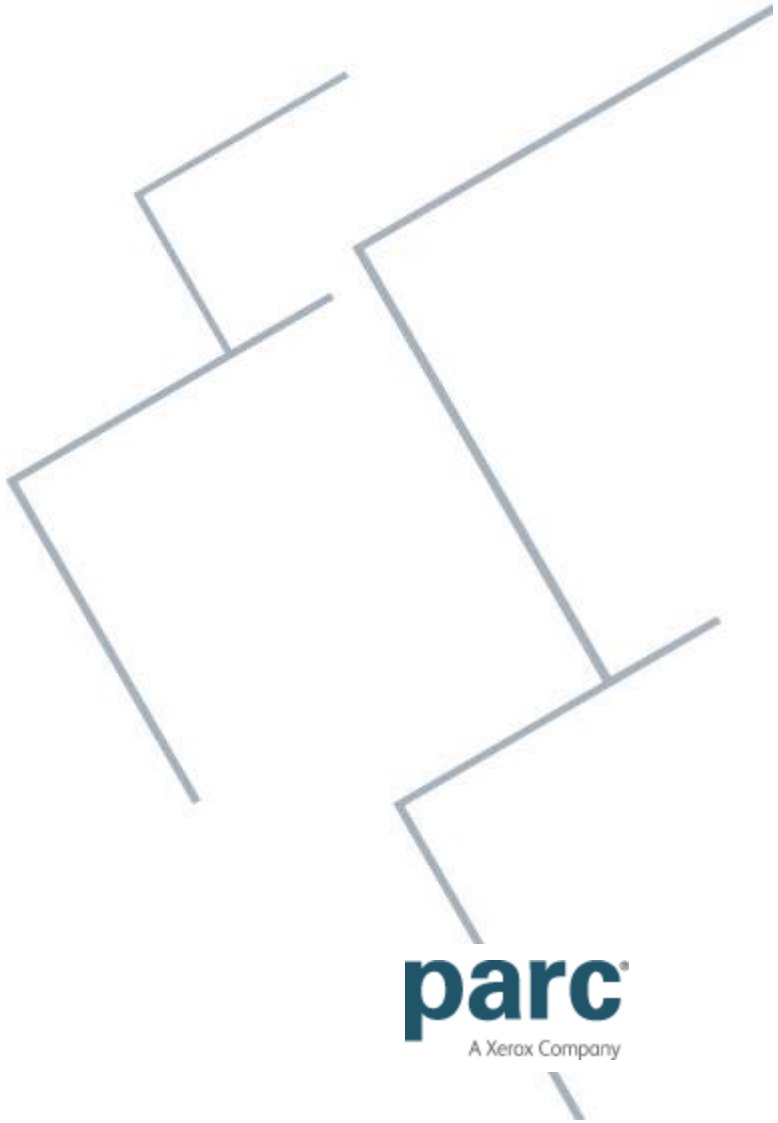


Acknowledgments:

The PARC Large Area Electronics teams led by:

Raj Apte, Ana-Claudia Arias, Bob Street

Backup



Market Size

- **IDTechEx**
- **2010 to 2020 Market Size**
  - IDTechEx find that the market for printed and thin film electronics will be $1.92 Billion in 2010. 43% of that will be predominately organic electronics - such as OLED display modules. Of the total market in 2010, 35% will be printed. Initially photovoltaics, OLED and e-paper displays grow rapidly, followed by thin film transistor circuits, sensors and batteries. By 2020 the market will be worth $55.1 Billion, with 71% printed and 60% on flexible substrates.
  - However, the topic is even bigger than this with some conventional electronics such as conventional aSi Photovoltaics now migrating to being printed, to reduce cost, be available on flexible substrates and in larger areas. In addition to the above, forecasts for such markets are given, as is progress to print them.

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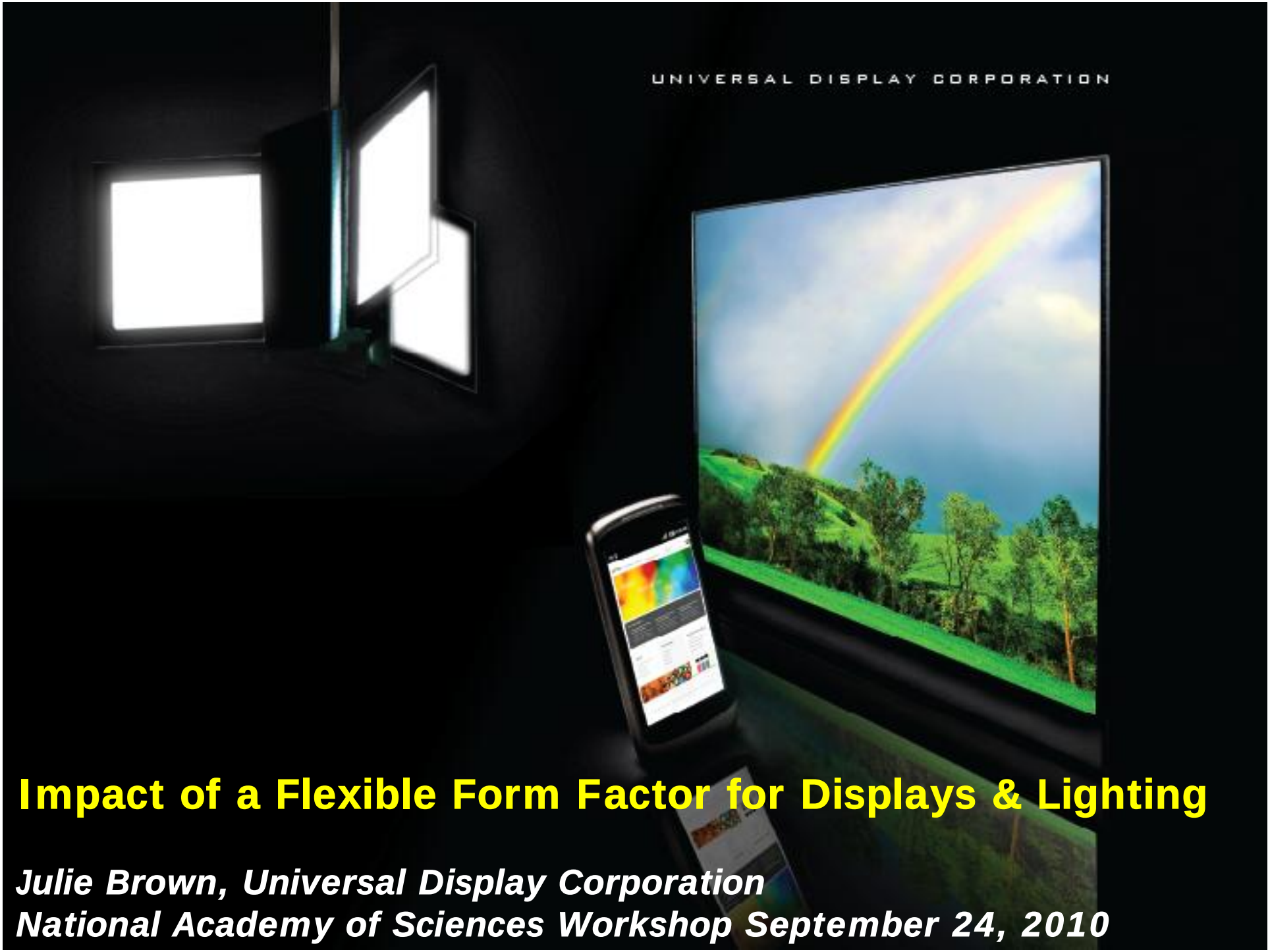


