FlexTech Alliance
for Displays & Flexible, Printed Electronics

Flexible Electronics: Why the Interest? Where Are The Markets? What's Next?

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CEO
April 14, 2010

What Is the FlexTech Alliance?

- A membership-driven organization serving the common interests of the flexible, printed electronics and displays industries in North America
  - Built on success of U.S. Display Consortium (USDC) with expanded R&D scope and business services
- Our mission is to advance the growth, profitability and success of our member companies and organizations by:
  - Supplying information through market reports and analyses
  - Providing R&D funding
  - Advocating for industry interests
  - Creating networking and information gathering opportunities

Who Should Join FlexTech?

- Current supply chain companies, developers and manufacturers of displays, flexible and printed electronics
- R&D organizations and universities
- Government organizations which fund R&D
- Any company or organization interested in getting involved with the displays and flexible, printed electronics industries

What's in a Name?

- Flexible electronics (substrate is conformable)
- Large area or macro electronics (military)
- Organic electronics (Europe)
- Plastic electronics (academia, UK)
- Printed electronics (primary printing platforms + conductive ink)
- **Flexible, printed electronics (FlexTech)**

Why the Interest in Flexible Electronics?

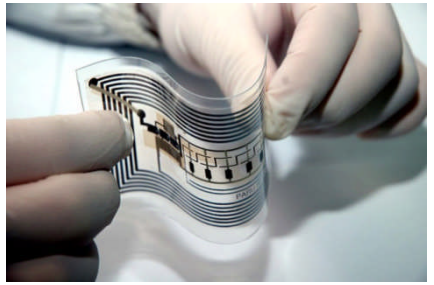
Flexible, Printed Electronics

- Microelectronics changed the world by putting intelligence in products, thereby enabling many new products

- A new field of electronics is emerging which cannot be made small, but must be big in order to interact with big things

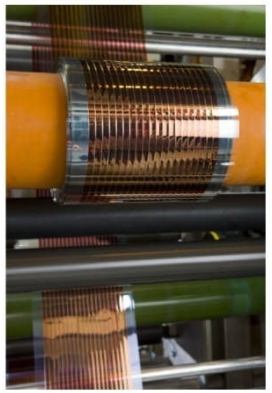
- This is flexible, printed electronics and its salient feature is that it can conform to surfaces to impact a wide range of applications

Lightweight, flexible display from Army/ASU FDC



Printed RFID from Sunchon National Univ. and Rice Univ.

