

PRINTED ELECTRONICS: A PATHWAY TO FUNCTIONALLY-RICH SYSTEMS

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Why print?

● Low cost?

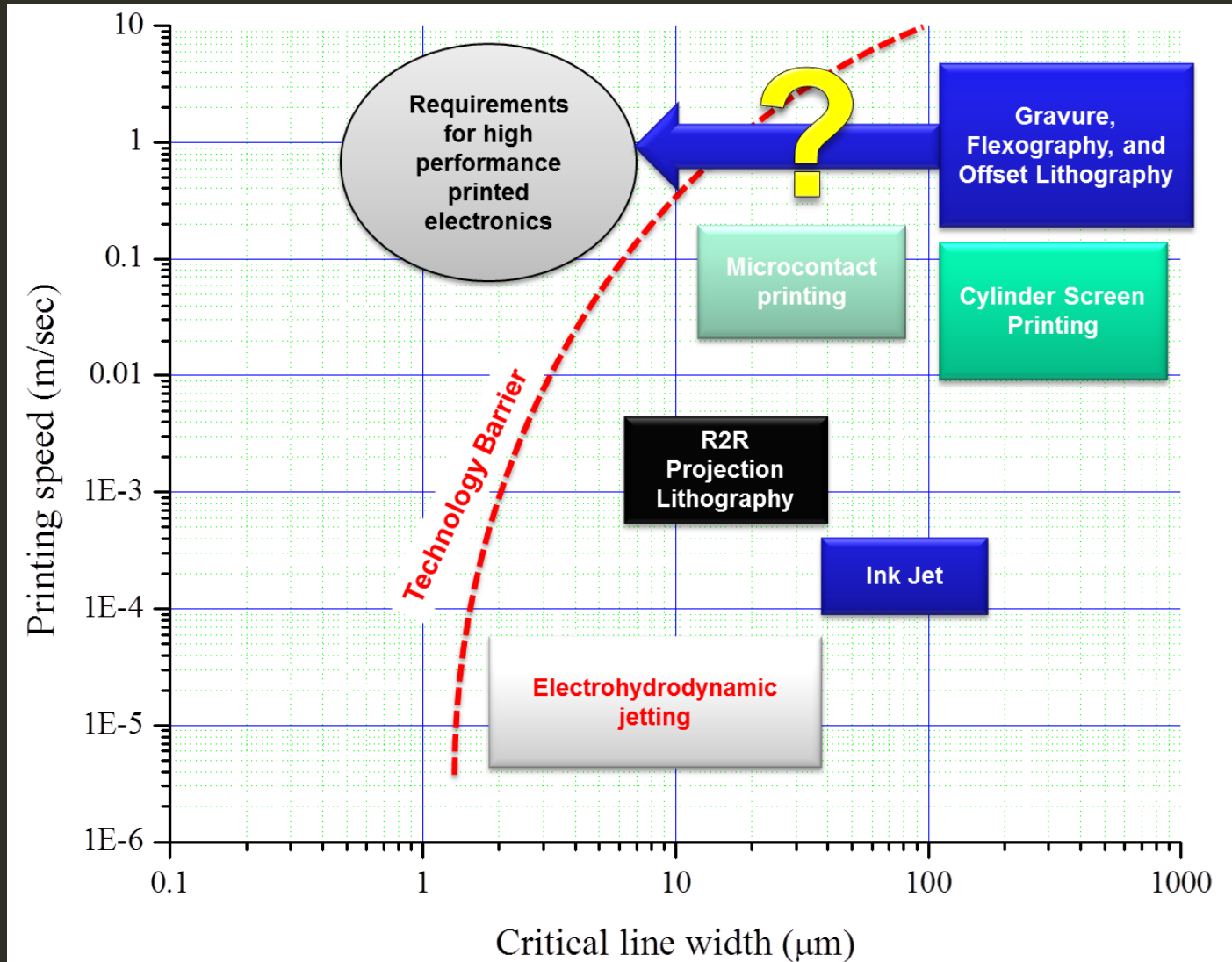


Courtesy:
G. Cho,
Sunchon National University

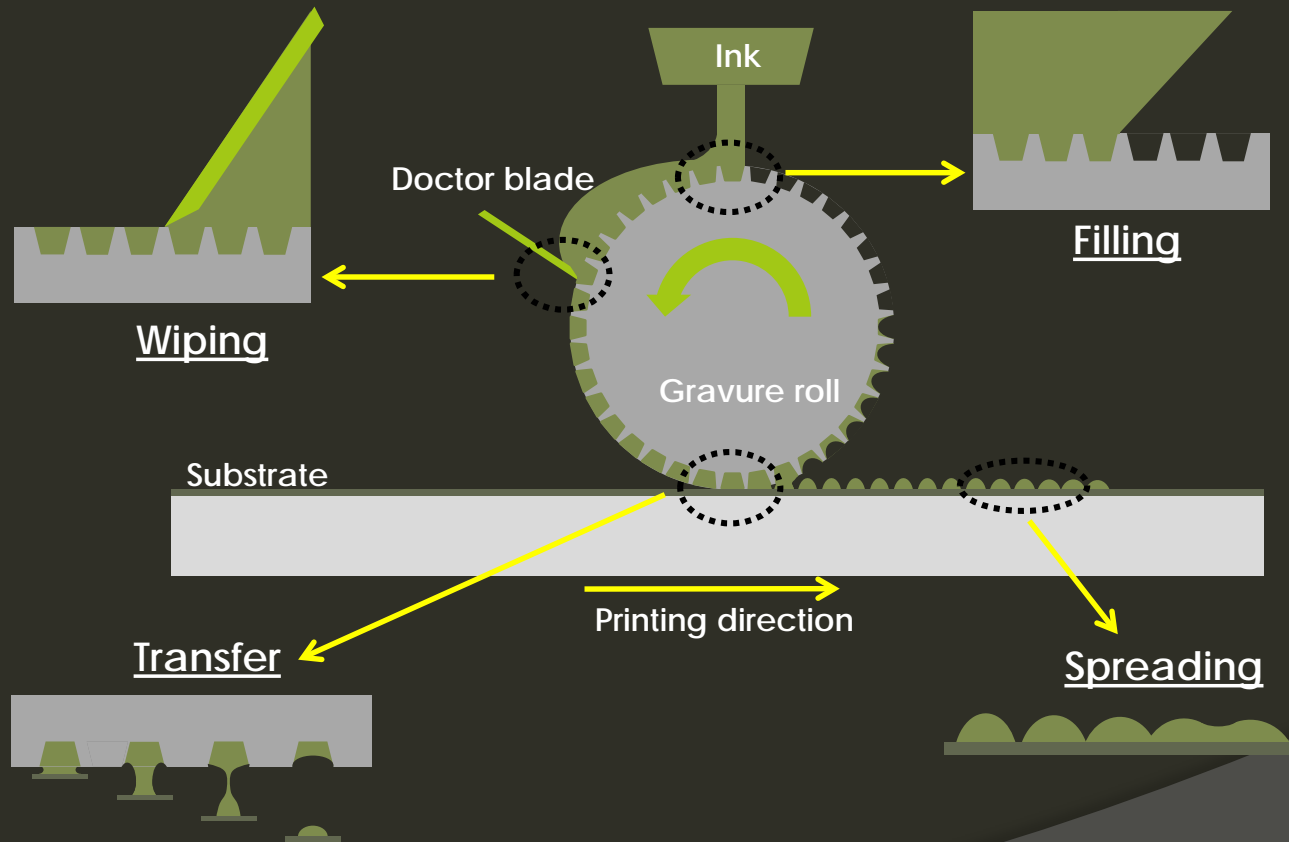
● Added functionality

- Integration – spatially specific deposition
- Customizability – digital printing
- Lightweight / robust / flexible

