Challenges and opportunities for the flexible electronics industry

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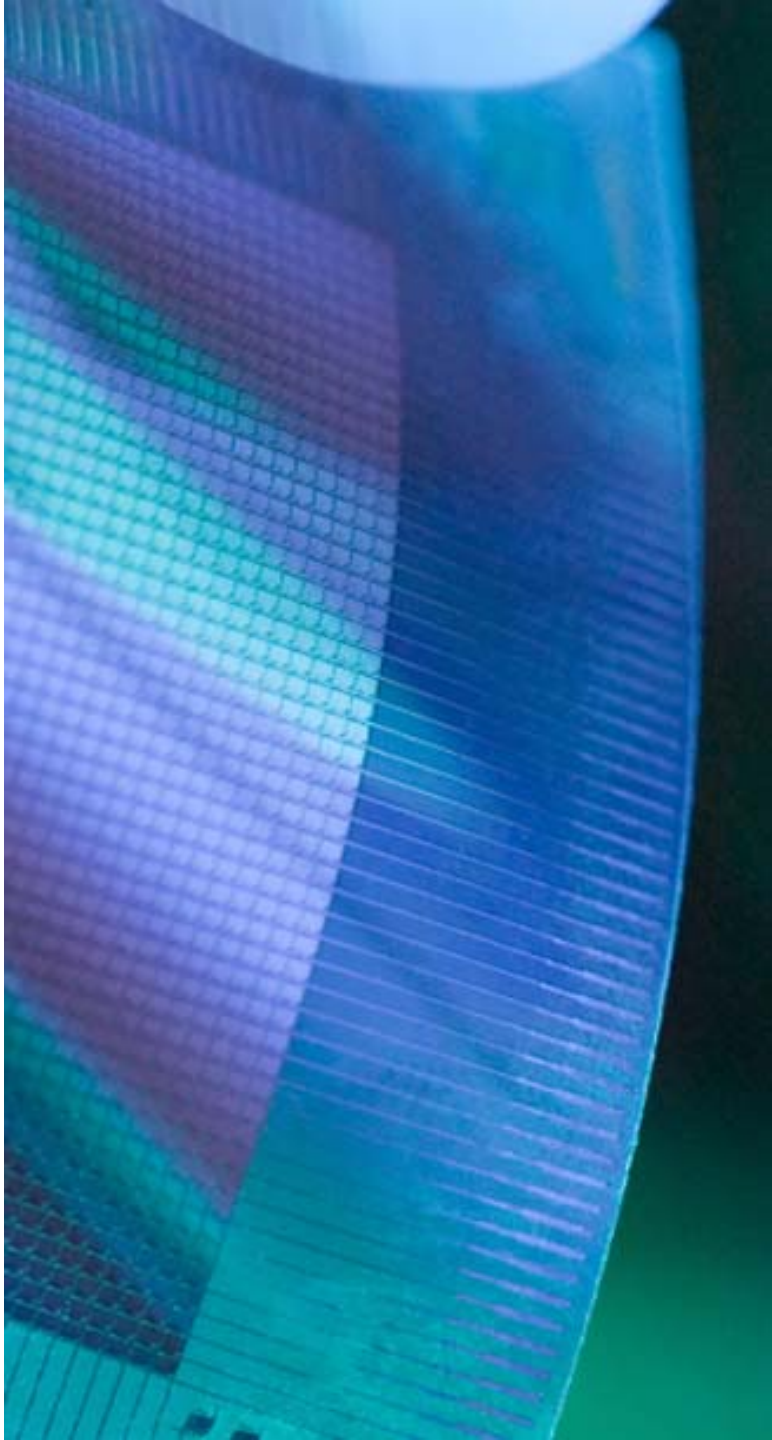

about PARC

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

- **There will be new applications that utilize flexibility**
- **And new applications that benefit from 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?