THINERGY Micro-Energy Cell (MEC) - Infinite Power Solutions



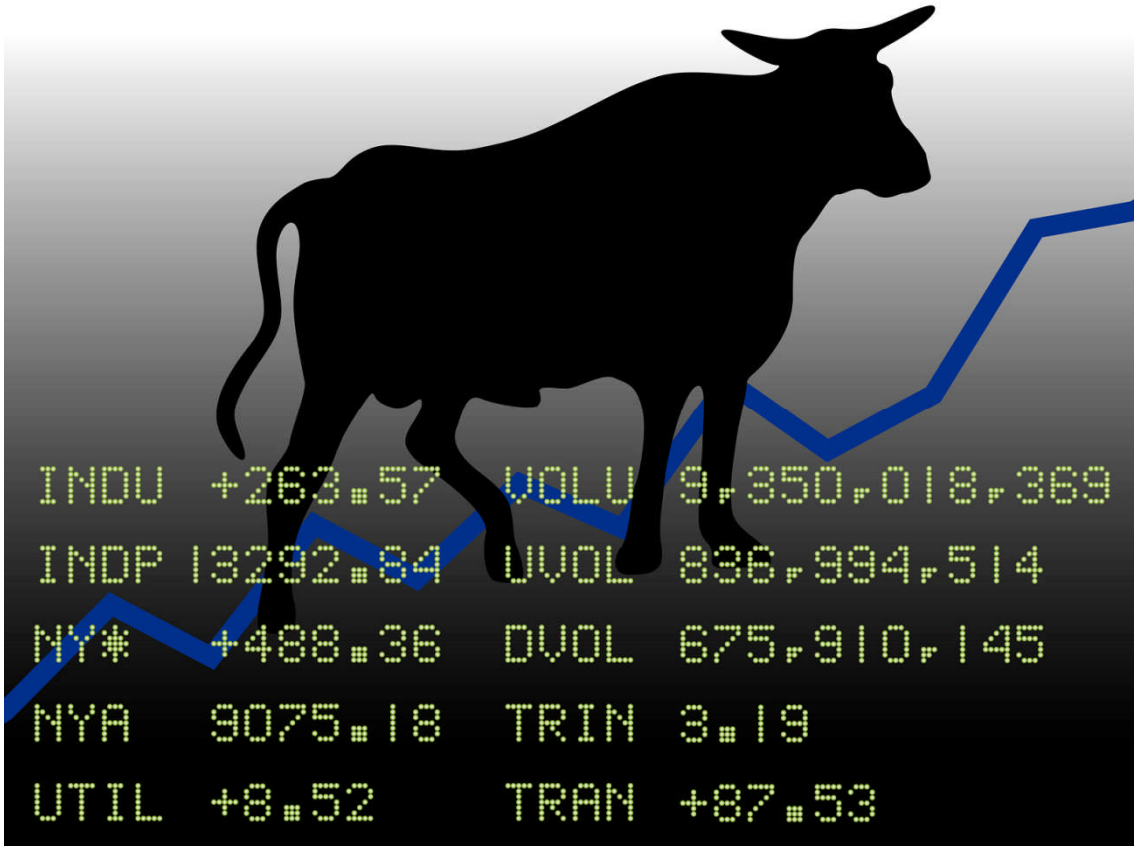
Konarka's flexible OPV

Flexible, Printed Electronics: A Different Path than Moore's Law

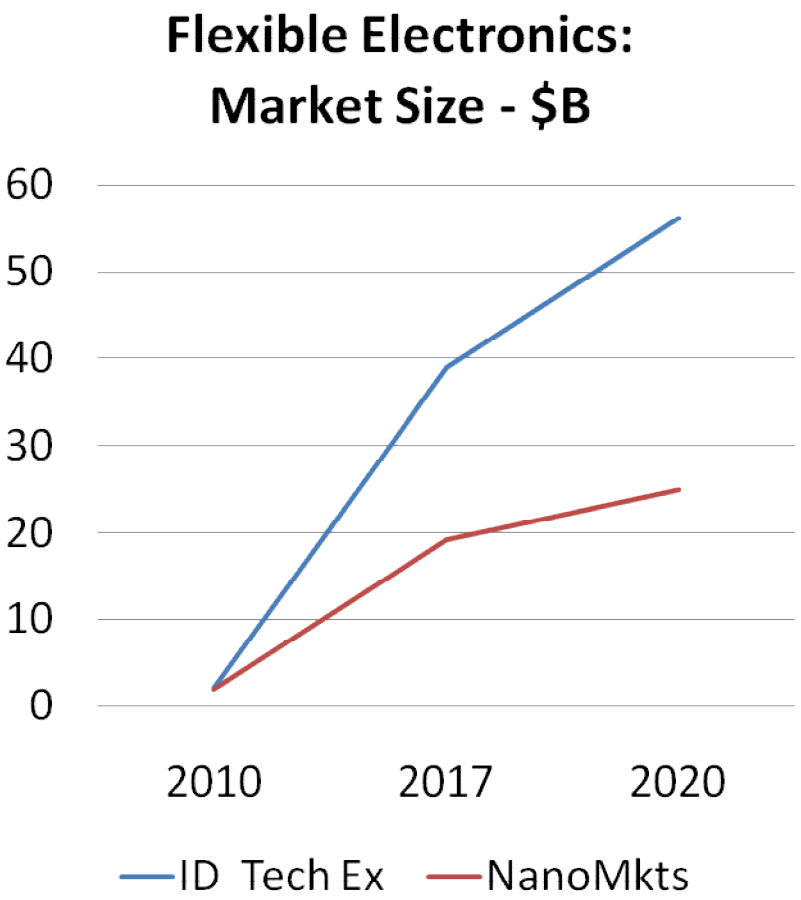
- Moore's Law in silicon electronics drives to smaller features, higher density and complexity, higher costs
- Flexible (and potentially printed) electronics enables sufficient functionality at lower cost

	Flexible & Printed	Silicon
Transistors	thousands	billions
Feature Sizes	10's of microns	10's of nanometers
Cost of Fab	~$ 10M-$200 M/fab	$ 2-3 B/fab

What's the Market Opportunity? Competing Views…



Competing Views



- Primary Applications
  - Displays
  - Lighting
  - Sensors
  - PV
  - RFID

Source: Presented at the 2010 Flexible Electronics and Displays Conference.