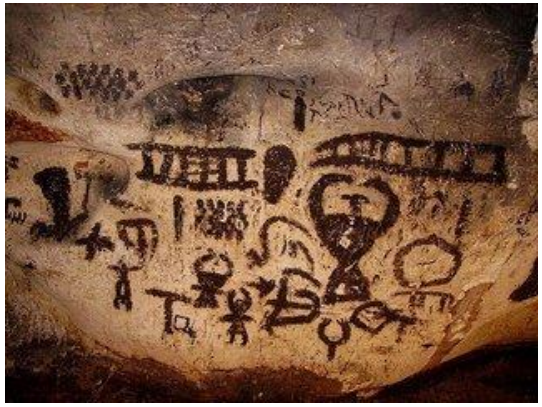
Impact of a Flexible Form Factor for Displays & Lighting

Julie Brown, Universal Display Corporation

National Academy of Sciences Workshop September 24, 2010

Why Flexible ? – *Looking back in history*

Displays

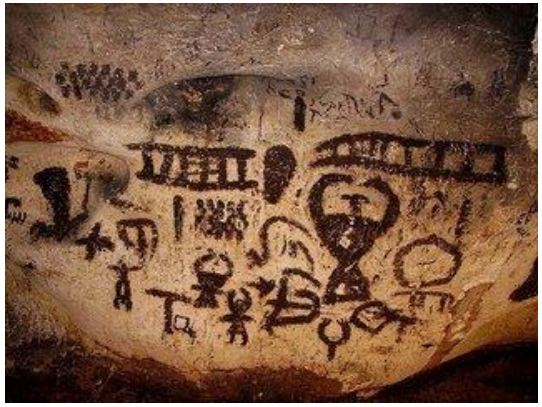


Practical *to Portable* *to Convenience* *to…*

Lighting

UNIVERSAL DISPLAY CORPORATION

Why Flexible ? – For *Displays*



Portable
+ Real Time Information
+ Vivid Color
+ Green Technology

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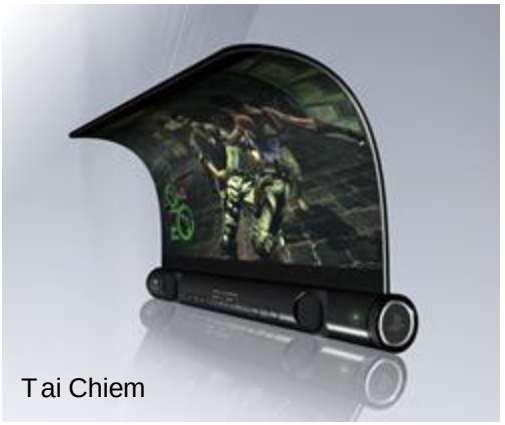
Flexible Design Opportunities

- Non-breakable, light weight, ultra thin
- Increased design opportunities
  - New shapes
  - Curved
  - Rollable
- Enables new concepts
  - Wearable
  - Ultimate portability

Tirshathah Hunter

Aleksandr Mukomelov



Tai Chiem

NOKIA

UNIVERSAL DISPLAY CORPORATION

How will flexible displays develop?

Form Factor

Low Power	Rugged	Bendable	Rollable	FreeForm
• Thin and light	• Light and slim • Rugged	• Light and slim • Wearable	• Compact	• Total flexibility • Paper-like
 	 	 	 	
				

Performance : Full-color, vivid, video rate, low power

Prototypes – *some examples*

LGD

Plastic Logic

Polymer Vision

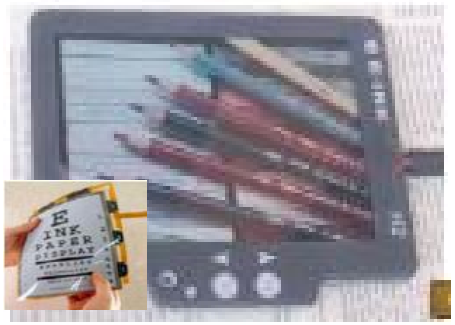
UDC/LGD

Samsung SMD

Sony

ITRI

PVI



E Ink

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UNIVERSAL DISPLAY CORPORATION

OLED Display Offer High Quality Image

AMOLED

The Prominent Next-generation Display

Samsung Galaxy S

Superior Image

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- High Contrast
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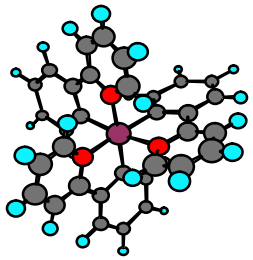