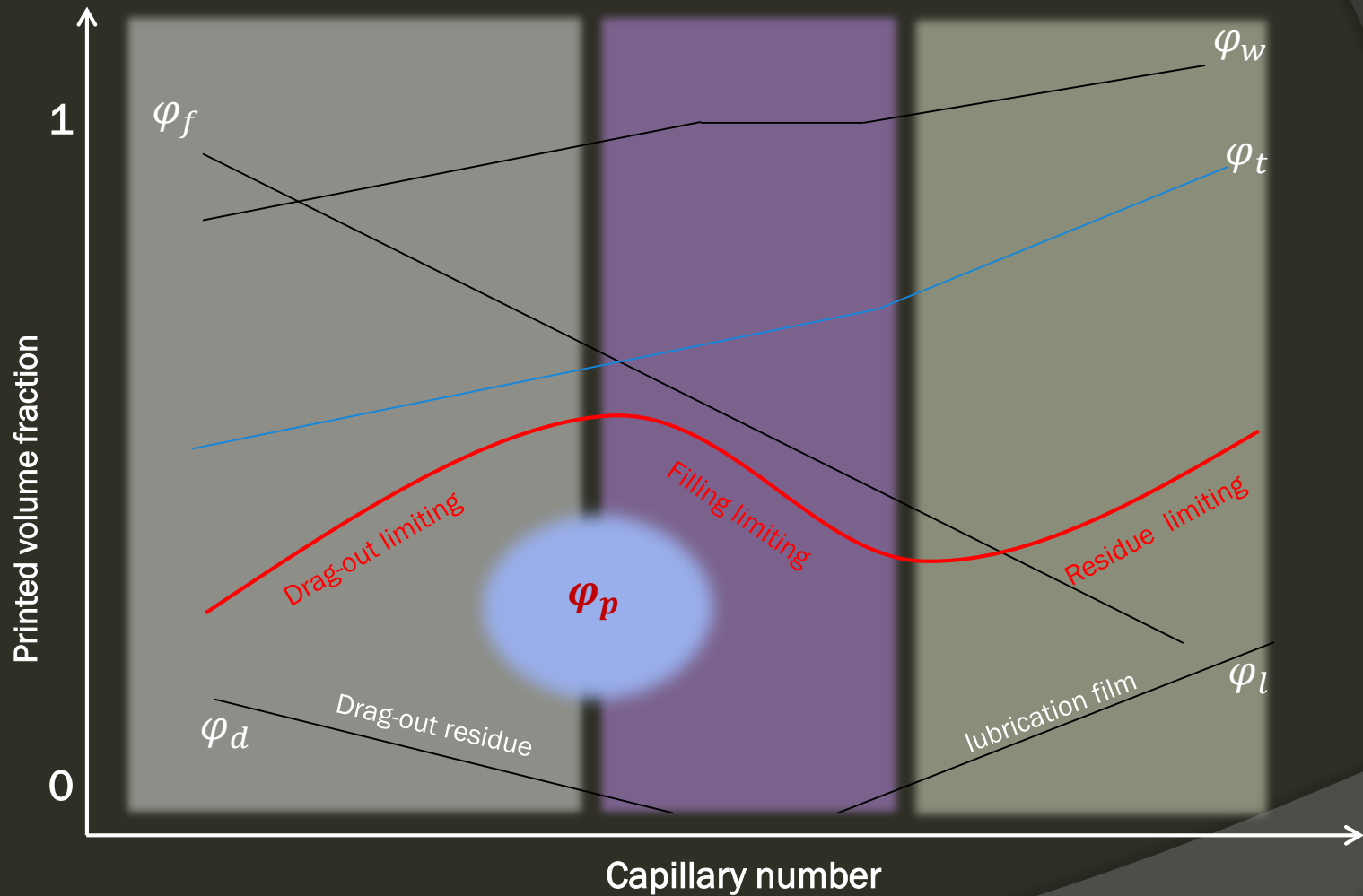
Towards a viable printing technique...