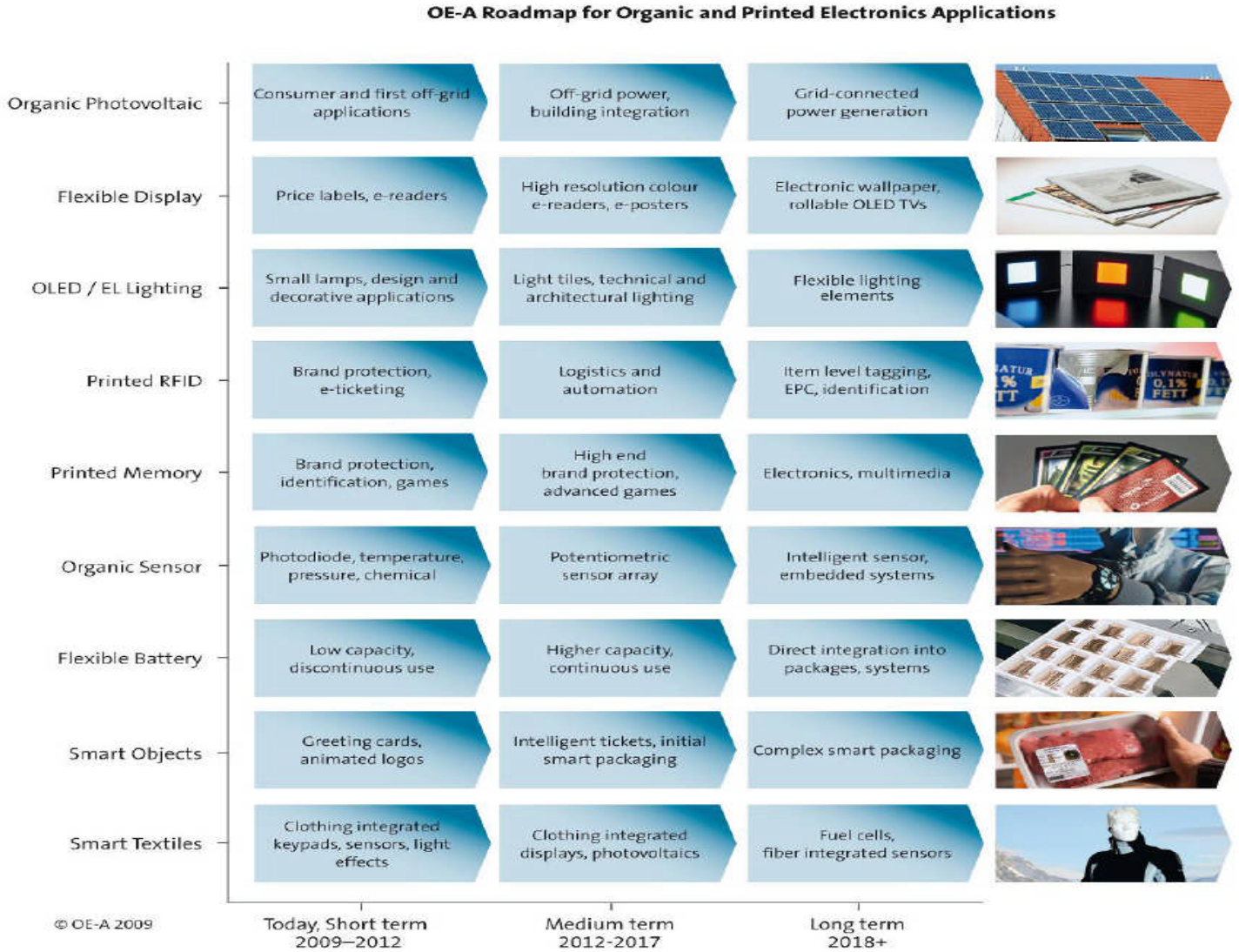
Where Are The Markets?

Areas of Agreement

- Analysts and business development executives agree that there is a flexible, printed electronics industry emerging
- Multiple technical and business challenges
- Primary applications are:

Analysts	FlexTech Alliance
Sensors	Sensors
OLED Displays and Lighting	Flex Lighting
RFID	Communications
PV	Power Films

OE-A's View



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Federal Agency Unmet Needs

Application	DoD	DOE	NIH	DOT	FAA	HSA
Sensors 	•medical: low cost bandages for treatment, triage, trauma care, patient monitoring •force protection	• low cost energy usage control for Smart Buildings	•medical: low cost bandages for treatment, triage, trauma care, patient monitoring	• low cost conformal sensor for infrastructure maintenance and safety for structures	• airframe structural integrity	• low cost border security sensors large area sensors for WMD detection and plume tracking
Power Harvesting Photovoltaics 	• portable, durable, low cost, large area solar cells (off grid) •UAV power on conformal surfaces	• low cost, lightweight, durable integrated solar cells (on grid)		• integration with conformal sensors above		• power sources for unattended, long life, durable sensors above
Power Storage Batteries 	• portable, conformal, long-life, durable	• conformal batteries off grid for alternative energy sources	• power sources for medical sensors	• remote power sources for structural sensors	•power sources for conformal sensors above	• power sources for unattended, long life, durable sensors above
Conformal, Printed Light Emitters	• mission planning/training: low cost, large area displays • conformal maps for dismounted soldier	• large area smart lighting •flexible under counter, around edges lighting	• medical light therapy • professional, collaborative training • more effective patient treatment at lower cost		• conformal displays for collaborative air traffic control • conformal cockpit displays	• on-site, large area displays for first responders
Biotechnology Devices			• non invasive devices			
RFID	• low cost logistics planning/distribution • tracking inventory		• surgical item tracking	•low cost logistics planning/distribution • tracking inventory	• parts tracking and shelf life (out of date)	• personnel tracking

