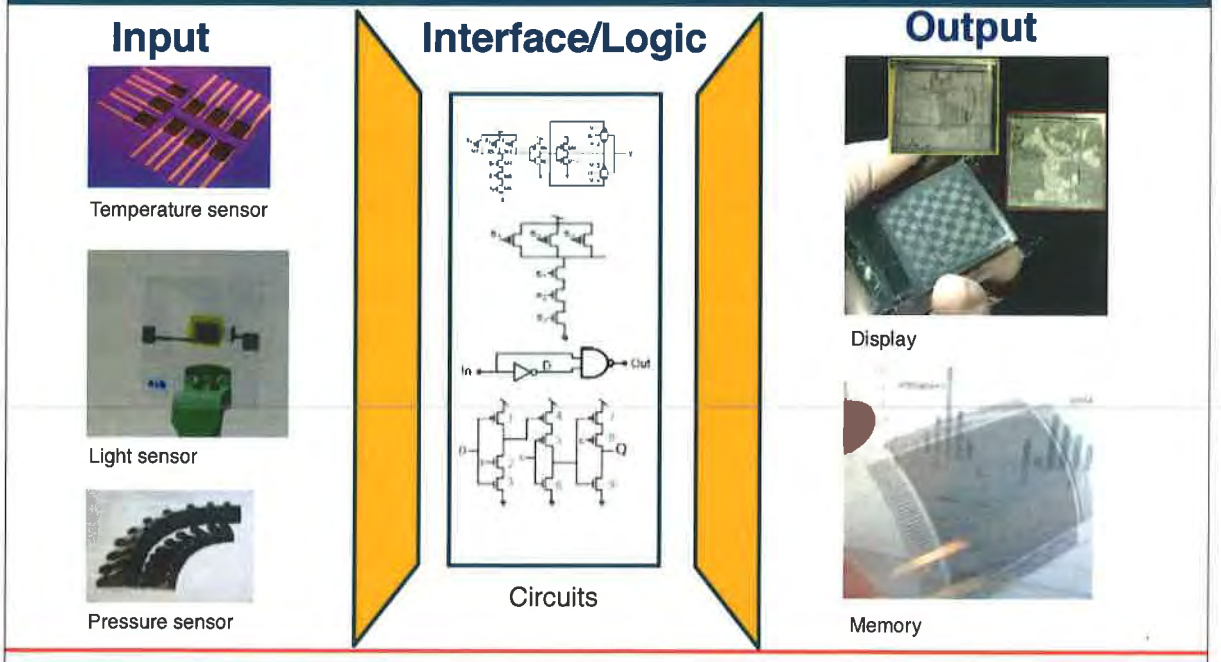
Application example: Smart Tags

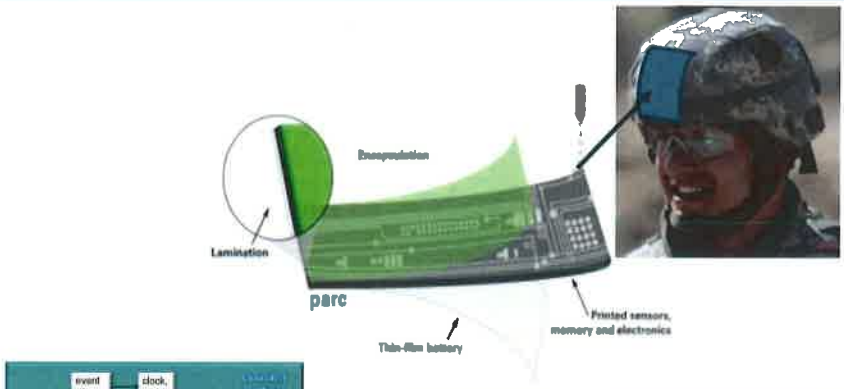
- Brand protection
- The internet of things
- Medical sensors
- Quality assurance

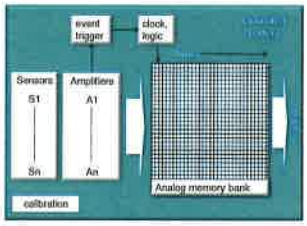
For an overview of applications, see:
http://pinterest.com/aipia