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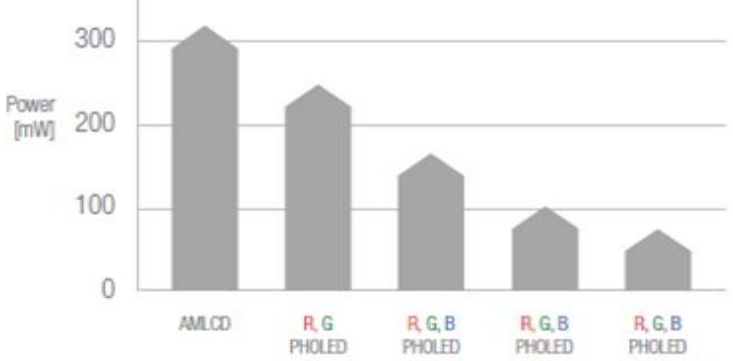

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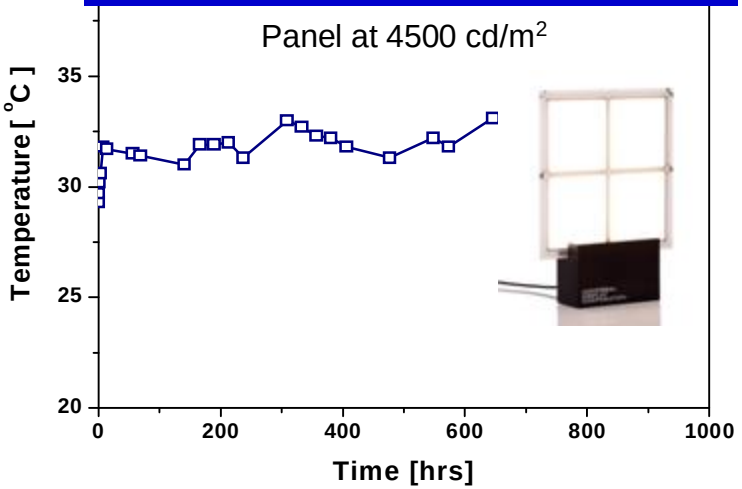

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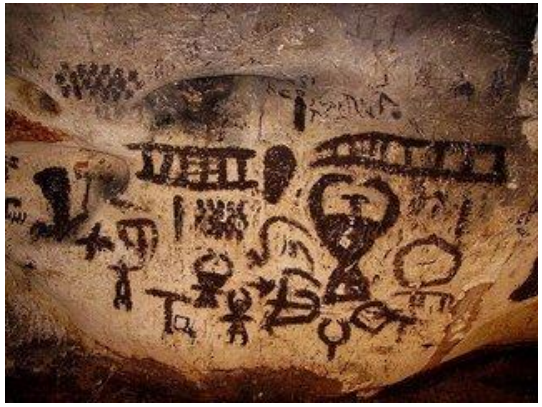

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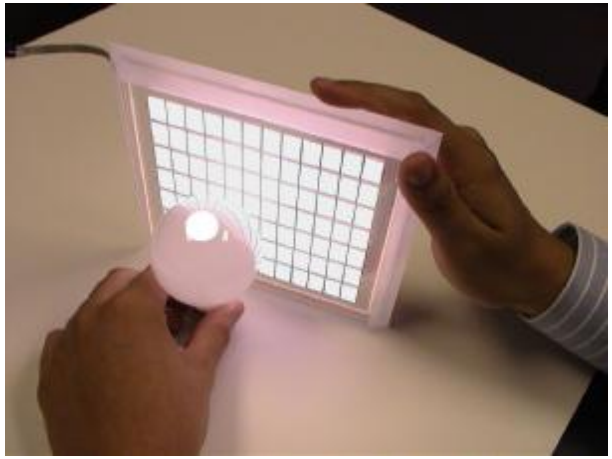

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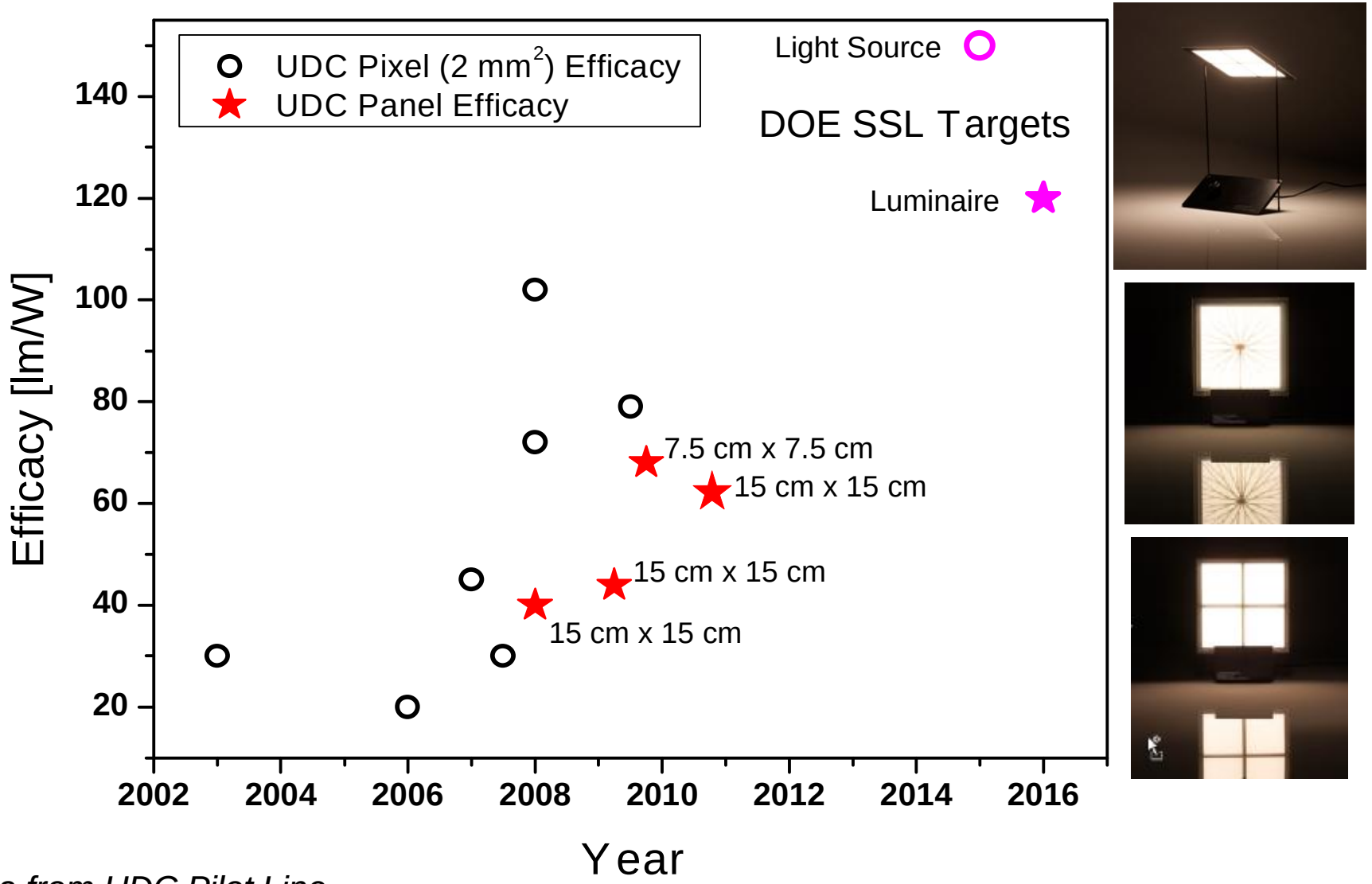