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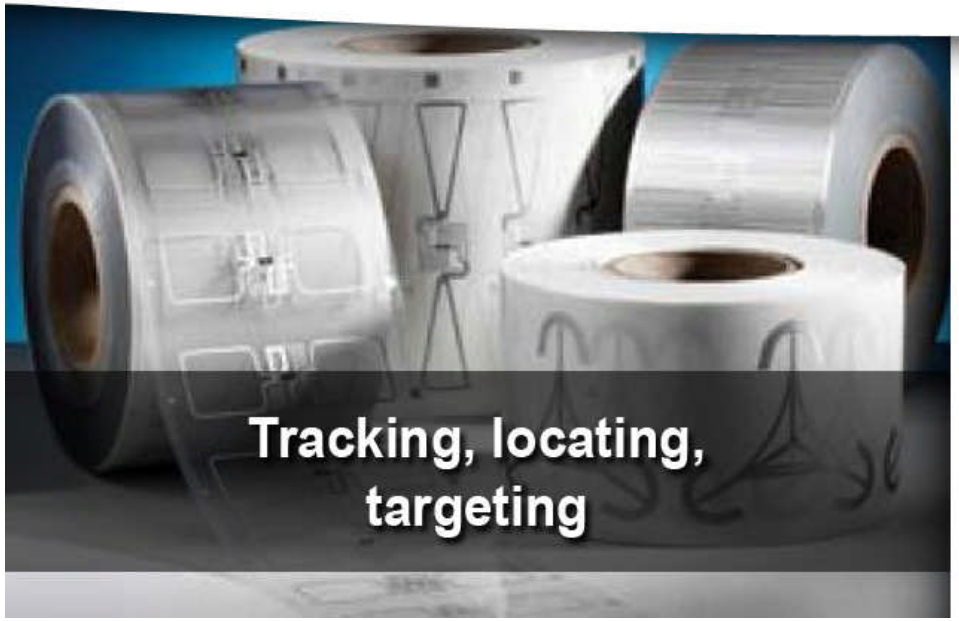