Understanding Gravure Printing

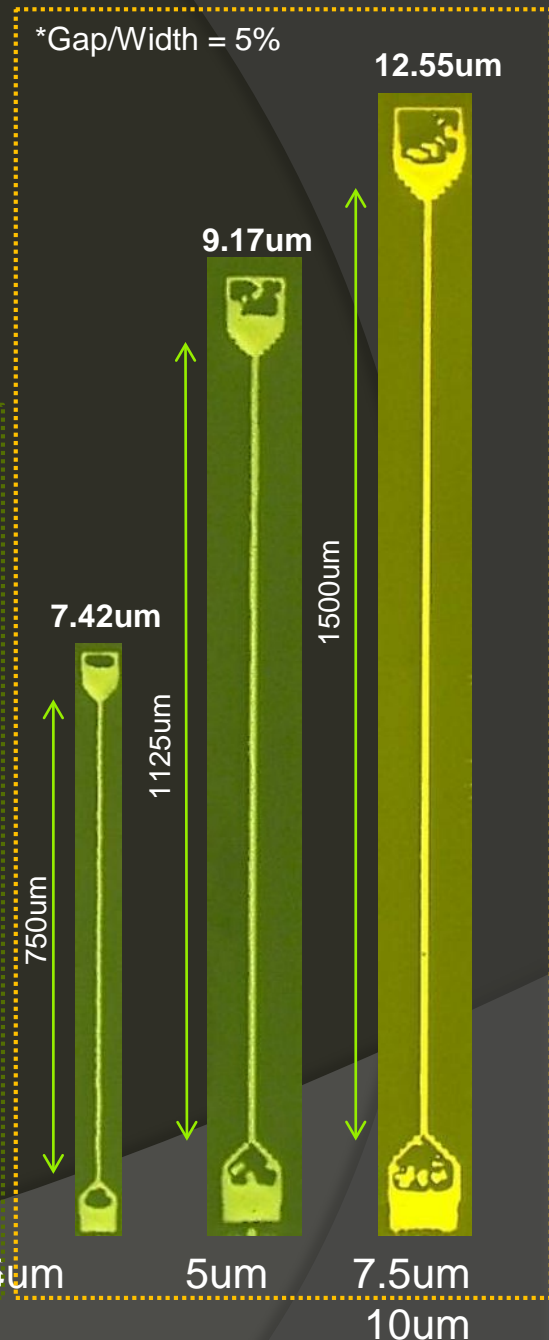
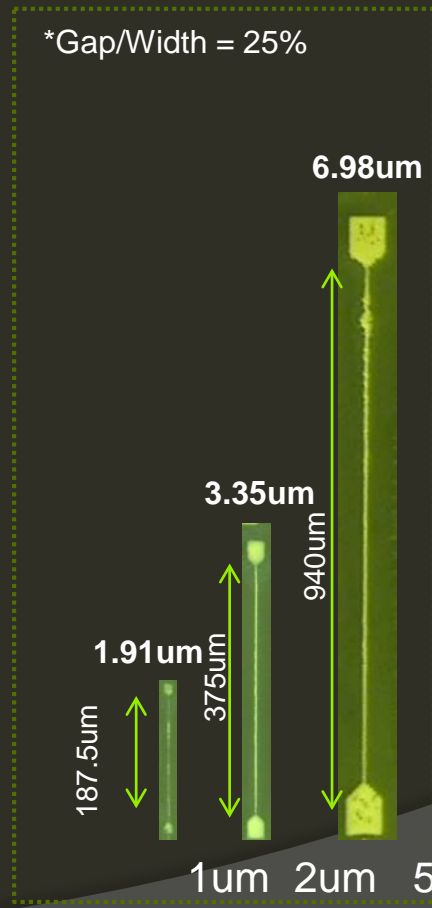
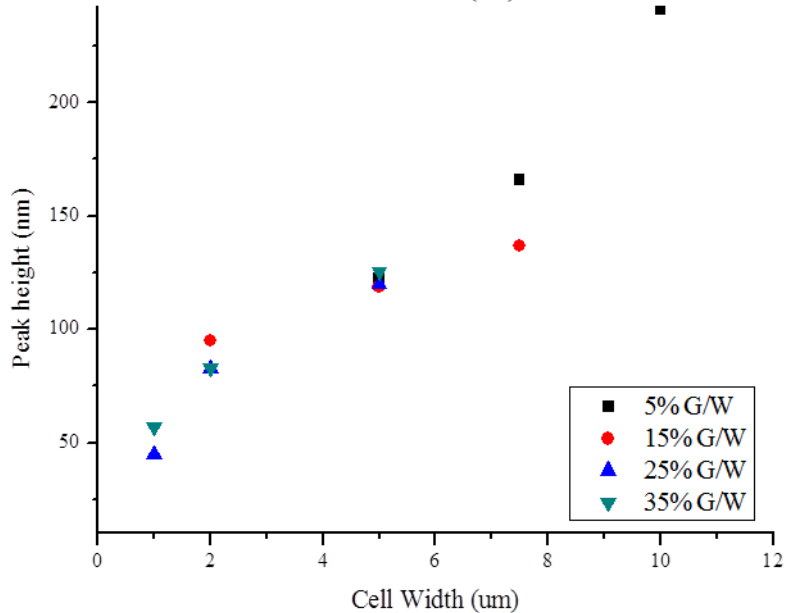
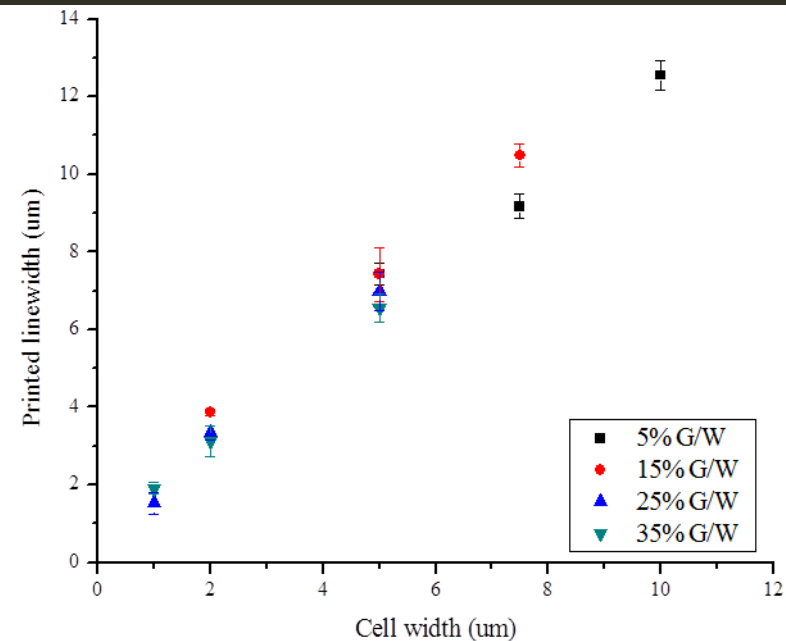


Characteristics of Gravure Printing



Printed volume fraction: $\varphi_p = \varphi_f \varphi_w \varphi_t$

Gravure Scaling



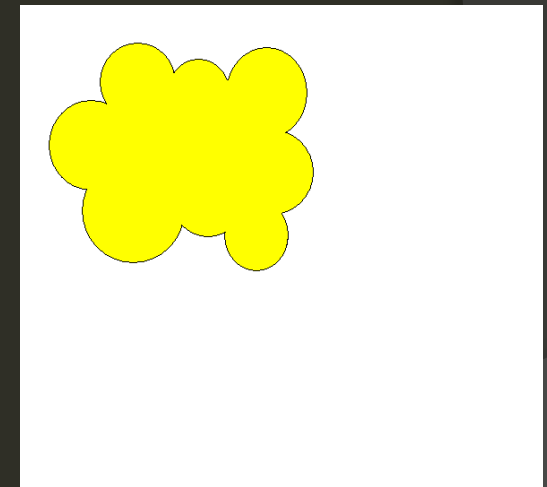
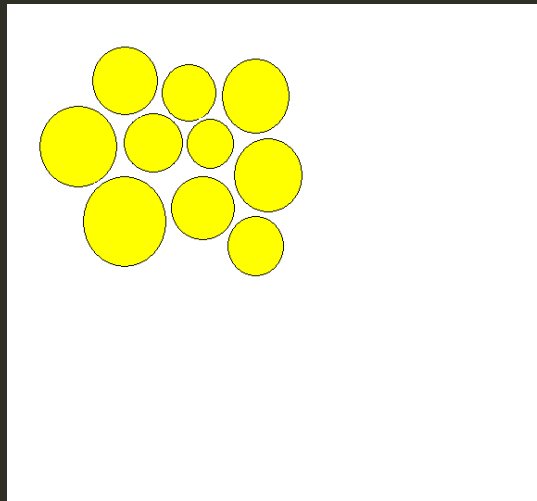
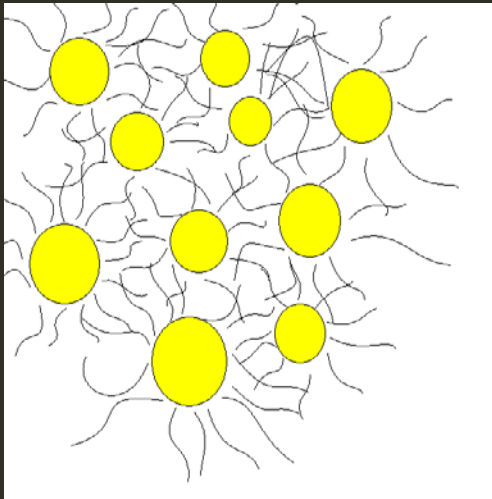
Cell width:

Nanoparticles as printable precursors

- Nanoparticles generally show a reduction in melting point relative to bulk counterparts

$$T_{melt}(R) = T_m^{bulk} (1 - \sigma / R)$$

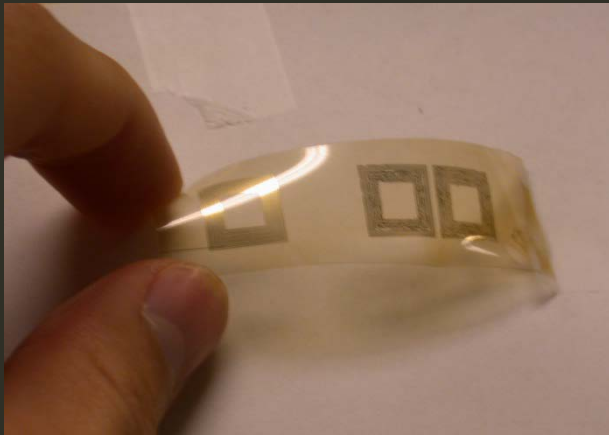
- Additionally, nanoparticles may be stabilized in solution by encapsulating them in organic ligands, which may be removed after printing by subsequent annealing