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Applications that need flexibility

- **Displays**
  - Placed on curved surfaces, wearable
  - Roll-able
  - Robust
- **Photovoltaics**
  - Placed on curved surfaces
  - Aesthetics as well as function
- **Digital X-ray imagers**
  - Conformal – surrounding the object
  - Robust
- **Medical devices**
  - Electronic patch
  - Implantables
- **Systems on a foil**
  - Wearable devices
  - Designed for people, not imposed on them

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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…….

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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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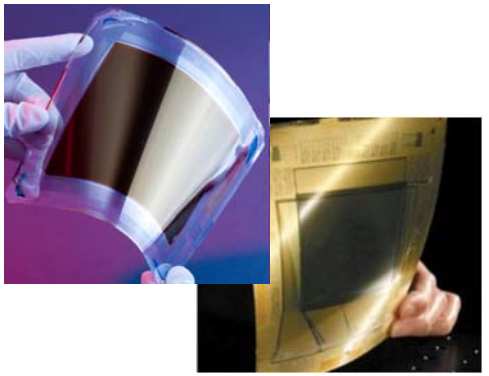
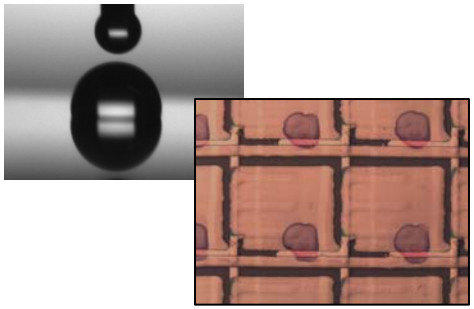
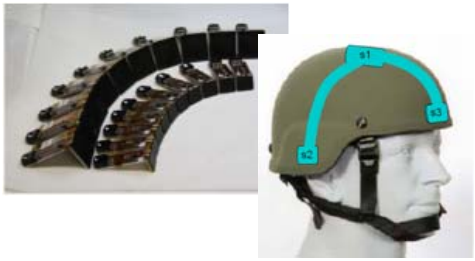
PARC's approach

- **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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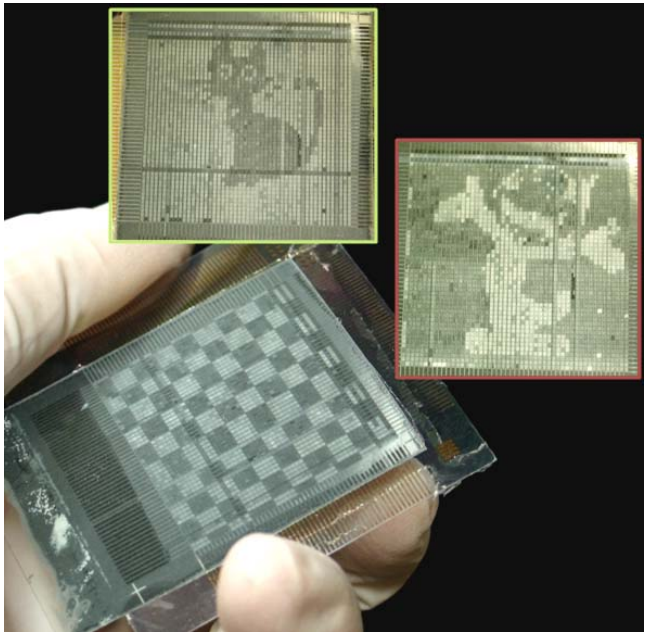
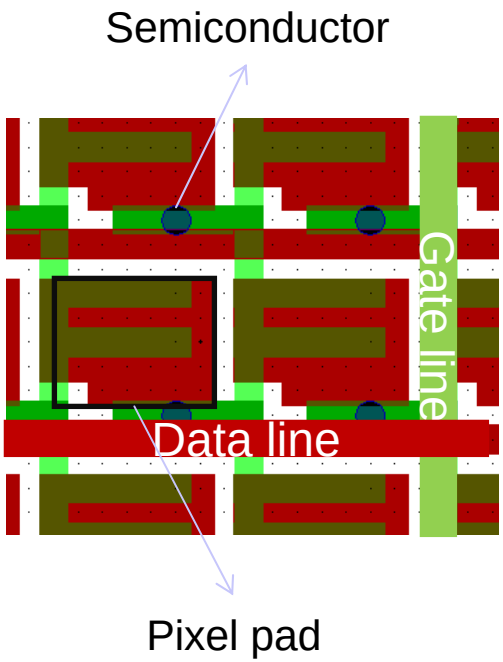
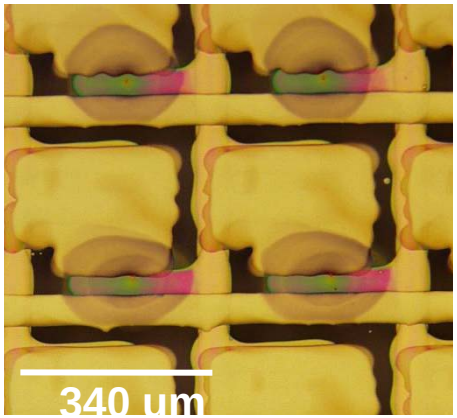
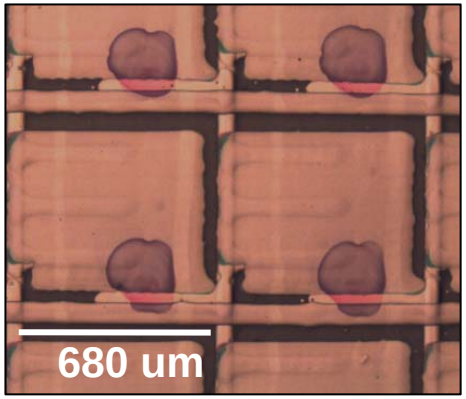
Example 1:
All-additive printed arrays