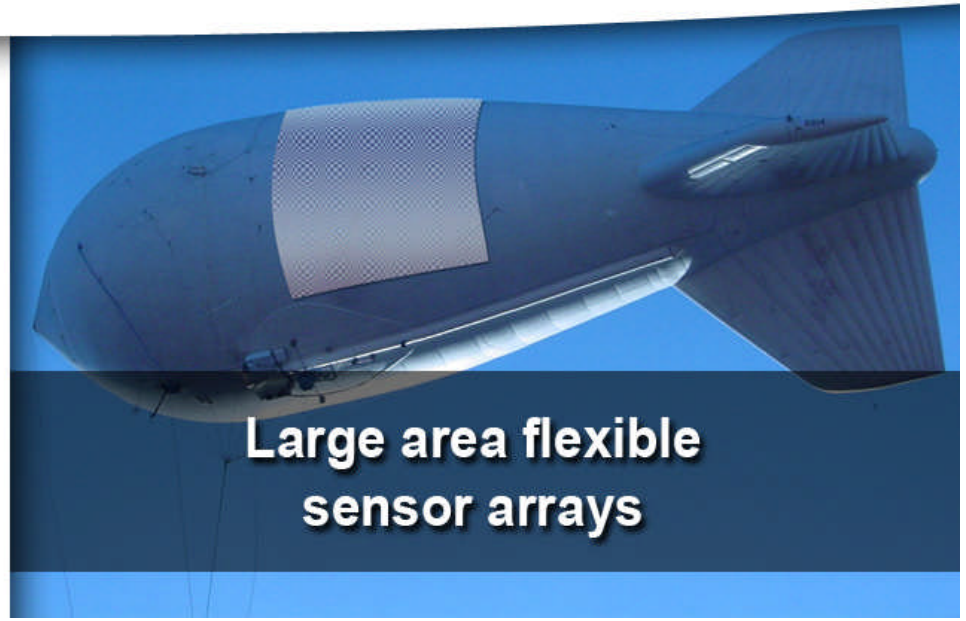
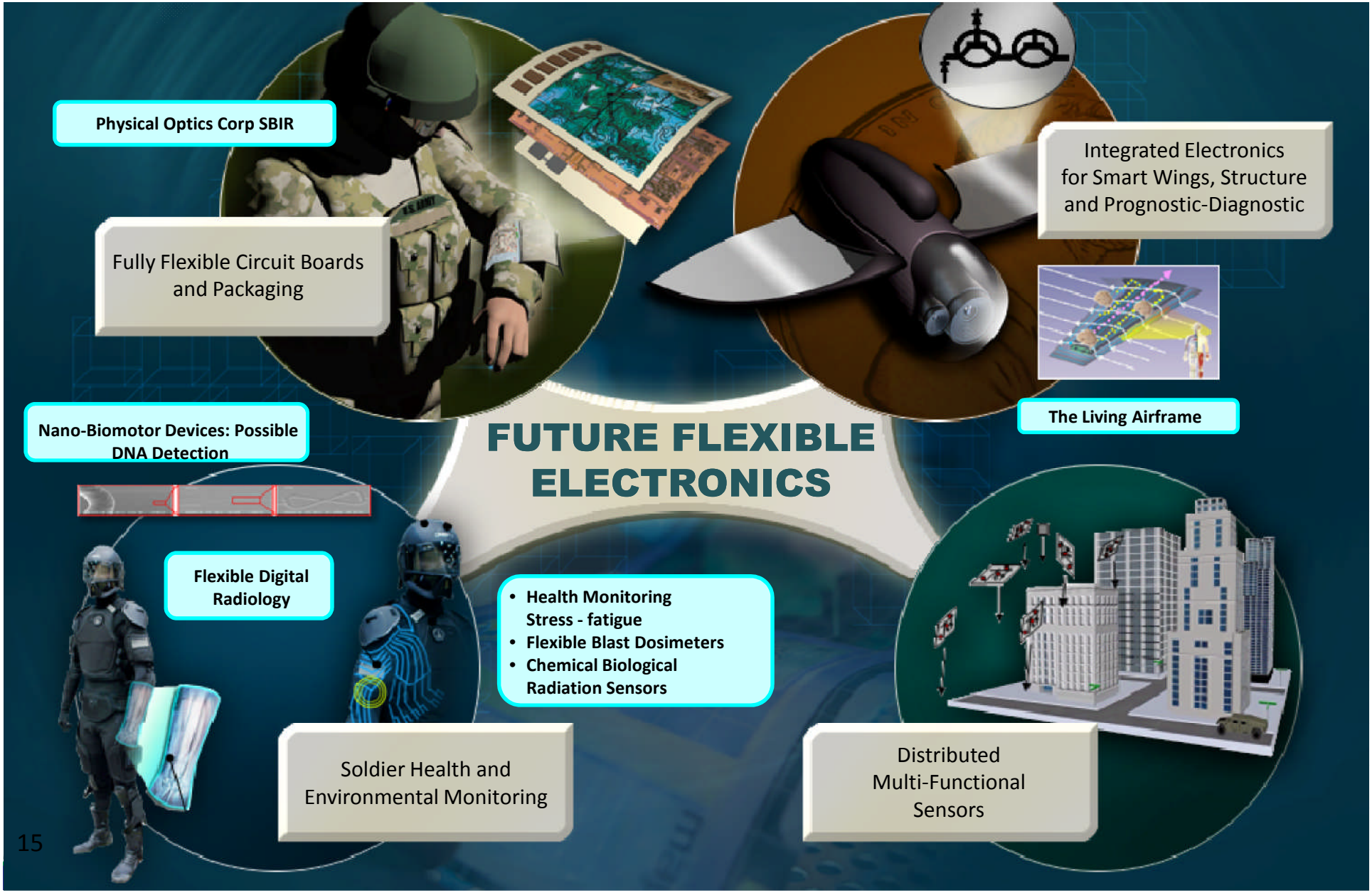
Flexible Electronics in Military Applications