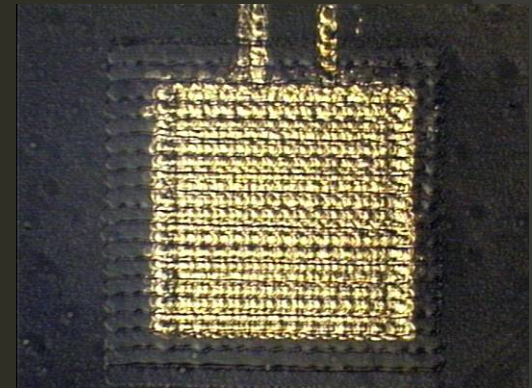
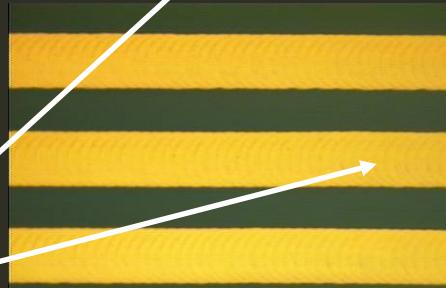
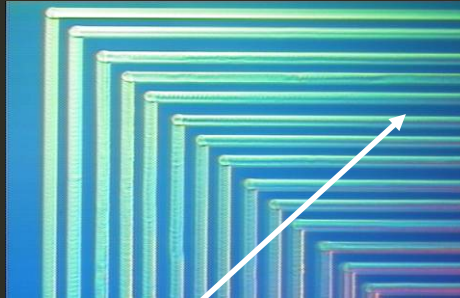
- Achieved thin film conductivity as high as 70% of bulk @ <150°C!

Passive Components

- We have made numerous passive components for use in tagging applications.

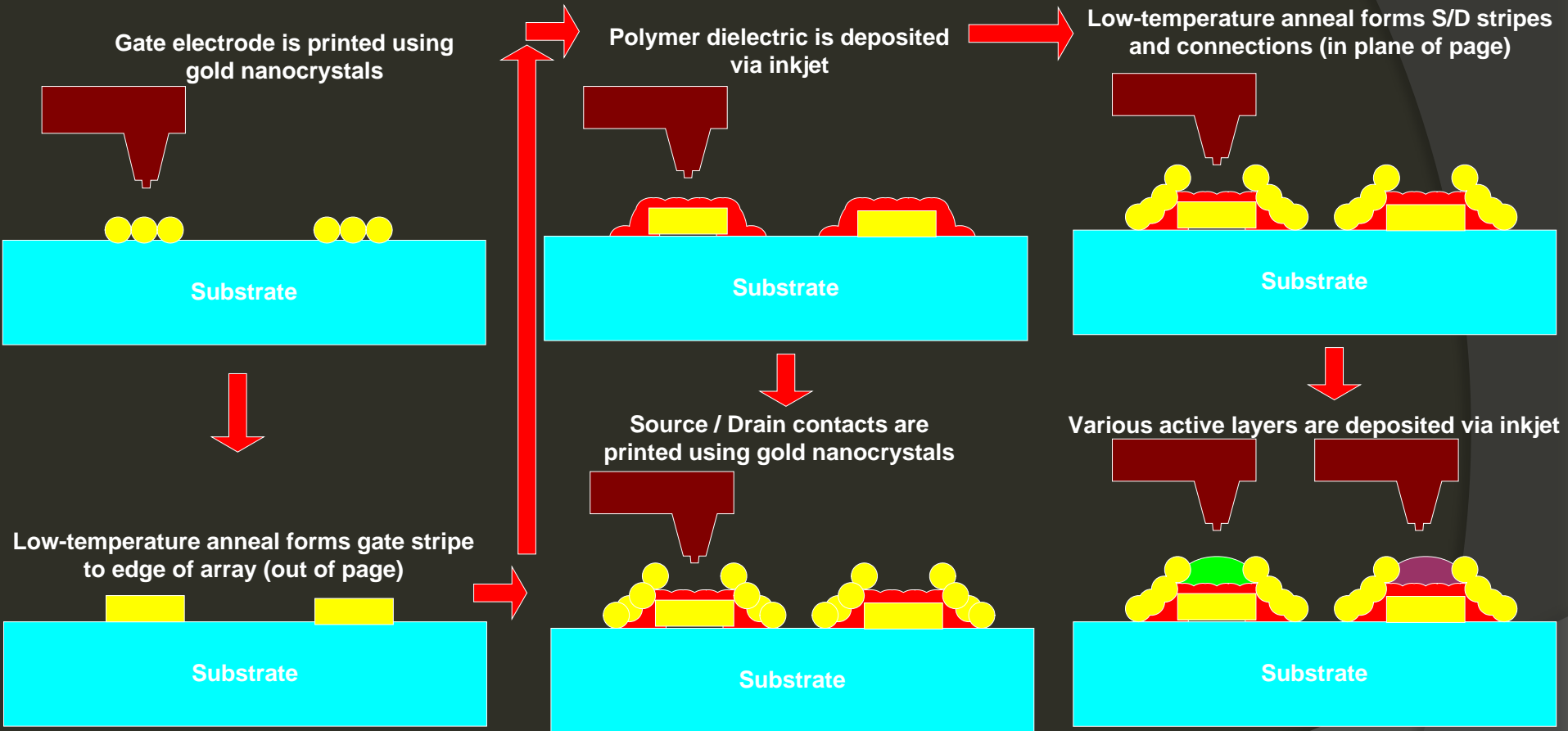


Close-up of inductor on plastic ($Q > 30$ have been demonstrated)

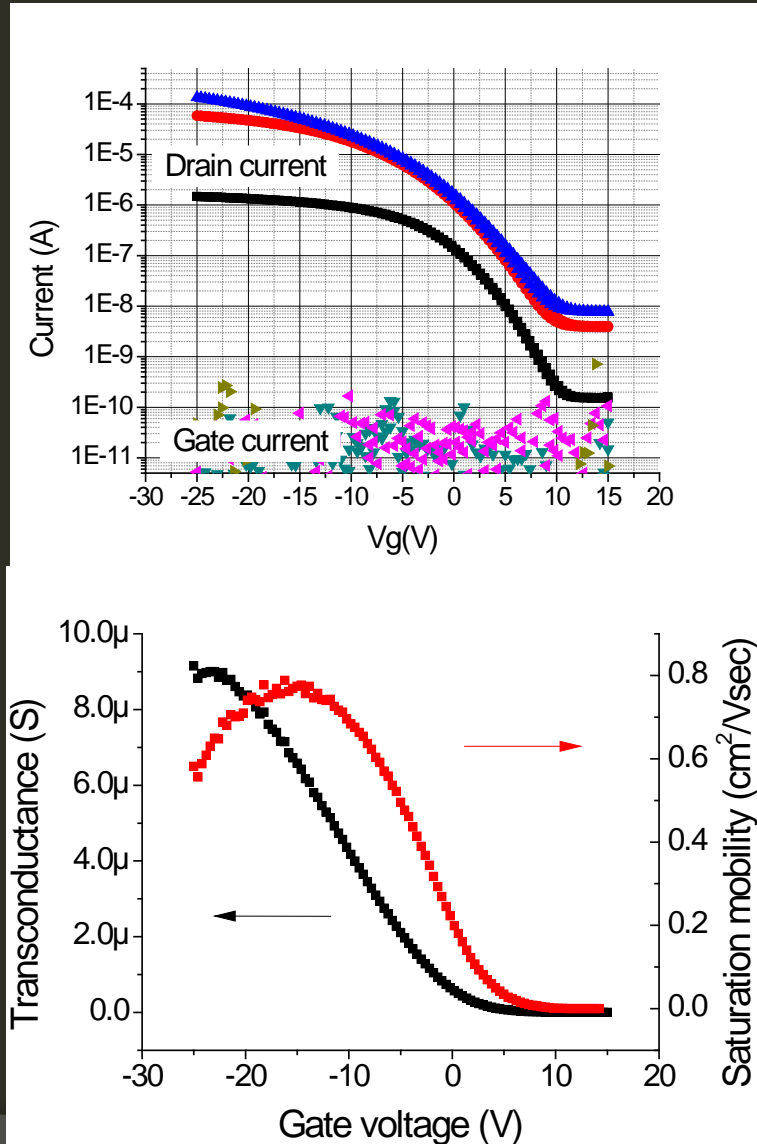


Close-up of capacitor, showing 2 layers of gold separated by 100nm of polyimide.