Generalized: printed sensor systems



An early example: printed sensor tape

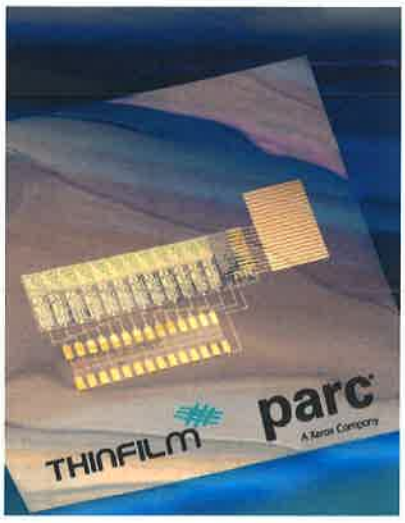




- Monitor pressure, acceleration, sound, light
- Signals recognized, processed, sent to memory
- Non-volatile memory holds data for one week
- Off-board readout system

Monitoring environment to prevent traumatic brain injury (DARPA)

Moving towards commercial reality: Thinfilm and PARC



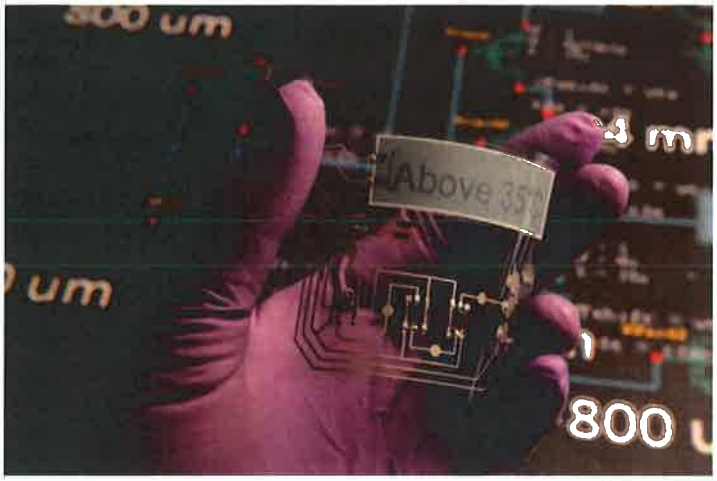
Thinfilm printed memory

PARC organic printed addressing logic

Thinfilm & PARC demonstrated read/write through printed addressing

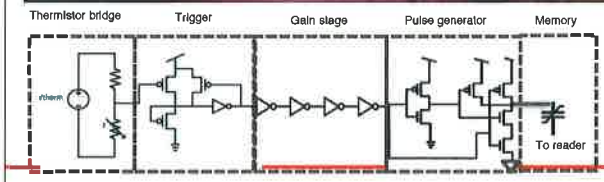
*PARC/Thin Film joint project

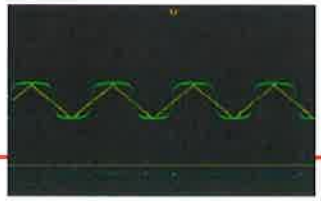
Example: Temperature sensor tag

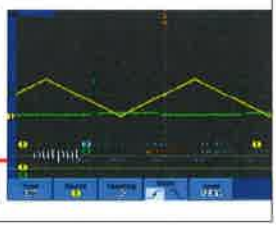


Thinfilm memory
PST sensor
Acreo display
PARC logic

*Trigger circuitry supported by Flextech







Display Backplane

Photo: Plastic Logic Ltd.
http://spectrum.ieee.org/consumer-electronics/gadgets/inside-the-plastic-electronics-revolution