PRINTED ELECTRONICS WILL IMPACT A BROAD ARMY BASE





U.S. Army -- Defense and Security Applications



MeadWestvaco: Enabled Smart Packaging

More than a container. A smart package enhances the customers product experience.

Promotes

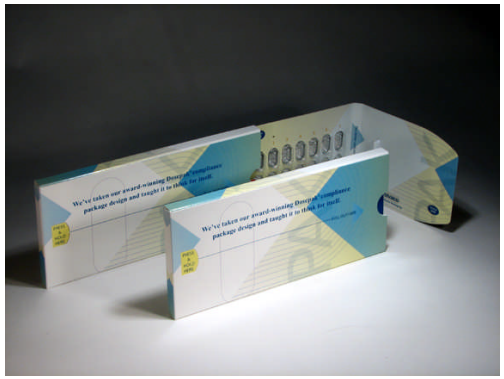
Entertain

Lights

Sounds

Interactive

Multiple Touch Points



Informs

Prompts
Resets
Reminds
Recommends
Helpful
Motivates

Communicates

Connection
- **Wired or Wireless**

Interactive
Updates
Ease of Use
Programs

Secures

Theft Deterrence
Tamper Evident
Screamer Tag
RFID:
Attached to smart package
Anti-counterfeit

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Lots of Start-ups

innovalight is redefining solar energy manufacturing by using high precision inkjet manufacturing to replace many of the costly manufacturing steps required to make solar modules today.

PLEXTRONICS
Light. Power. Circuitry.™

Plextronics, Inc. is an international technology company that specializes in printed solar, lighting and other electronics.

kovio

Kovio is developing a new category of semiconductor products using printed silicon electronics and thin film technology.

SOLARMER Energy, Inc.

Solarmer Energy Inc. is a developer of transparent, flexible plastic solar panels, the next wave in generating renewable energy from the sun.

PAPER BATTERY CO.

The Paper Battery Company is developing energy storage devices engineered as integrated nanocomposites, enabling properties that create strong customer value propositions.

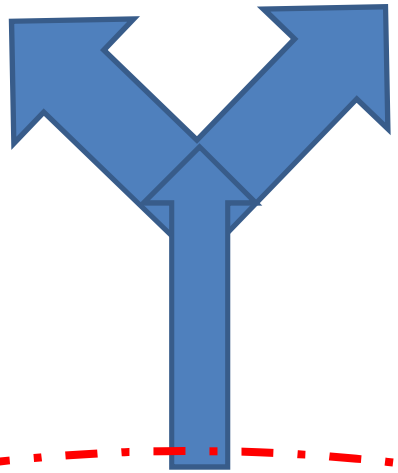
soligie® PRINT ELECTRONICS | DELIVERING THE VISION.

Soligie® is dedicated to providing manufacturing solutions for printed electronics.

What's Next?

Two Paths to Commercialization?

Good enough devices
-Suitable substrate
-Identify materials set
-Qualify a printing process
-Move to R2R



High performance devices
-Suitable substrate
-Construct materials
-Build prototype tools
-Sheet or roll
    -Lower processing temperatures

Conformable substrate
-Polymer
-Metal foil(s)
-Glass
-Other

Substrate as a system of materials

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Nanomarkets: What is Needed for Flexible Electronics?

- Flexible substrates
  - Resistant to high-temperature processes
- Low-temperature processes
  - To accommodate sensitive substrates
- Encapsulation
  - Prevent degradation, extend lifetimes
- Device layers
  - Avoid brittleness

FlexTech funded R&D in all these areas

U.S. Army: Technology Challenges

MATERIALS	DEVICES	INTEGRATION
• Organic engineered • Inorganic hybrids • Nanoparticle-matrix (printed metals) • Multifunctional • Uniquely processable	• 2-50 cm^2/V-s • CMOS, analog circuits • Operating Stability • Transistors • Sensors • Printed antennas • Energy harvesting	• Printing vs. photolith (add vs. subtractive) • Flexible substrates • Woven substrates • Leverage Chip on flex

Challenges to North American Industry

- R&D funding
- Developing prototypes
- Transition to manufacturing
  - Establishing high volume production capability
  - Cost of initial tooling /ROI
  - High volume quality assurance & control

The Printed, Organic and Large-Area Realisation of Integrated Circuits (POLARIC) is a four-year, €9.9m project involving 13 partners from seven European countries. Launched in January 2010 by the EU, the project aims to remove the barriers preventing large-scale production of organic thin film electronics to develop electronic products such as flexible sensors, photovoltaics, batteries and lighting.
the Engineer 3/25/10

The German Federal Ministry of Education and Research (BMBF) is to sponsor a €15 million project to advance the development of high-performance printable RFID tags. The BMBF will contribute about €8 million to the total project cost. One of the aims of the project is to secure Germany's current leadership as a research base in the printable electronics sector.
Cintelliq 2/25/2008

PLACE-it (Platform for Large Area Comformable Electronics by InTegration) is a 40 month €10.9M project that received funding from European Community's FP7 programme. The PLACE-it project aims to realize technology platform for lightweight, stretchable and flexible optoelectronics systems.
Cintelliq 3/23/10