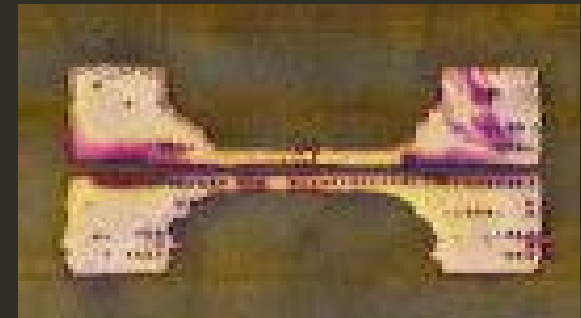
Printed Transistors



Device Characteristics



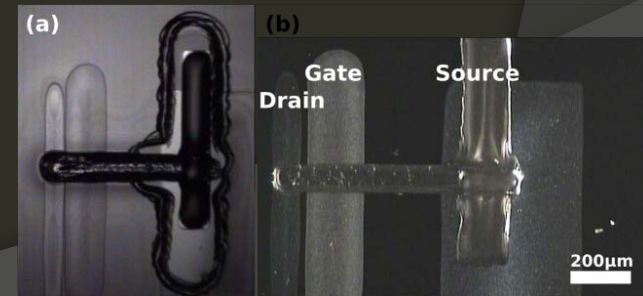
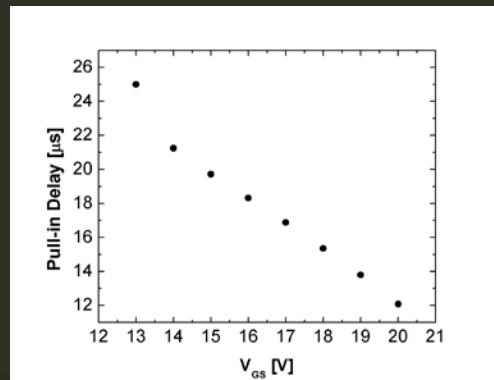
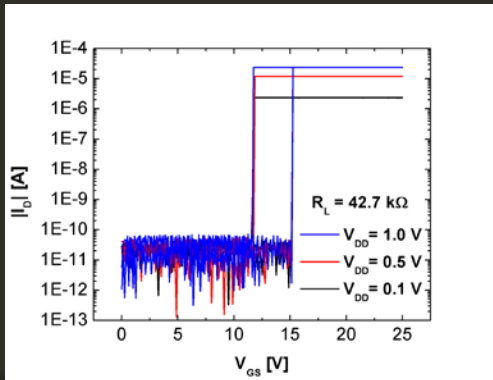
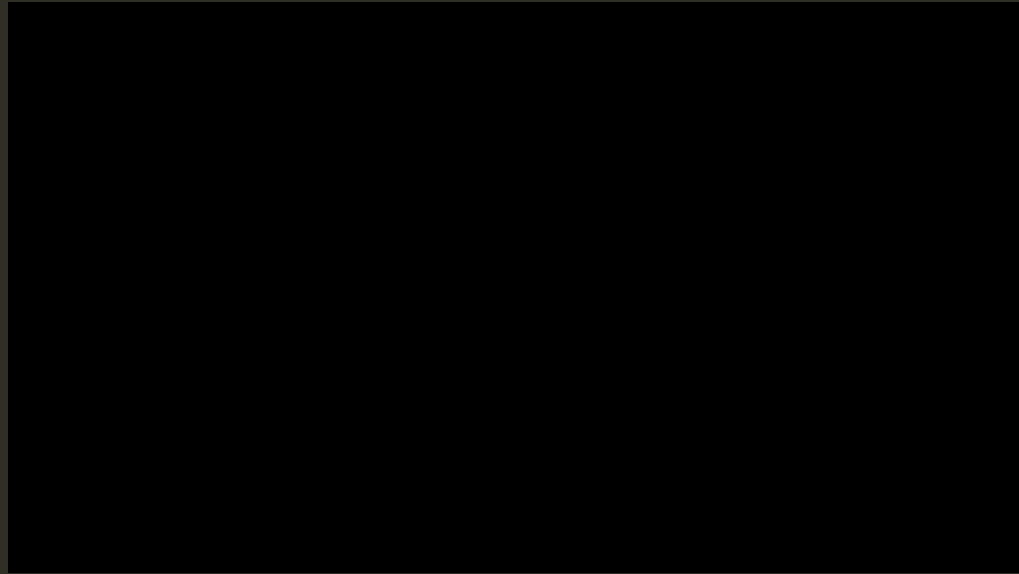
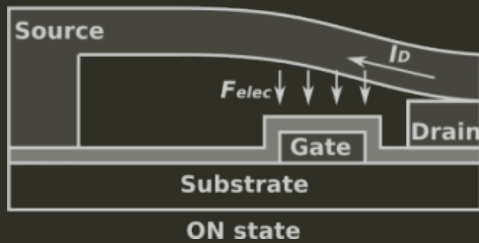
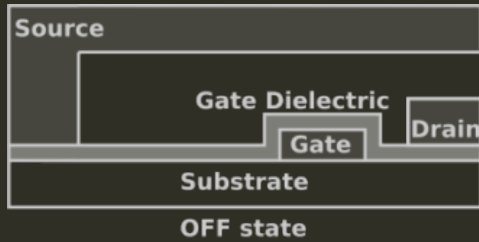
	μ_{sat}	$I_{\text{max}}/I_{\text{min}}$ (sat)	μ_{lin}	V_t (V)	Swing (V/dec)
Average	0.58	2.77E+03	0.28	1.83	4.83
STD	0.14	4.46E+03	0.05	0.68	0.59
Number of devices:					19