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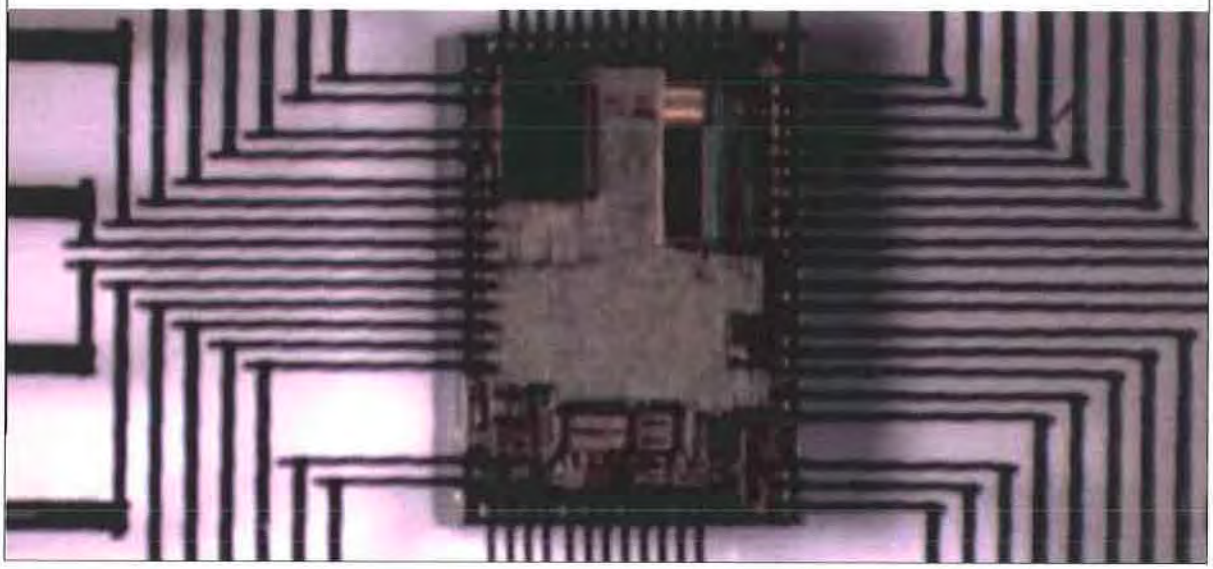
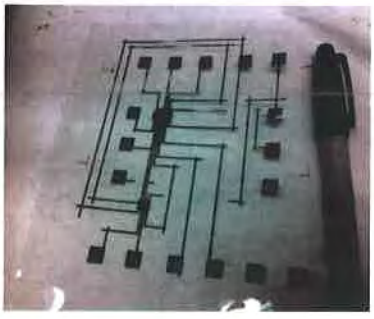
A Xerox Company

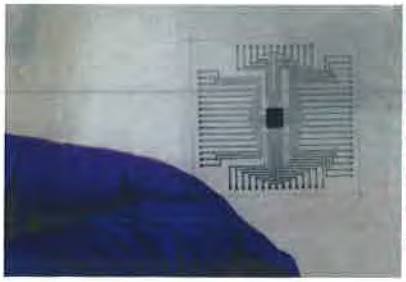
2. Hybrid Electronics

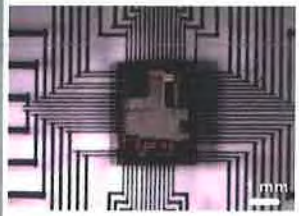


Example: Interconnects – the first step

- Ink-jet silver used for fine pitch connections (60 µm min. feature size)
- Extruded silver used for low resistance traces (~10s mΩ/□)
- Soft adhesives used for chip attachment and interconnection
- Extruded dielectric for cross-over isolation







Ink-jet wiring for bare-die interconnection

Wireless Temperature and Light Sensor System

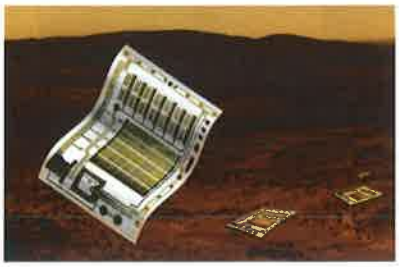
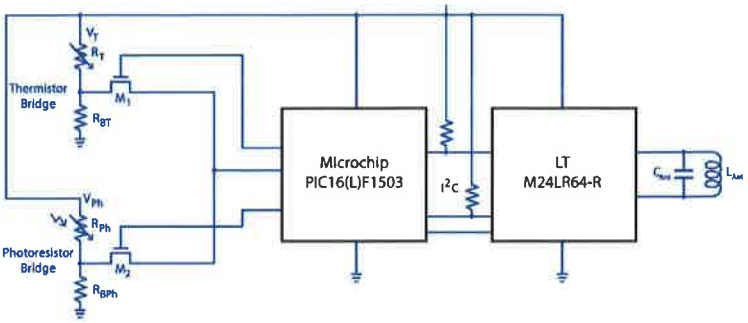