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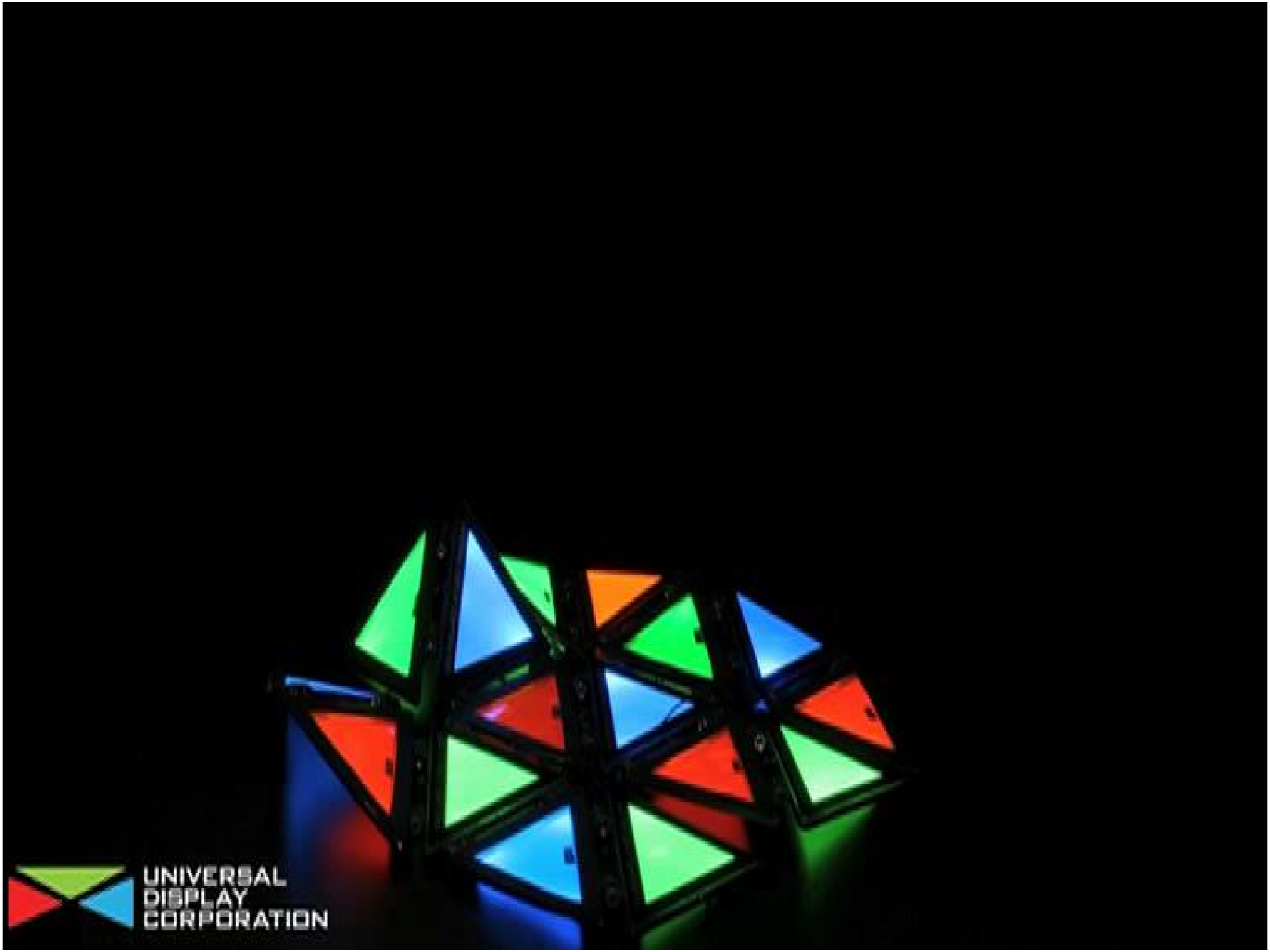
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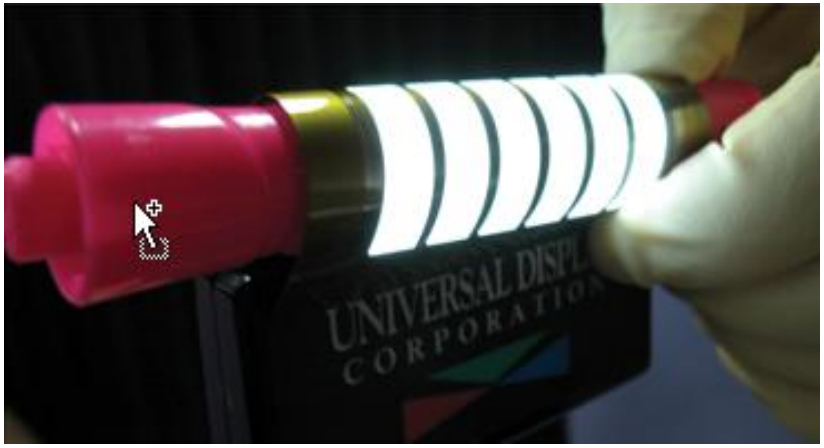