We are able to realize circuits running @ >1Mhz entirely using printing on flex

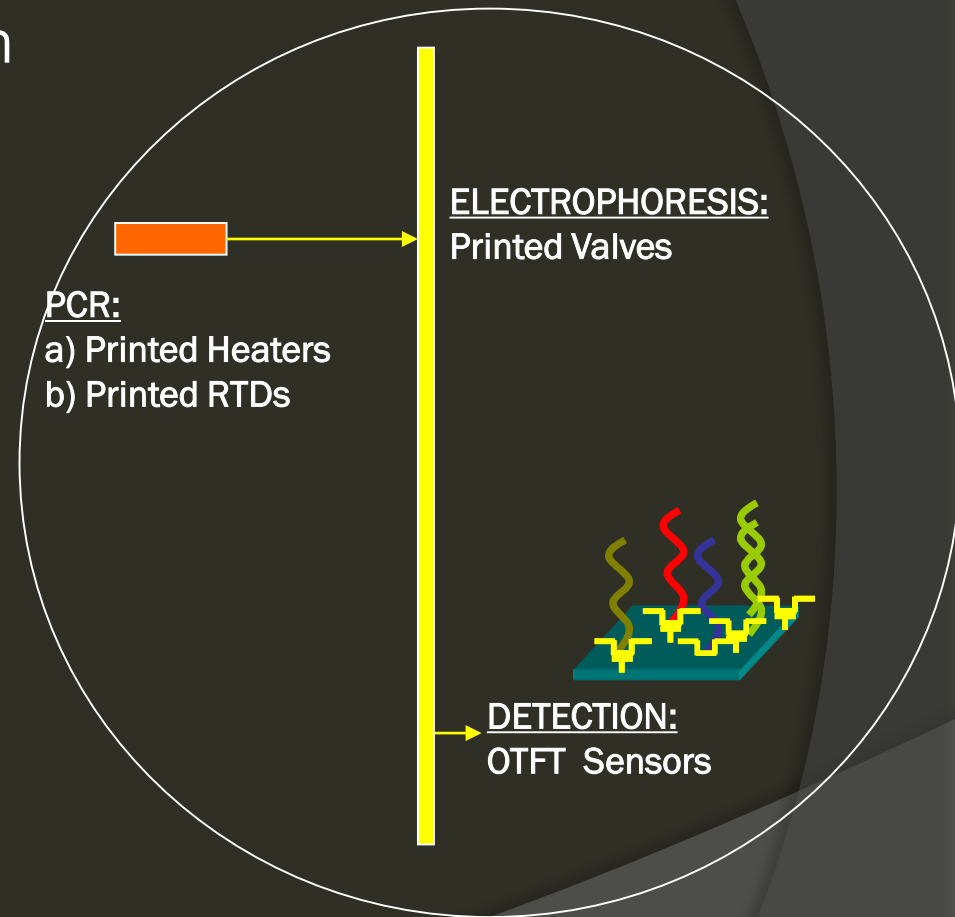
Novel devices

Exploiting the advantages of printed materials

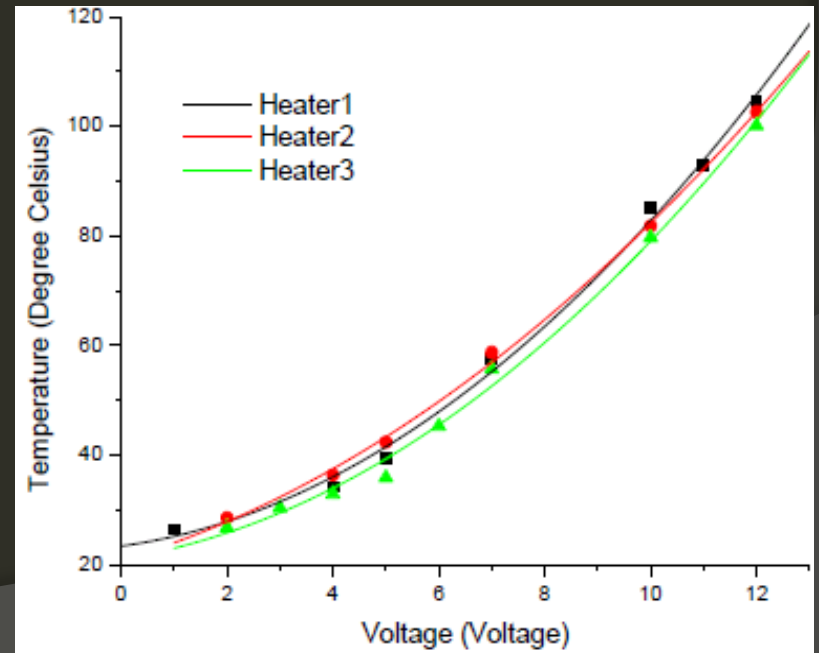
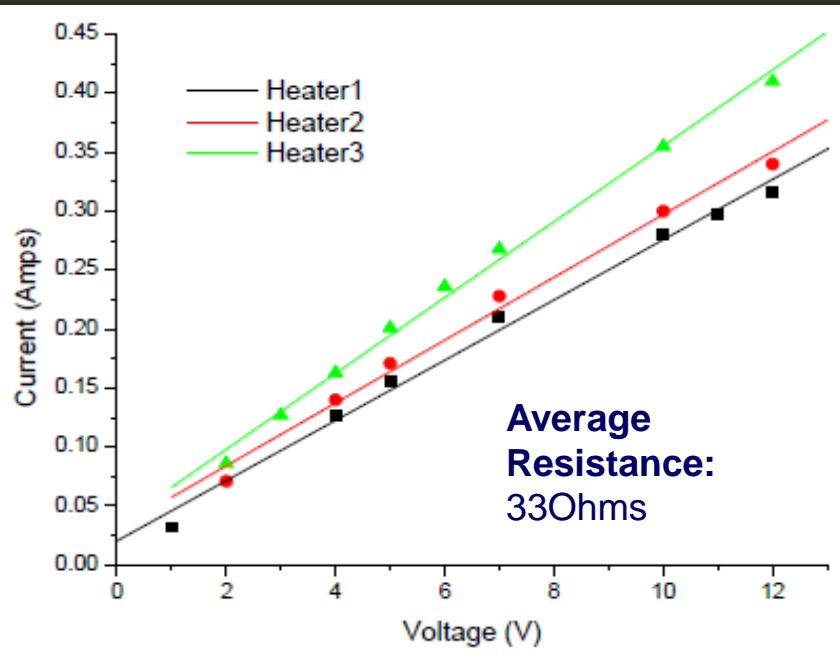
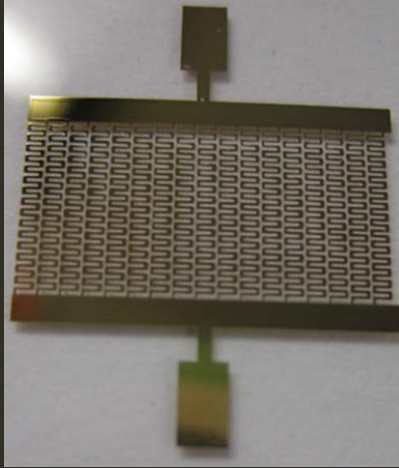


Printed healthcare analytics

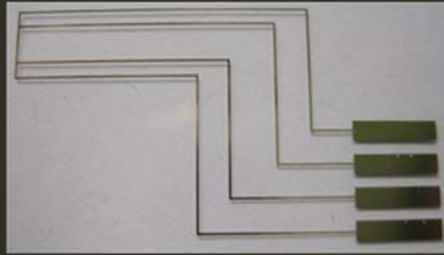
- Thin film components needed in biological chips can be very efficiently printed
- Additive Processing- saves cost and time in fabrication
- Integration of diverse biological functionality and materials on the same substrate