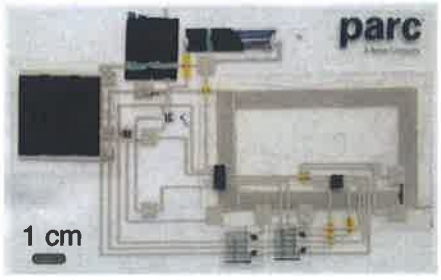
image courtesy of JPL

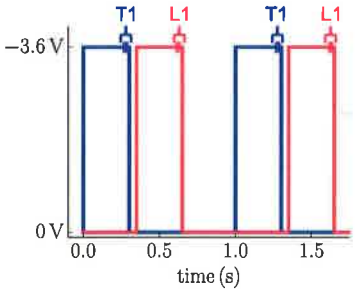


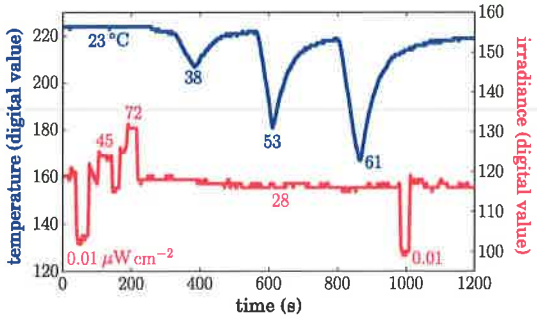
- Specific example for measuring temperature and light intensity
- Wireless data transmission
- Can be used generally for other sensor types
- Printed device, CMOS integration issues critical

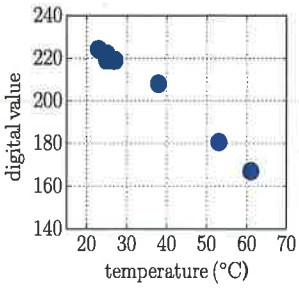
PST SENSORS · JPL Jet Propulsion Laboratory California Institute of Technology · parc A Xerox Company · BOEING

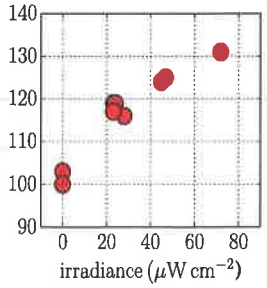
Complete System









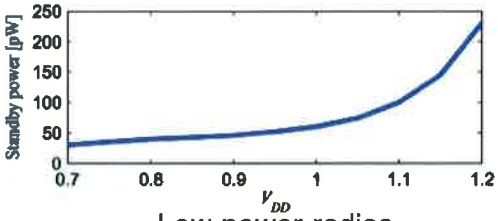


Power

- Powering low-profile flexible printed systems (particularly those with a radio) is a challenge
- Energy harvesting to directly power or to charge flexible power sources useful for some applications

imprint energy flexible batteries

PARC

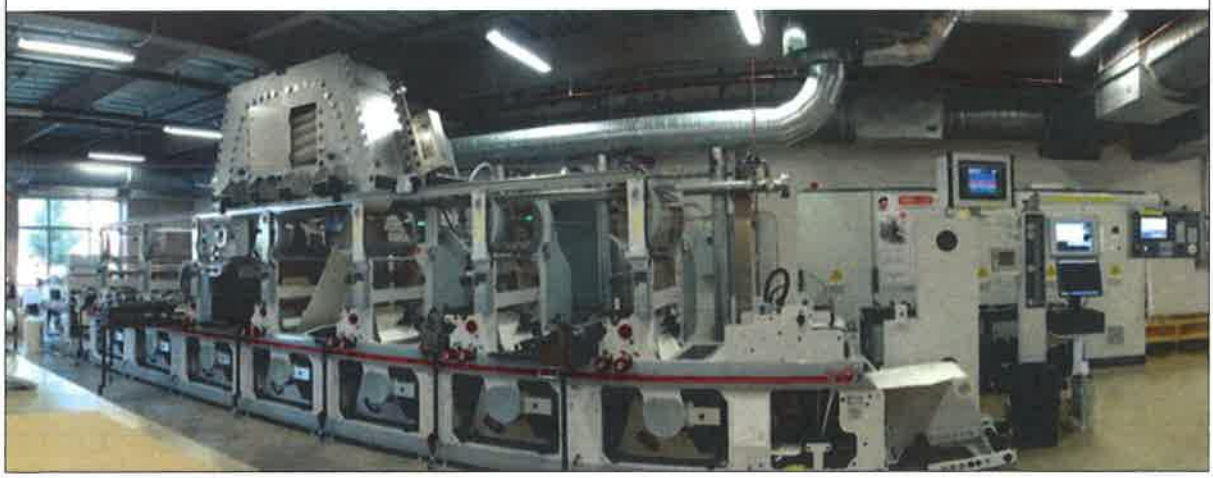


Low-power radios (UCSD/MIT)