12 Years of Directed Funding For Flex (2001-2013)

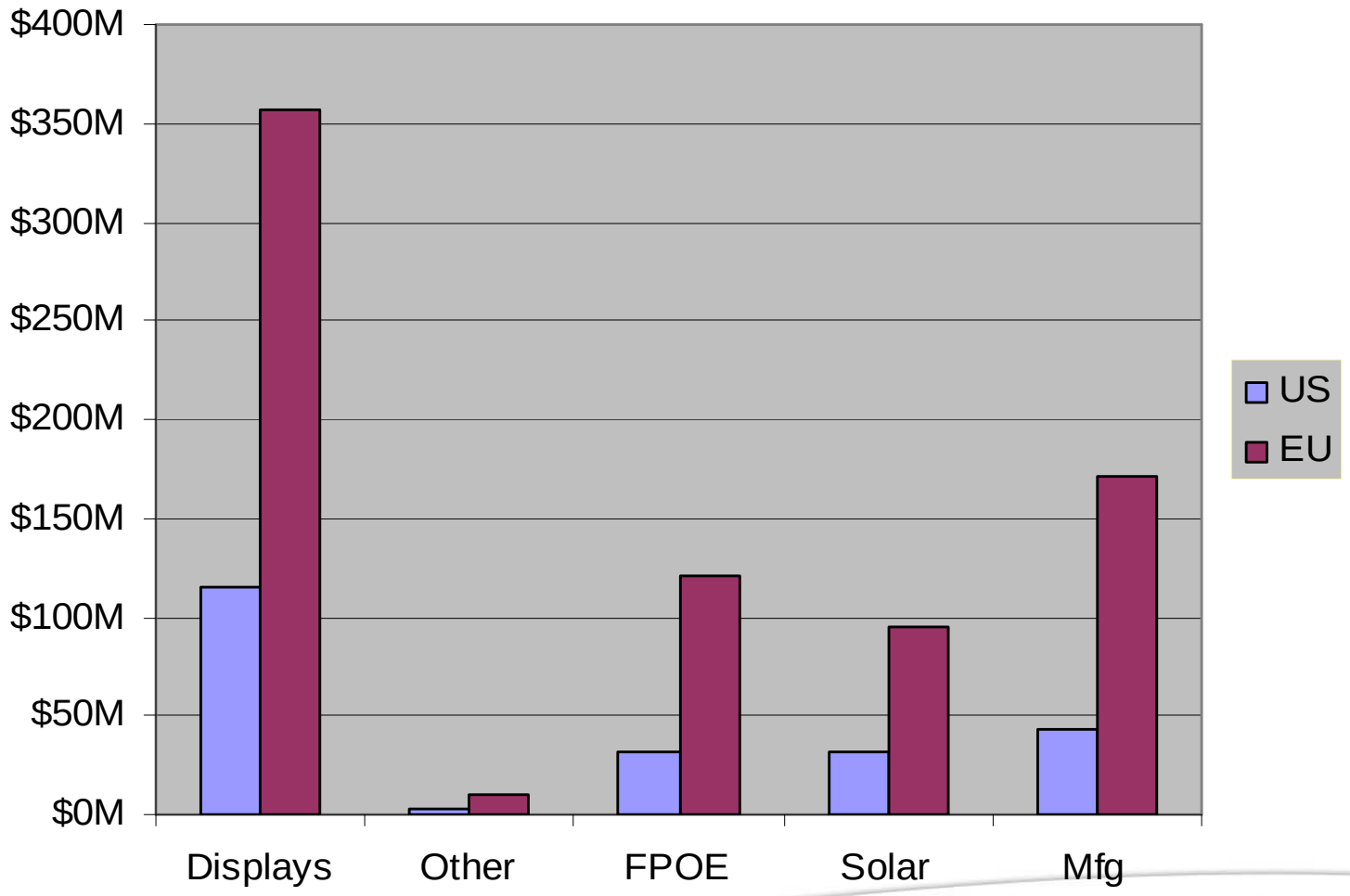
USA - $193M

- NIST-ATP, $12.2M
  - 2 Projects
- DARPA, $15M
  - Mesoscopic Integrated Conformal Electronics
  - Flexible Emissive Displays
- Army, $97.3M
  - FDC, Phase I
  - FDC, Phase II
- USDC, $69.3M
  - 44 cost-shared projects and centers

EU - $715M

- FP6, $186M
  - Advanced displays
  - Flexidis
  - Micro/nano sub-systems
  - OLLA
- FP7, $183M
  - Organic display systems
  - Organic Electronics
- BRD $265M
  - Initiative Organic PV
  - OLED Initiative
  - Smart labels
- UK $79M
  - CPI/CENAMPS