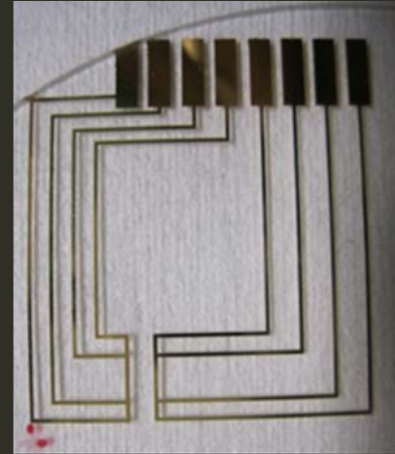
Printed Heaters for PCR



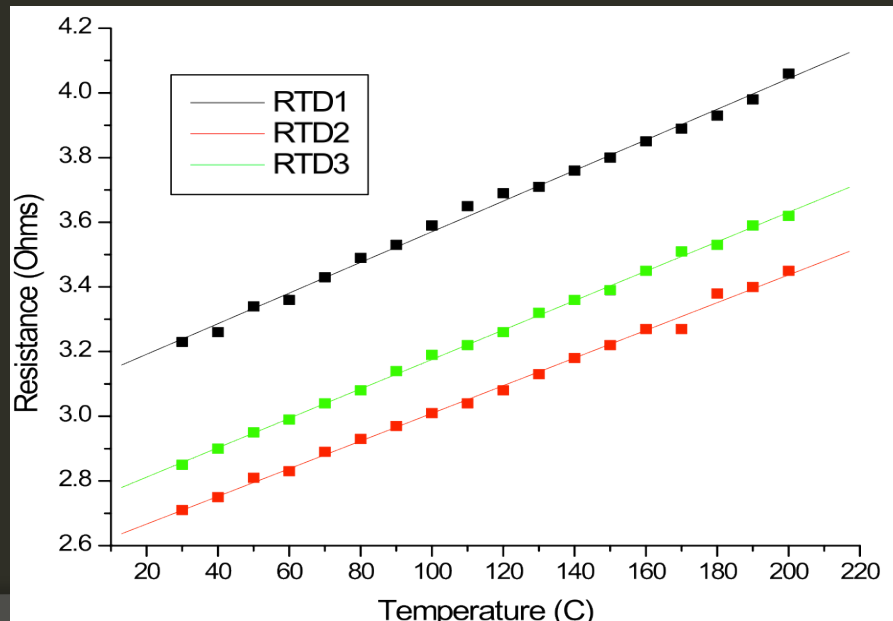
Printed Temperature Detectors



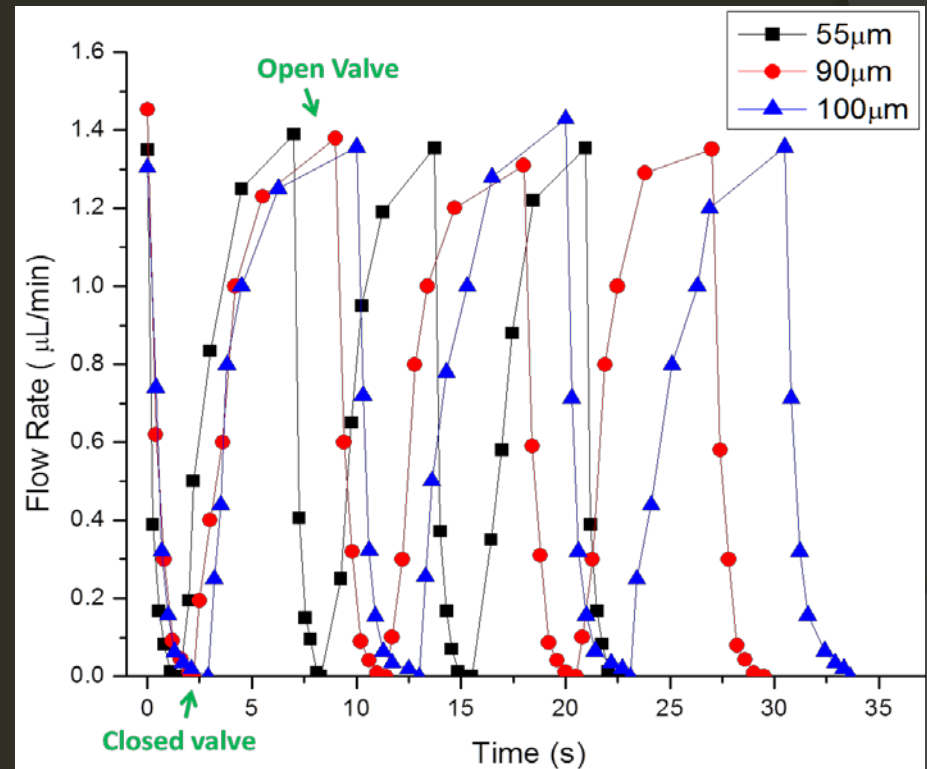
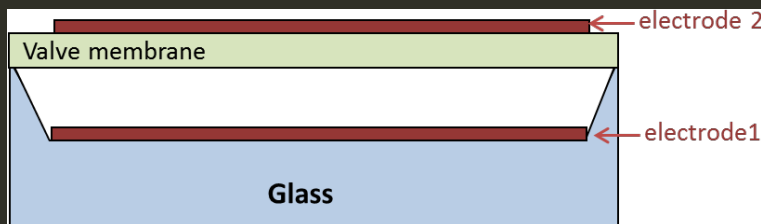
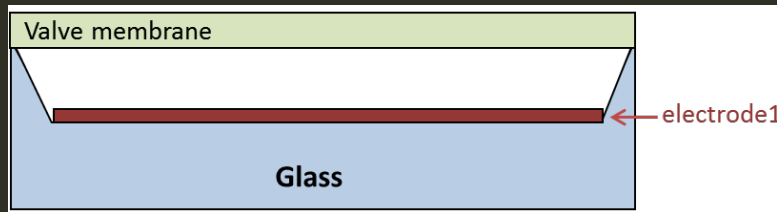
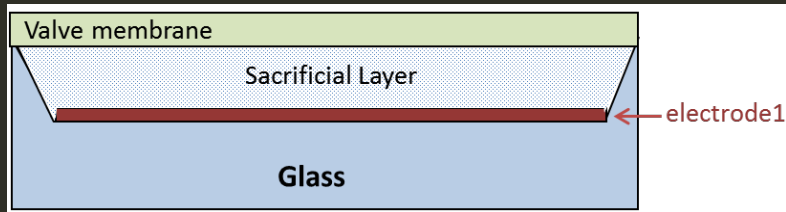
1-RTD Structure