Integrated systems (Tampere)

supercapacitors UCLA/Stanford

Manufacturing Considerations



Towards Industrial Processes

Ink-jet

Gravure

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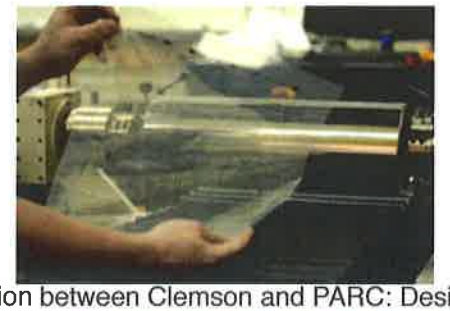
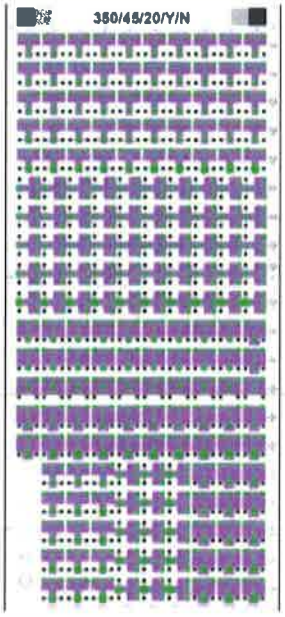


THE SONOCO INSTITUTE
OF PACKAGING DESIGN AND GRAPHICS
at Clemson University

Collaboration between Clemson and PARC: Design rules & scalability*

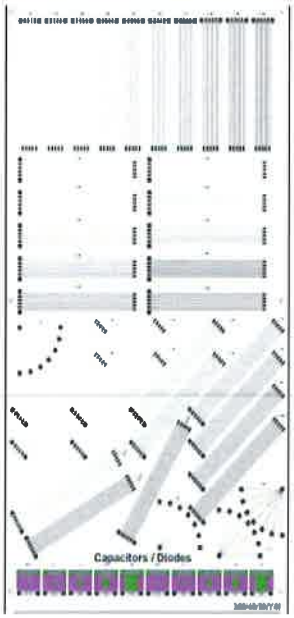
*Funded by the FlexTech Alliance

From graphics to electronics: design rules

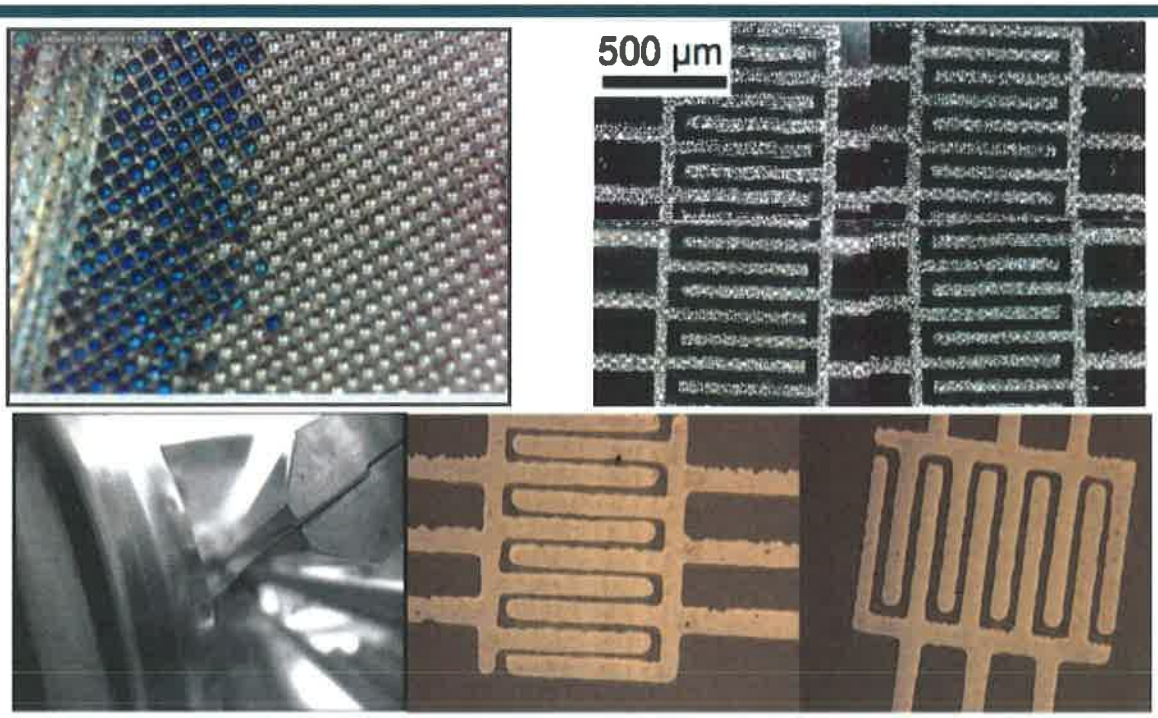


← Transistors

→ Serpentines
→ "Flowers"
→ Capacitors
→ Diodes



Gravure



3D printing + printed electronics

Early results

- Optomec + Stratasys + Aurora

- An Optomec Aerosol Jet system was used to print a conformal sensor, antenna and circuitry directly onto the wing of a UAV model.
- The wing was 3D printed with the Stratasys Fused Deposition Modeling Process.
- The electrical and sensor designs were provided by Aurora Flight Sciences, a supplier of UAVs.