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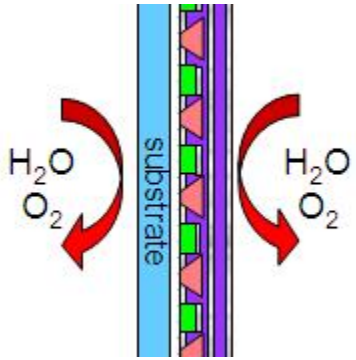

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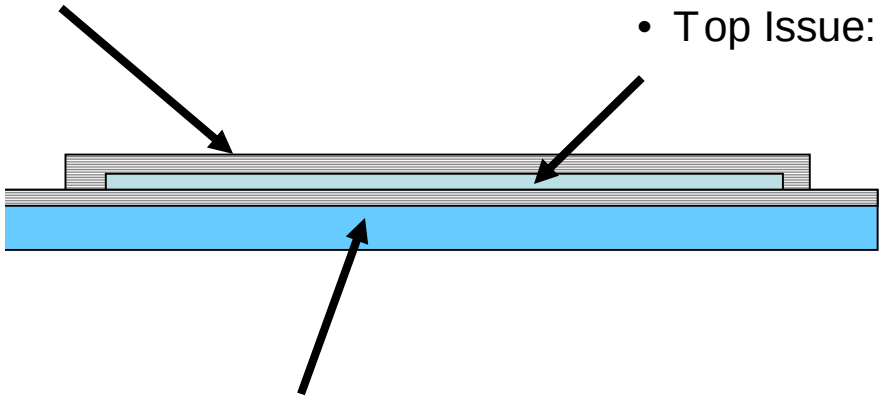

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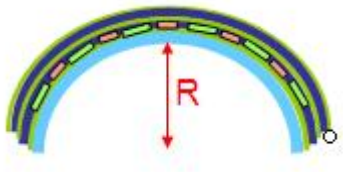

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UNIVERSAL DISPLAY CORPORATION

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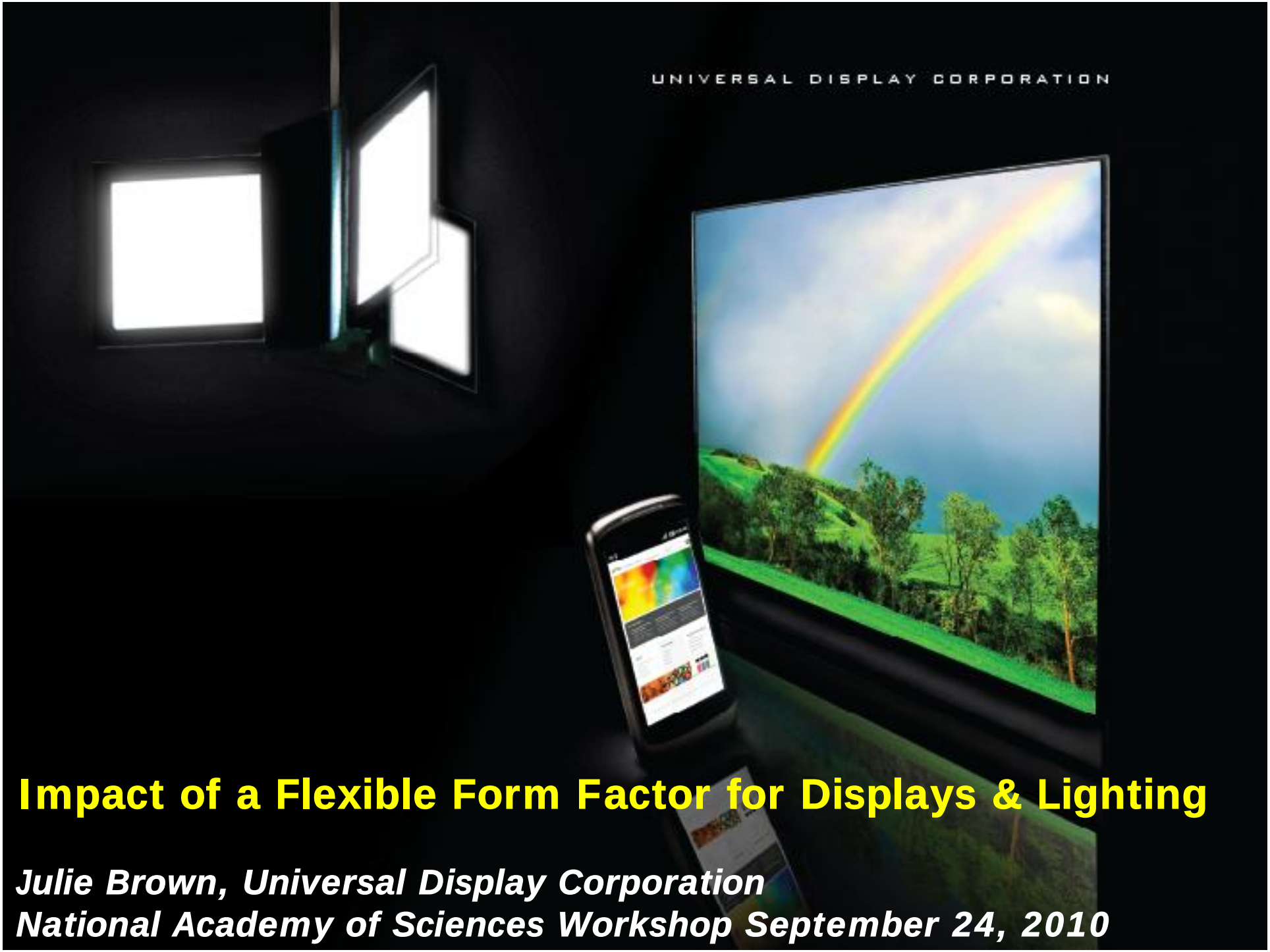