PARC has demonstrated all-printed TFT backplanes for displays

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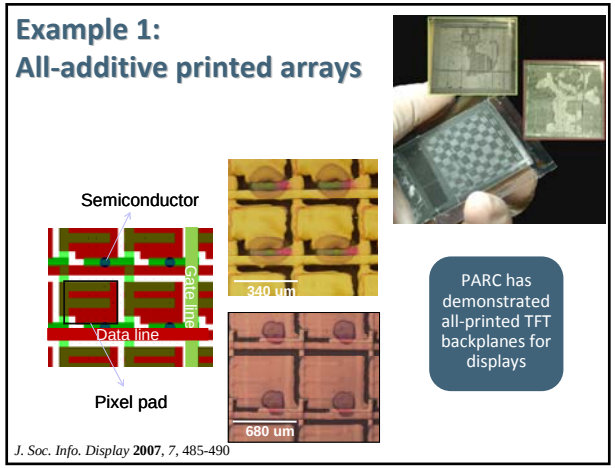
J. Soc. Info. Display 2007, 7, 485-490

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.



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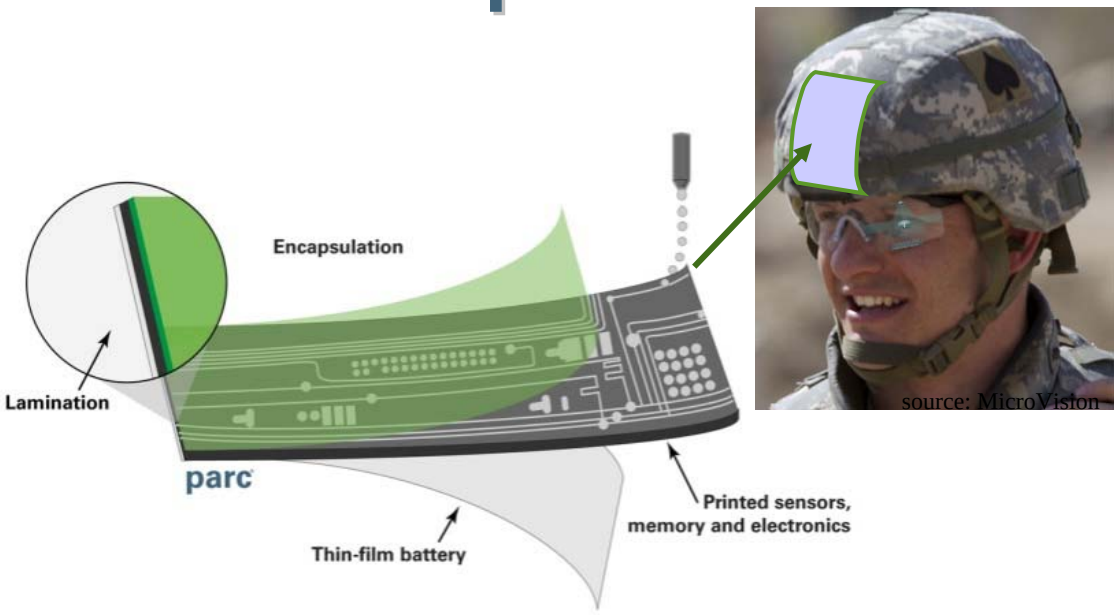
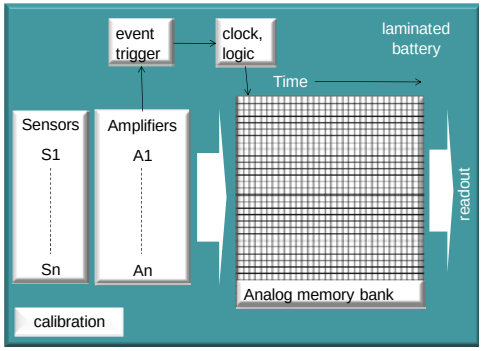
Example 2:
Printed Sensor Tape





- 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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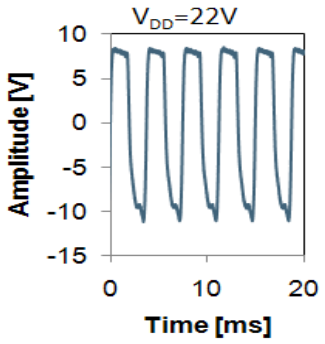
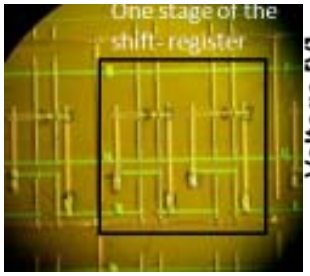
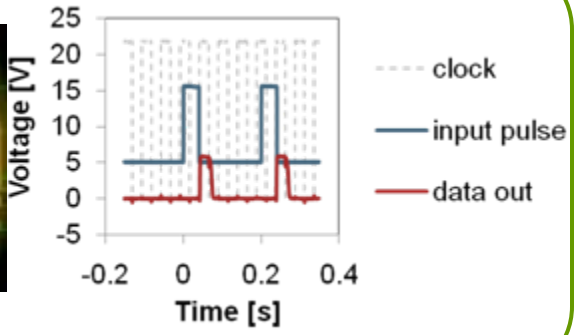
Sensor Tape: Printed Electronics