www.optomec.com www.stratasys.com www.aurora.aero

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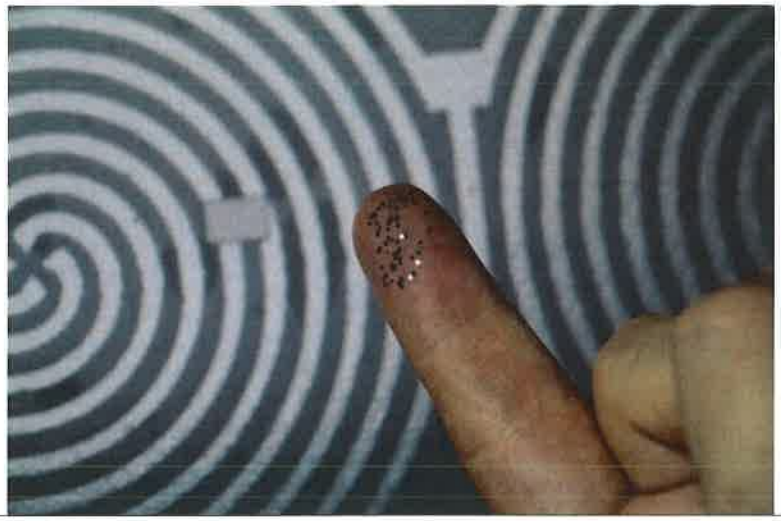
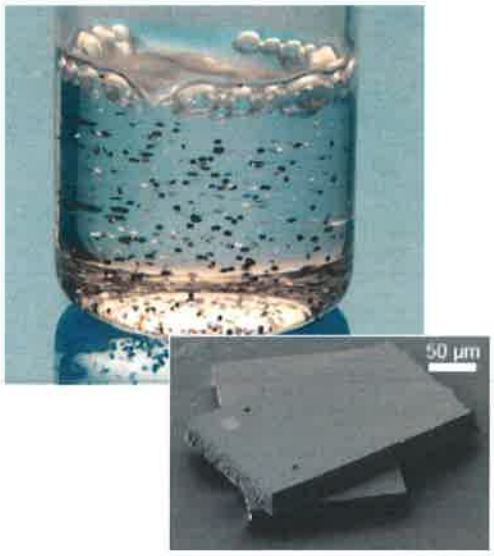
3. Assembly

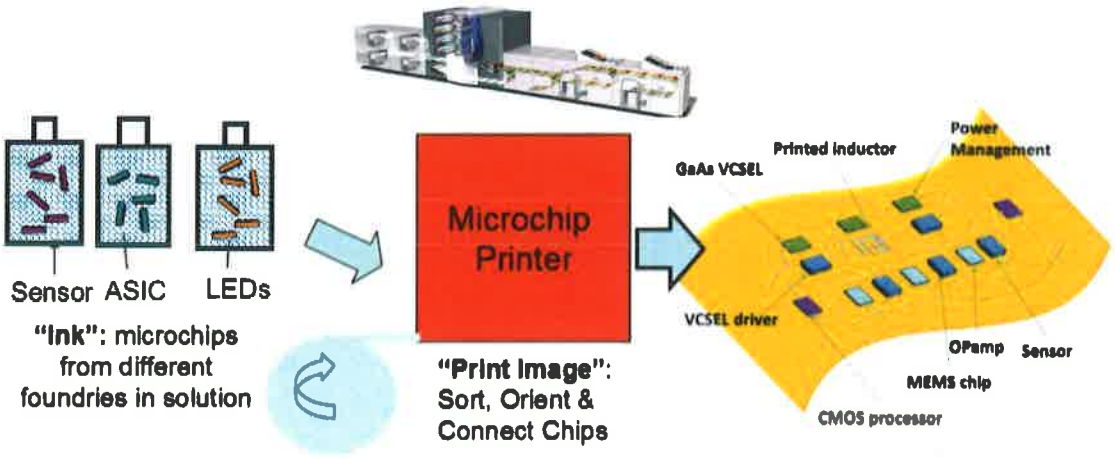


Chips as ink

- Concept
  - Utilize Si technology
  - Create different inks
    - Each "ink" containing a different chip
  - Print onto substrate
    - Manipulate to pattern circuit
- Applications
  - Multi-chip applications
  - Hybrid structures