Flex Application Funding Areas
(2001-2013)



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Recent FlexTech Funded Projects

- Substrates (higher T_g - less distortion)
  - Akron Polymer Systems
  - Princeton w/ DuPont
  - Lehigh University (metal foils)
- Barrier Layers, Encapsulation, Planarization
  - Vitex
  - Dow Corning
  - Honeywell
- Printing
  - Optomec (aerosol ink jet)
  - UniPixel (high resolution ink jet)
  - Sonoco Institute (graphics printing)
  - Western Mich. Univ. (materials registry)
- Materials
  - Solarmer (polymers for OPV)
  - Polyera (high performance N-type semiconductors)
  - AKT (high performance mixed metal oxides)
  - HP (color filters)
- Tools
  - Azores
  - CHA
  - HP (imprint lithography)
  - Applied Materials

Academic Partnerships

- U.S. Army – Arizona State University Flexible Display Center (FDC)
  - Fully operational 6” wafer pilot line and Gen 2 (370 mm x 470 mm) line in former Motorola Bldg.
- Binghamton University – Center for Advanced Microelectronics Manufacturing (CAMM)
  - R&D and prototyping facility housed in Endicott Interconnect Technologies facility with lab resources from BU and Cornell
    - Azores litho tool, CHA deposition tool, ECD inspection tool and other assets
- Others
  - Clemson University – SONOCO Institute
  - Lehigh University – metal foils
  - Princeton University – flexible electronics, OLED
  - Western Michigan University – printed electronics

Some Federal Funding Sources

- National Science Foundation
- Defense Advanced Research Projects Agency
  - Mitigation of IEDs
  - Innovative medical triage and care
- U.S. Army
  - Pervasive surveillance
  - Soldier systems incorporating communications, lighting, power and sensors
- Dept of Energy
  - Energy Efficiency and Renewable Energy
  - Advanced Research Projects–Energy
- FlexTech Alliance partnership w/ Army Research Lab for supply chain development

SBIR and STTR Funding Available Starts at $150K

FlexTech's Public Policy Initiatives

- NIST and NAS have agreed to conduct a study on flexible, printed electronics
  - Launch late Spring/Summer 2010

NIST

THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine

- FlexTech has briefed White House Office of Science and Technology Policy staff on flexible, printed electronics
  - Supplied several white papers

Summary

Why Flexible Electronics?

- Form and Fit
  - Conformable substrates open up enormous application spaces
    - Textiles, buildings, paper
- Cost
  - Traditional IC lithography and vacuum processing are costly
    - Mix and match → printing → R2R provides significant savings if the target is "good enough"
- Ecology
  - Additive processes vs. removal

Why Now?

- Electronics industry always searching for new technology for markets
- Start-up capital available
  - e.g., Kovio, Novaled, Plextronics
- Early adopters available
  - Military services
- High volume consumers seeking ideas → solutions
  - Dole, P&G, SmithKline Glaxo
- Early results promising
- EU R&D spending

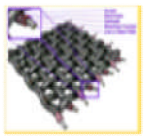
Value Chain Opportunity

Materials

Non-Crystalline Materials
Nanomaterials
Flexible Substrates and Coatings

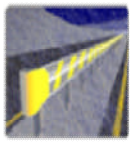
Processes

Printing and Patterning
Roll-to-Roll Manufacturing
Polymer/Organic Synthesis



Devices/ Integration

Energy Conversion
Sensors/Detectors
Thin-film Transistors



Products

Energy Harvesting and Storage
Lighting, Signage, Displays and E-Books
Smart Bandages & Clothing
Sensor Networks

Markets

Energy (flexible PV and batteries)
Solid State Lighting
Sensors (infrastructure monitoring for agriculture, civil, financial, medical, military applications)
Medical and Healthcare
Military and First Responders

Value Chain for Flexible, Printed Electronics

Significant market opportunities include thin film and flexible PV, solid state lighting, sensors for commercial and defense applications, and novel displays/communications products.

Resources

- www.cintelliq.com
- www.flextech.org
- www.nanomarkets.net
- www.oe-a.org
- www.PrintedElectronicsWorld.com

- 2010 DOE Solid-State Lighting Manufacturing R&D Workshop - April 21-22, 2010 in San Jose
- 2010 Flexible Electronics and Displays Conference Proceedings from FlexTech

FlexTech Quarterly Workshop – June 2-3, hosted by Mead Westvaco at NCSU – Smart Packaging

Thank you!

- Maria Peterson for the invitation and content guidance
- Army Research Lab, DuPont, ID Tech Ex, MeadWestvaco, NanoMarkets for info
- Thin Film Users Group

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