Ring oscillator

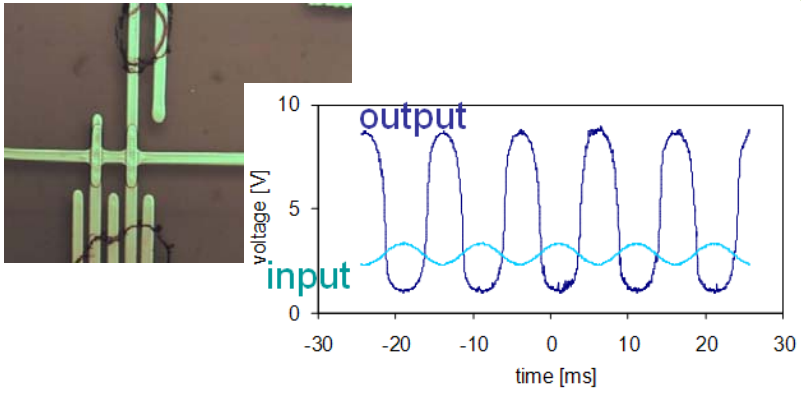


Shift Register

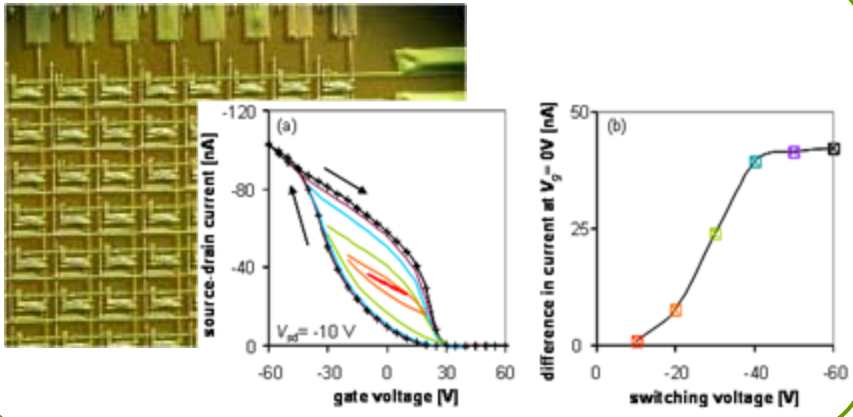




Amplifier



Memory



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

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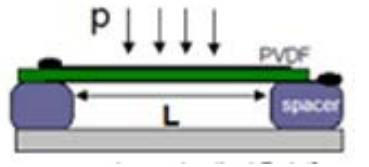
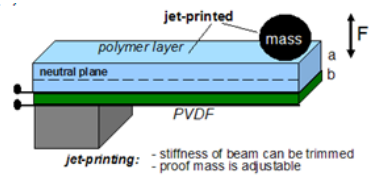
Sensors

- **Piezoelectric sensing**

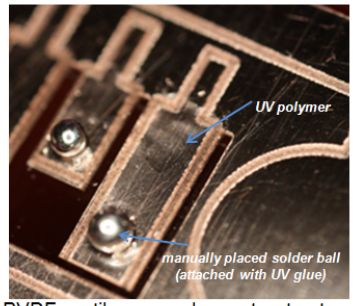
pressure



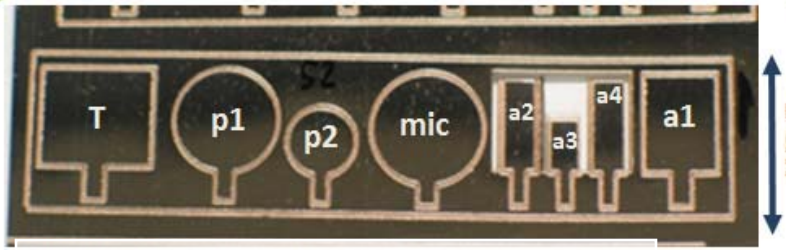
acceleration



Cantilever-based sensors



PVDF cantilever accelerometer structures
(proof mass manually glued to surface)



PVDF film with patterned sensor areas

Laminated PVDF foil or PVDF-TrFE solution

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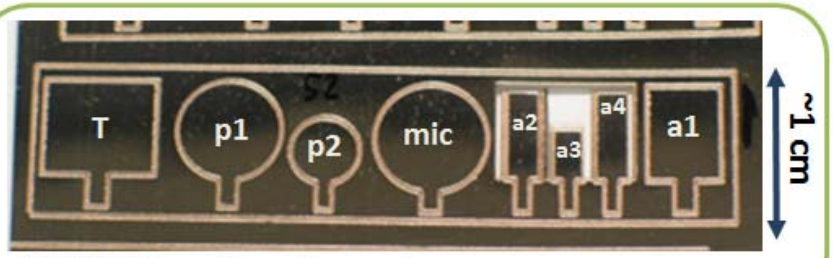
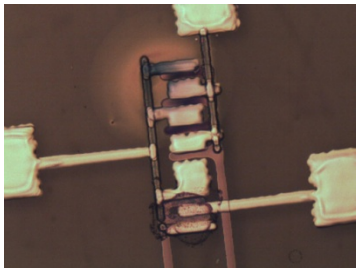
Sensor Tape: Next step: integration