Chips as ink: Microchip Printer

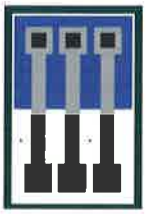


Substrate: unwind flex

Programmable, on-demand production of massively integrated heterogeneous materials and chips

Chip "ink"

Current mini library:


resistor


diode

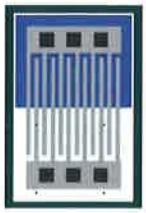


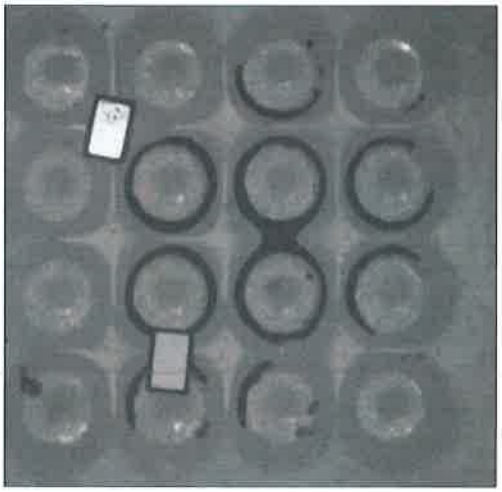
Photo sensor

Charge pattern

Manipulation and Assembly

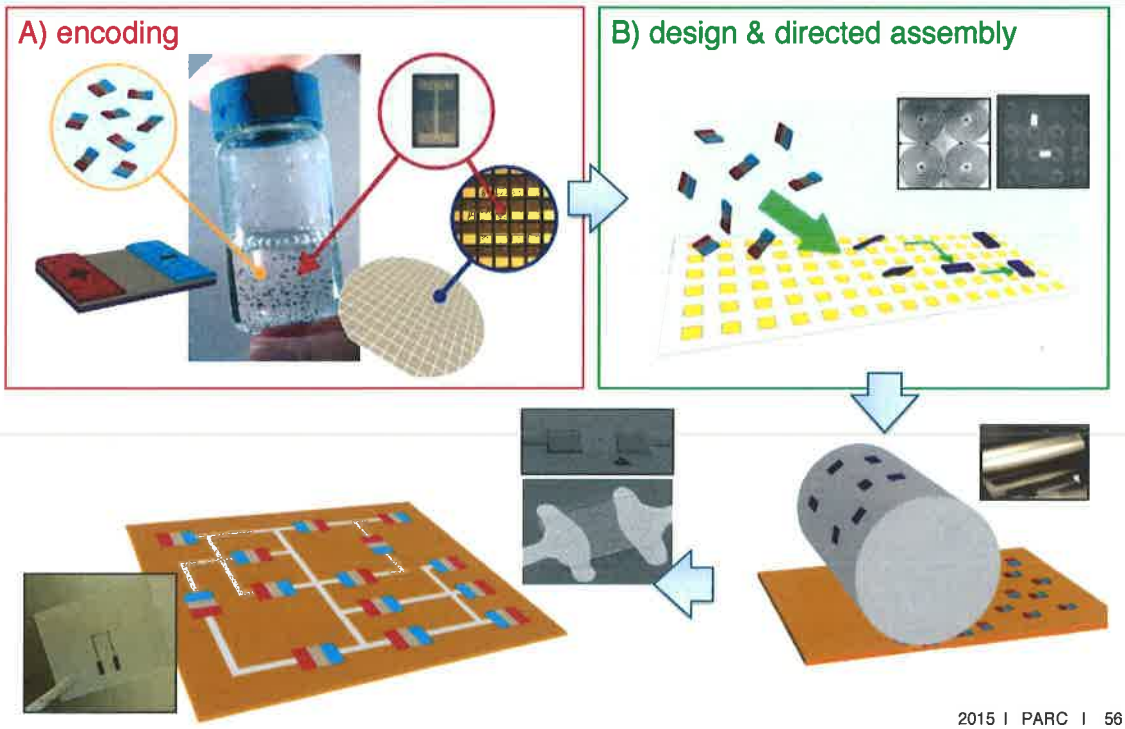
Open Loop Examples

arbitrary path



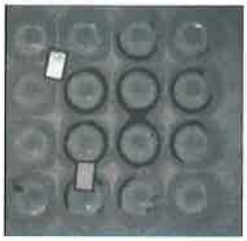
multiple chips

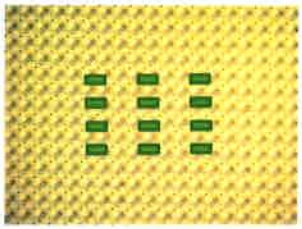
Digital Fluidic Microassembly



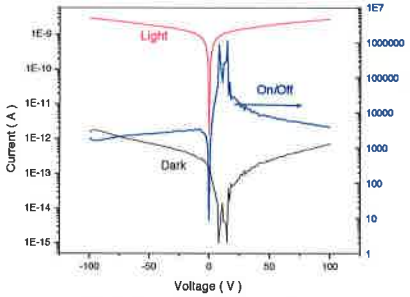
Improved Addressing Array

Use high voltage phototransistor array to convert images to patterned electric fields

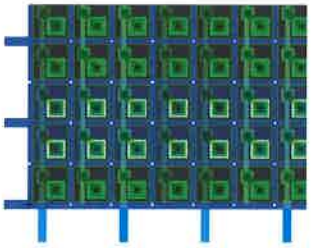




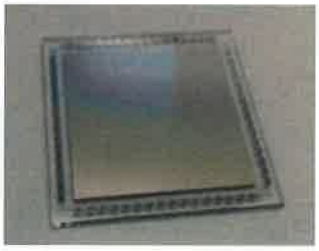
- High voltage active matrix array based on a-Si:H phototransistors
- > 10^3 on-off ratio
- > 50k element array



a-Si:H phototransistor

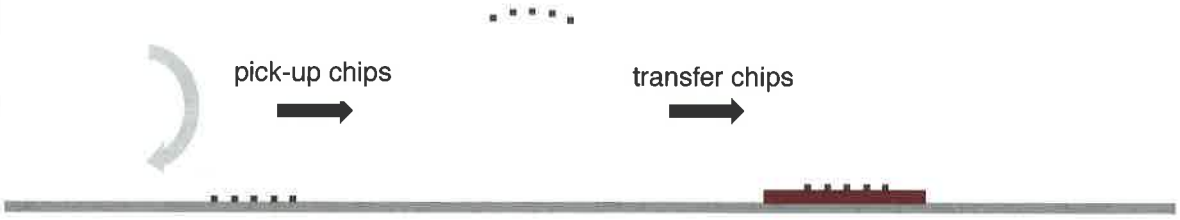


design

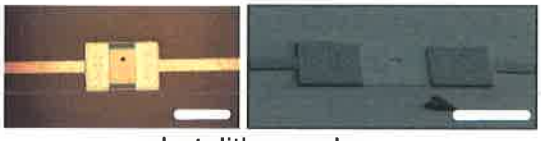


Complete addressing array

Transfer and Interconnection



chip on surface embedded



photolithography

ink-jet printing

Summary

- How can the world of manufacturing be changed
  - Democratization of manufacturing
  - Mass customization
  - Just in time delivery
- How can the printing business be expanded
  - Higher value "prints"
  - Completely new markets

Thank you

- Acknowledgements
  - The Printed Electronics and Digital Manufacturing teams at PARC and Xerox
  - Our many partners from the past and present

- Contact:

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contact PARC
engage@parc.com

Technology	Examples	Design reasoning
Printable materials & devices	chemical and biosensors, batteries, large area, flexible conformal devices and systems, (e.g., wearables, NBMC).	Device and composition modeling from material properties up.
Printed circuits	smart labels, logic and analog circuits, memory, sensors (Thinfilm Electronics & FlexTech partnerships).	Circuit design, layout design, modeling with printing constraints
Printing for volume manufacturing	gravure project with Sonoco Institute, packaging, RF shielding, metamaterials.	Design rules for inkjet, gravure, workflow
Printed Hybrid Circuits	on demand electronics (e.g. Printed Spacecraft, on demand sensors in space – in collaboration with JPL and Boeing)	Additive workflow , design rules
Chiplet printing -	Electrophotographic printing of microchips – high throughput, custom circuits and systems. High performance.	Process control
Integrated Objects -	additively manufactured objects with complex functionalities. Seamless electronics, sensing, actuators and form factor. (e.g. wearable devices, structural aircraft components, artificial limbs)	Design rules, advanced CAD, Additive workflow