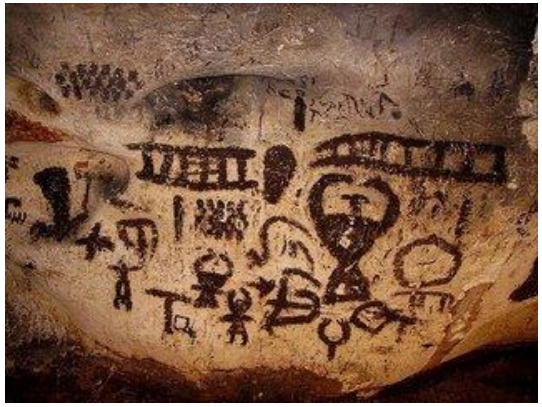
Impact of a Flexible Form Factor for Displays & Lighting

Julie Brown, Universal Display Corporation

National Academy of Sciences Workshop September 24, 2010

Why Flexible ? – *Looking back in history*

Displays



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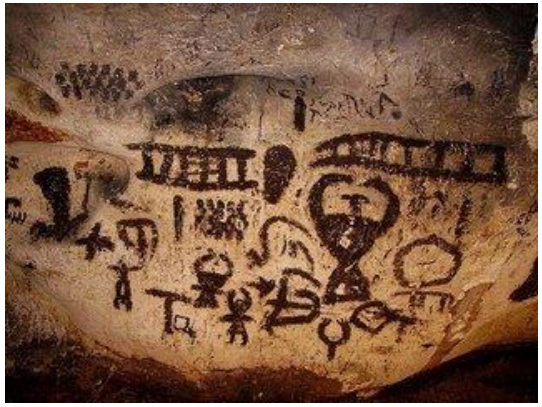

Portable
+ Real Time Information
+ Vivid Color
+ Green Technology

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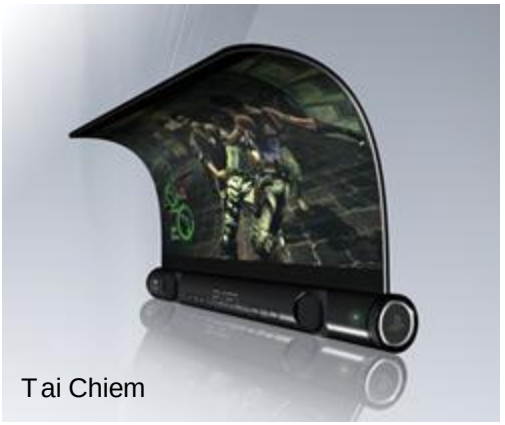
Flexible Design Opportunities

- Non-breakable, light weight, ultra thin
- Increased design opportunities
  - New shapes
  - Curved
  - Rollable
- Enables new concepts
  - Wearable
  - Ultimate portability

Tirshathah Hunter

Aleksandr Mukomelov



Tai Chiem

NOKIA

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How will flexible displays develop?

Form Factor

Low Power	Rugged	Bendable	Rollable	FreeForm
• Thin and light	• Light and slim • Rugged	• Light and slim • Wearable	• Compact	• Total flexibility • Paper-like
 	 	 	 	
				

Performance : Full-color, vivid, video rate, low power

Prototypes – *some examples*

LGD

Plastic Logic

Polymer Vision

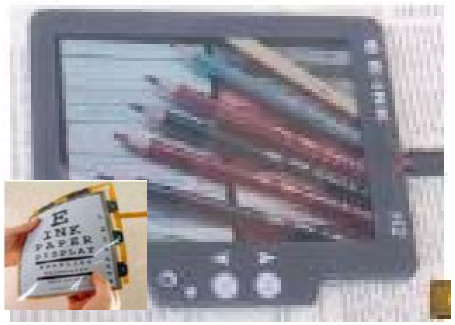
UDC/LGD

Samsung SMD

Sony

ITRI

PVI



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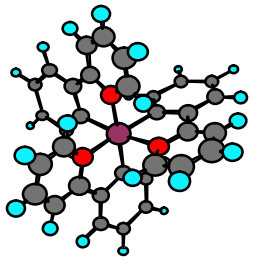

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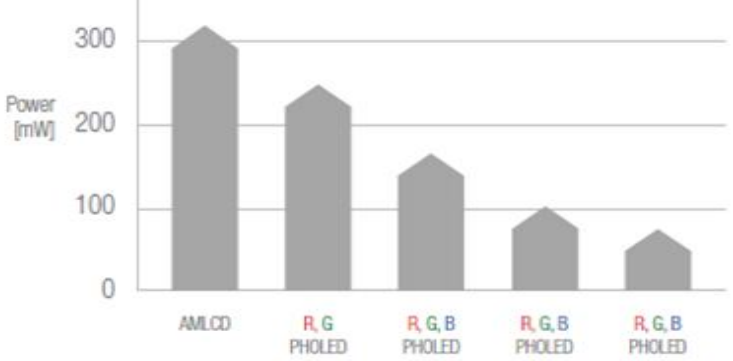

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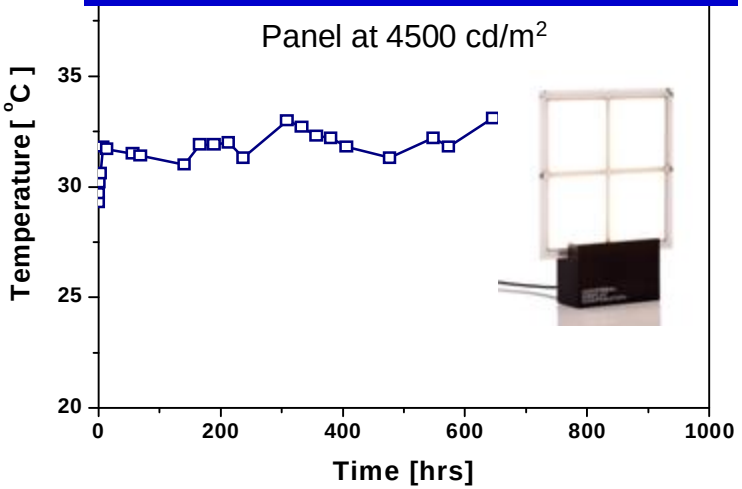