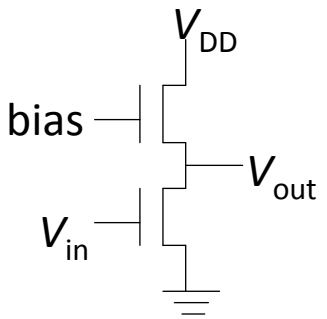
MEMS sensors

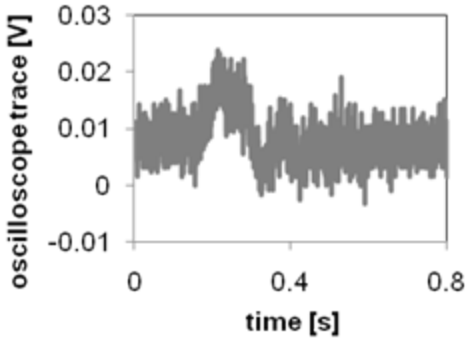


PVDF film with patterned sensor areas

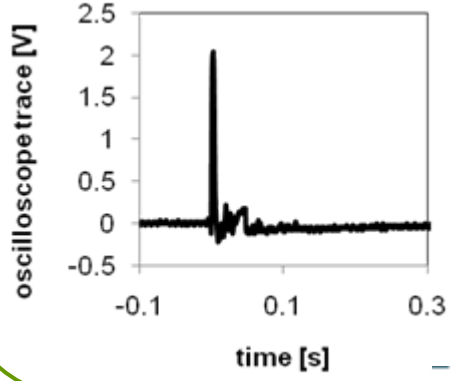
Printed organic amplifiers





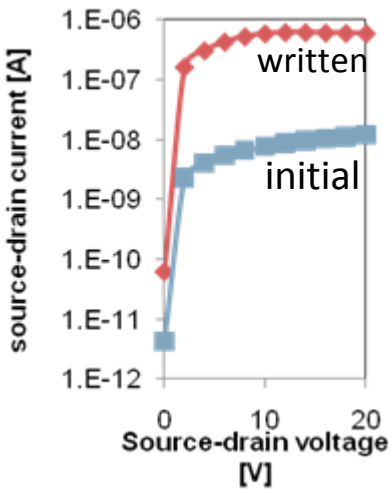


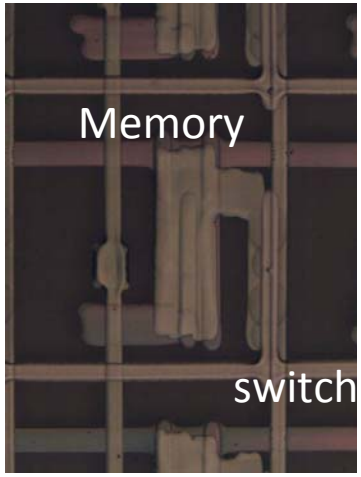
Pressure signal without amplifier



Pressure signal after amplifier

Printed memory cells

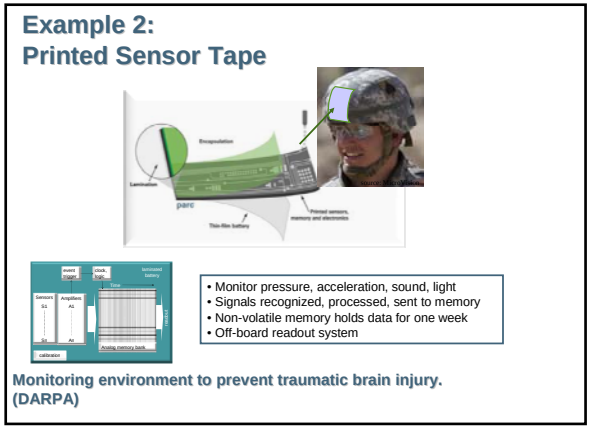




What we have learned

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

Applications need volume
Volume needs applications



  - 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:

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