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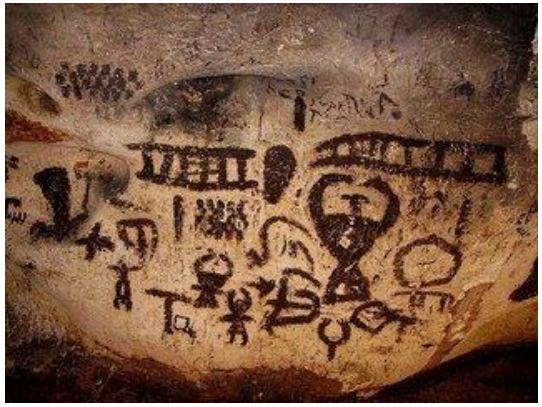

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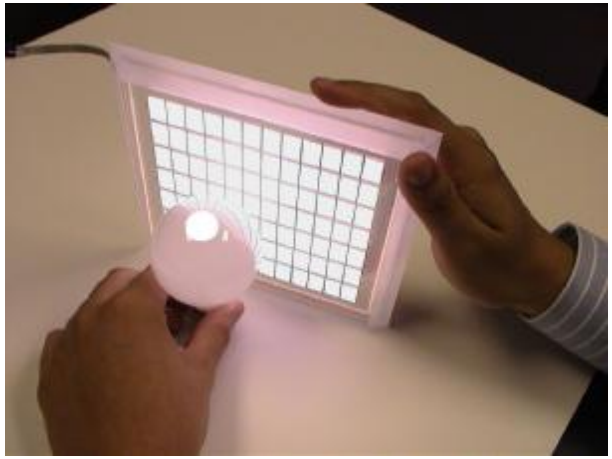

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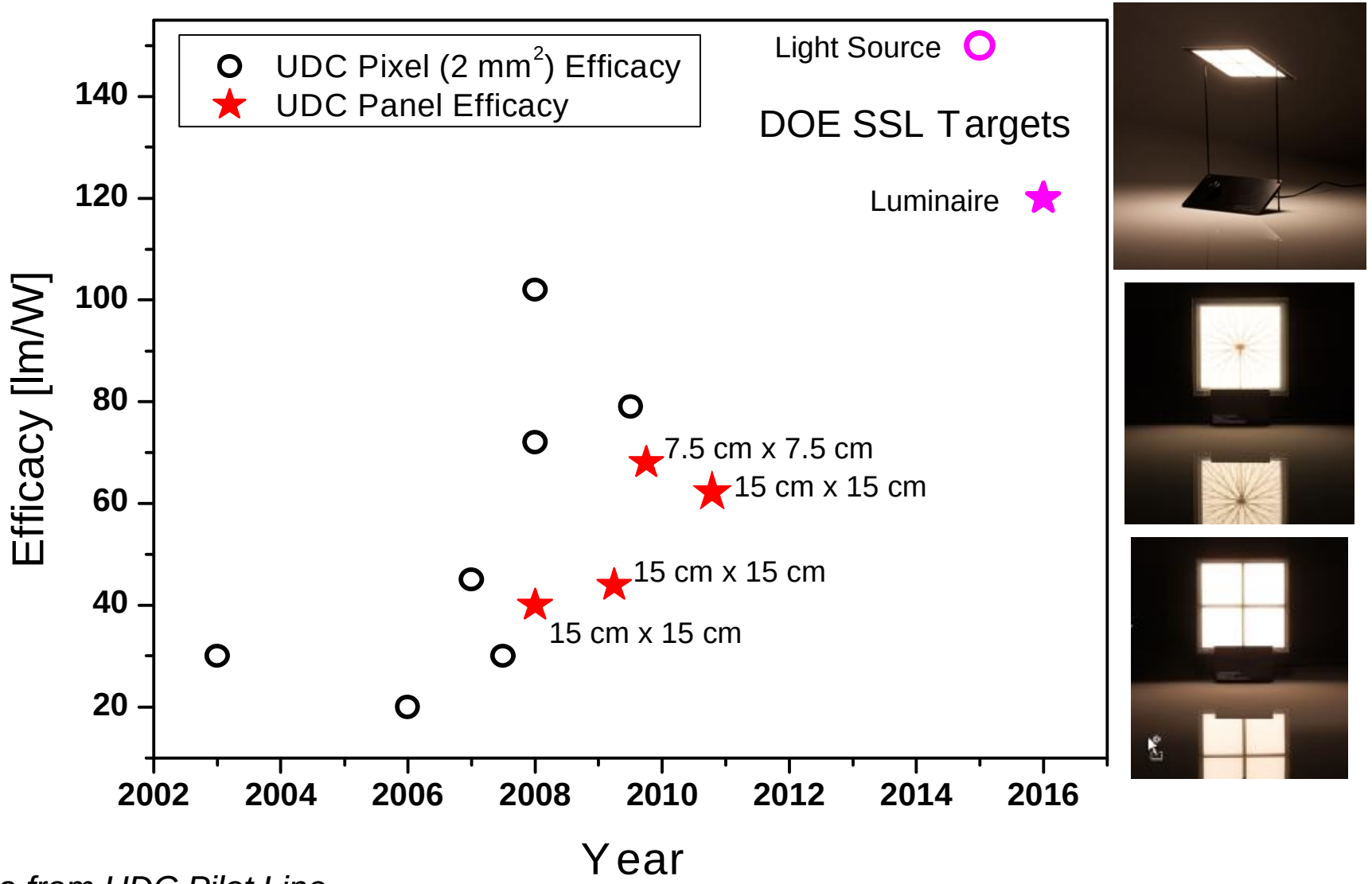

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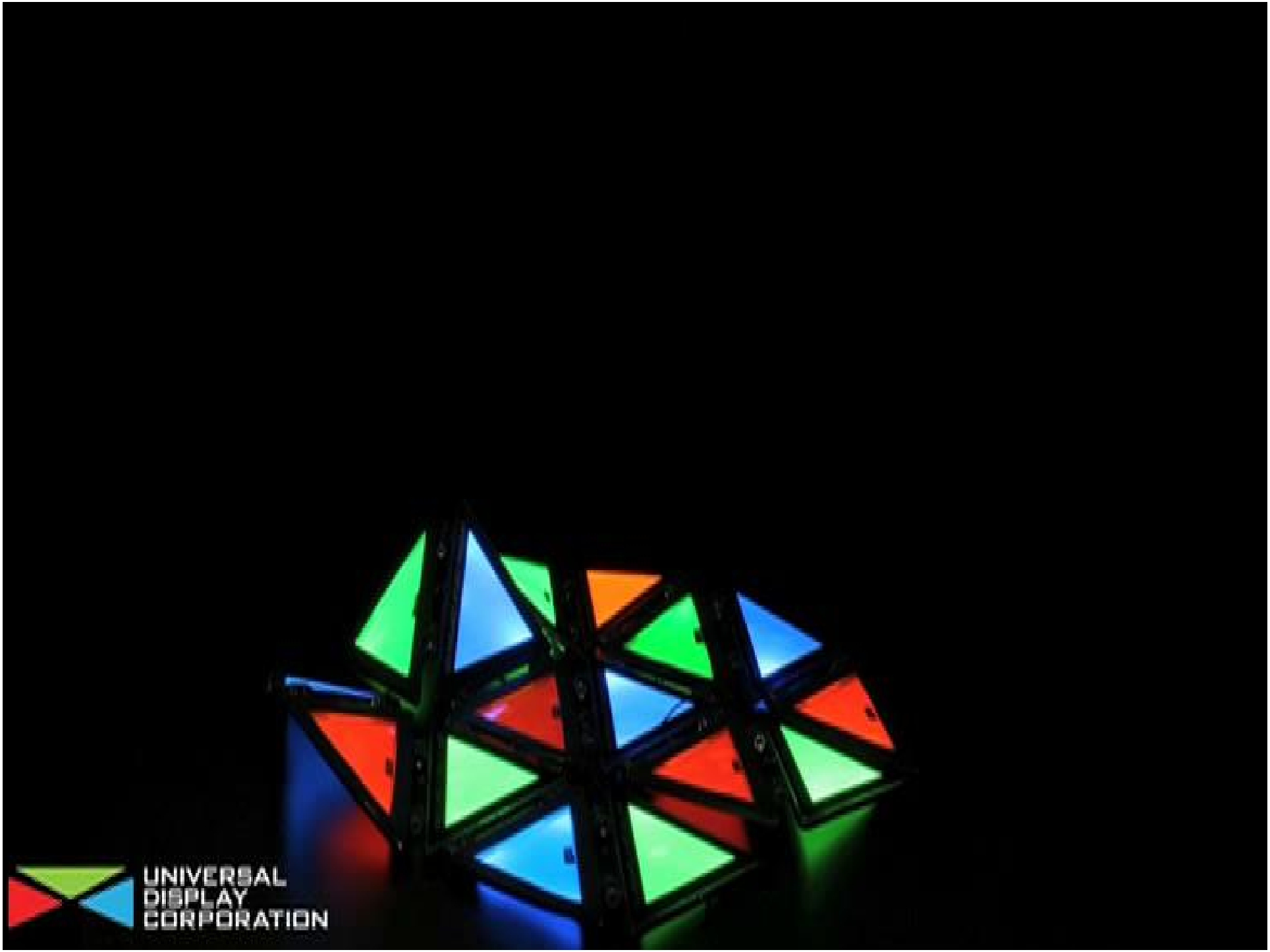
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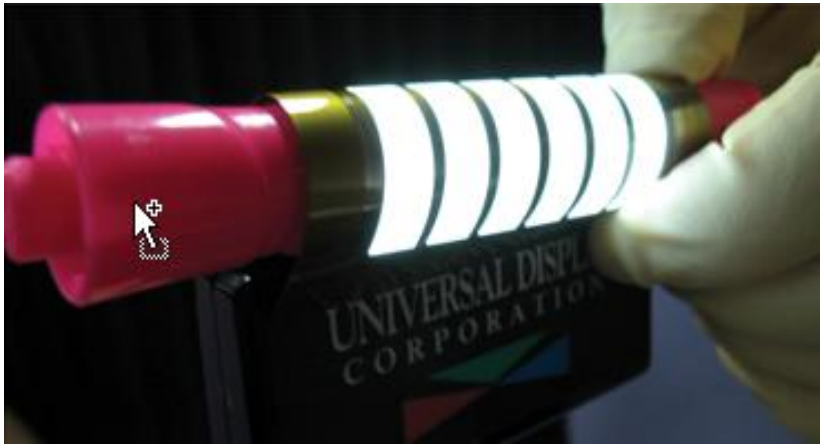

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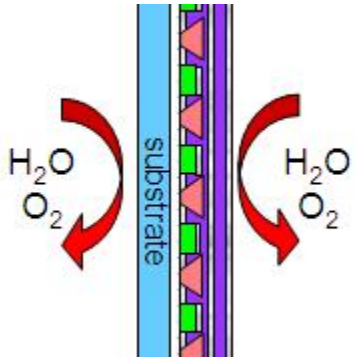

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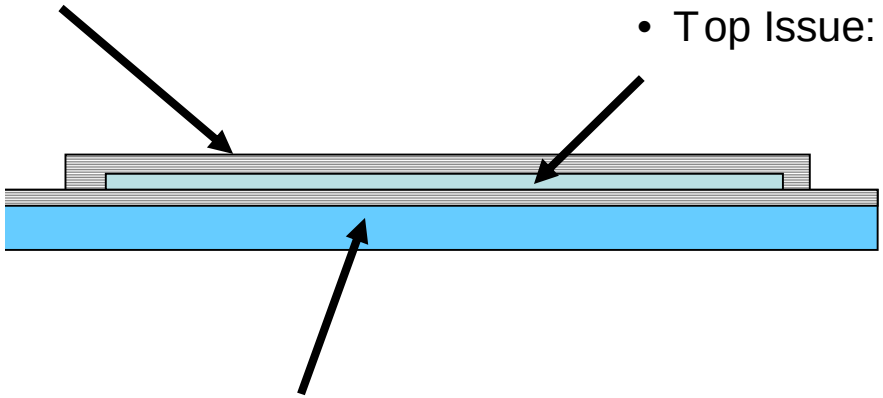

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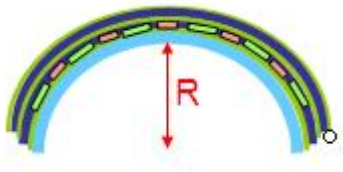

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