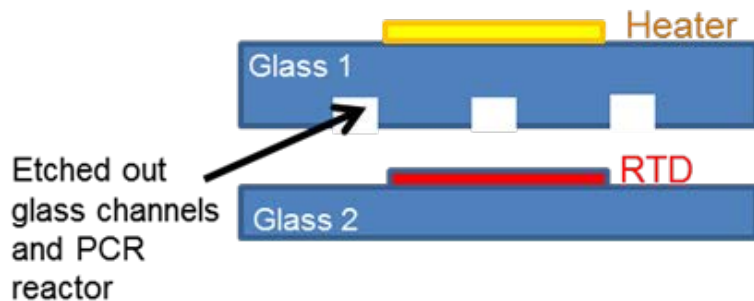
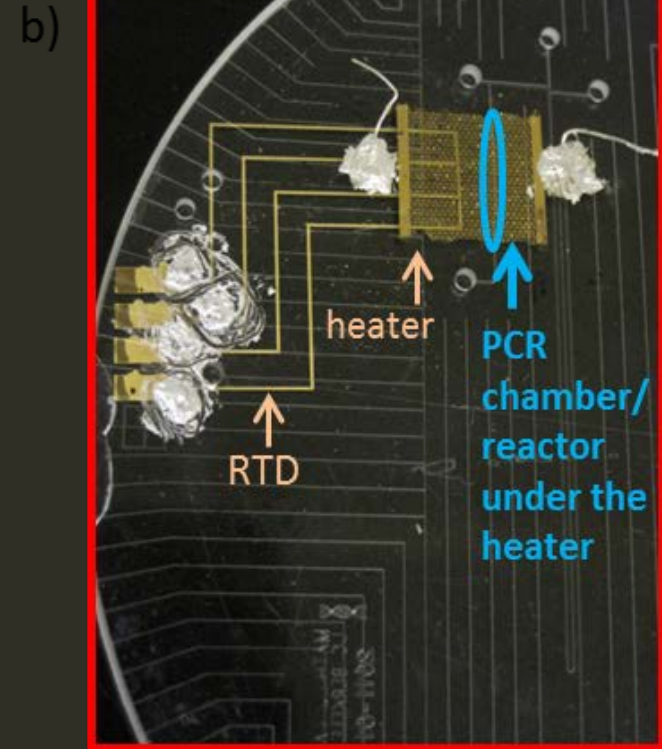
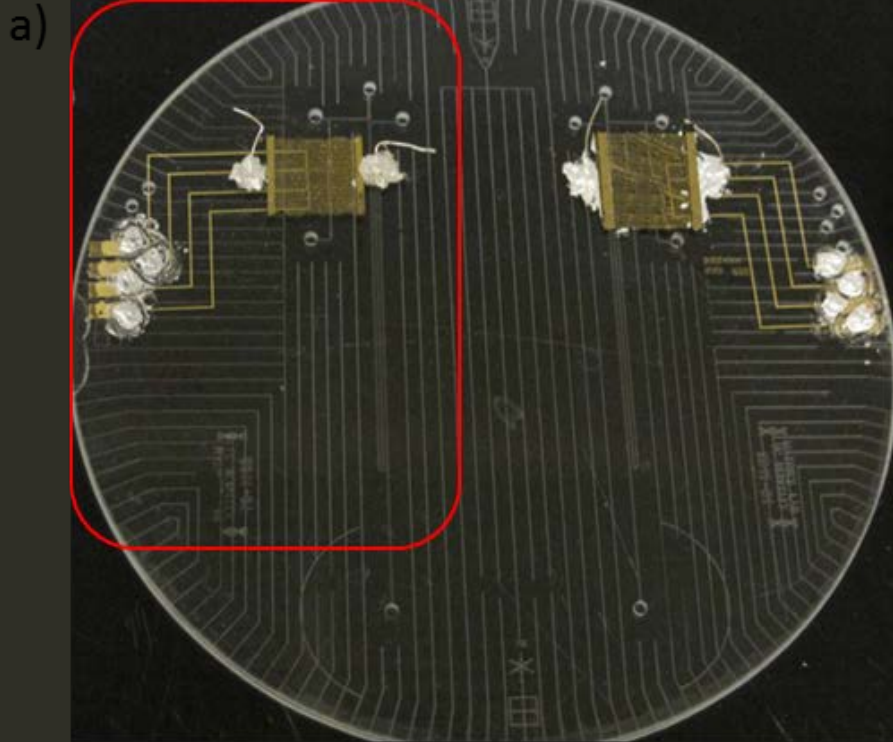
2-RTDs structure



Printed Valves for Control



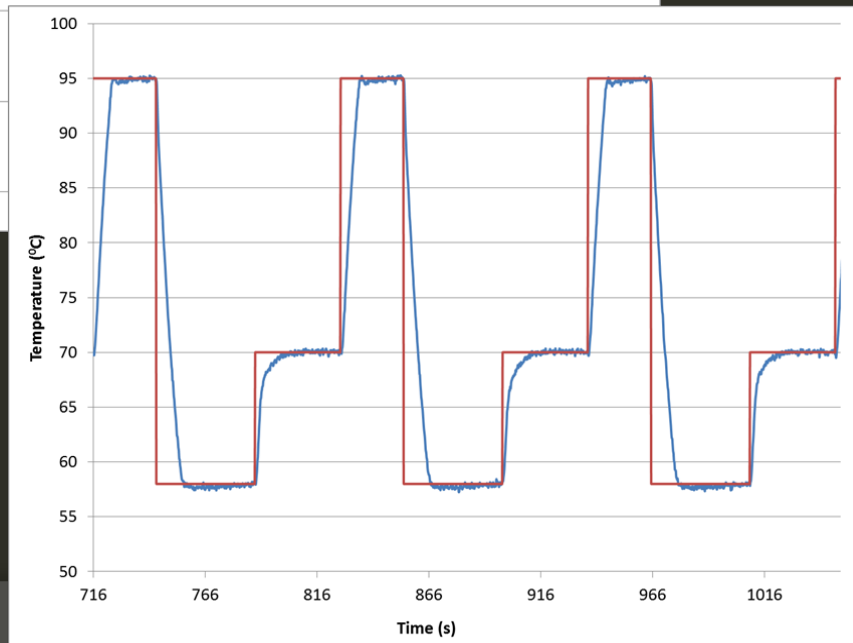
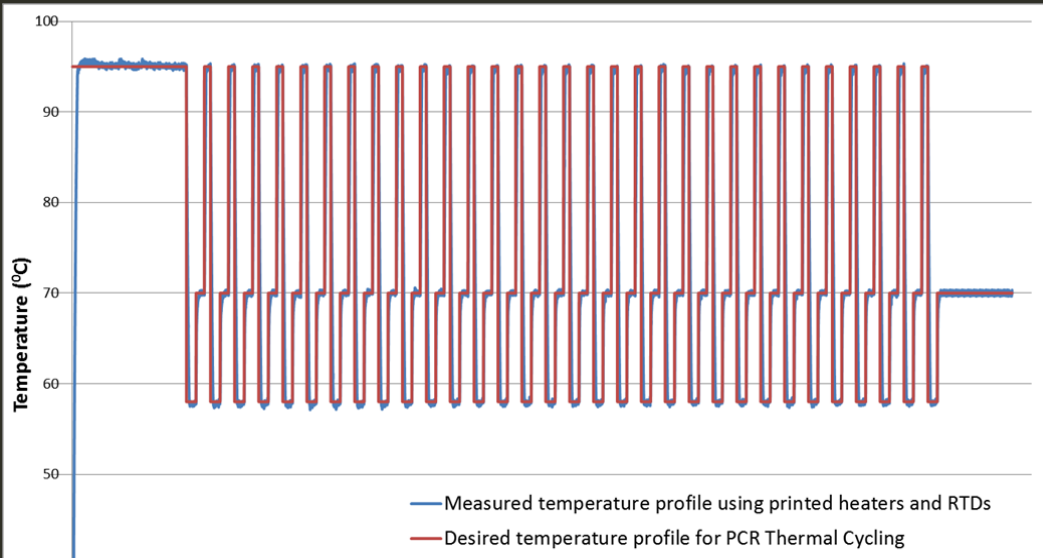
Integrated PCR Chamber



Top: Glass 1 layer with etched out channels, PCR reactor, and heater on top

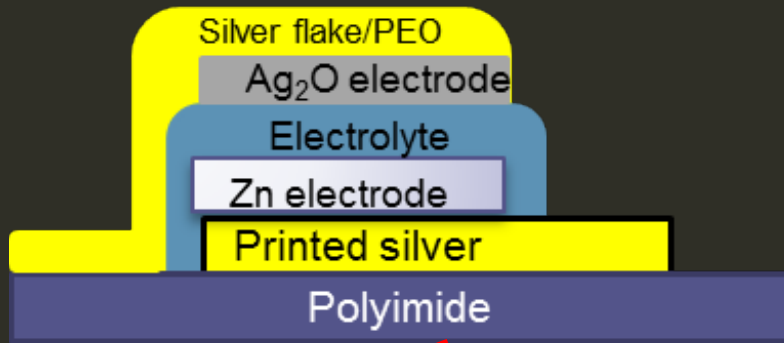
Bottom: Glass 2 layer with RTD on top

PCR Demonstration

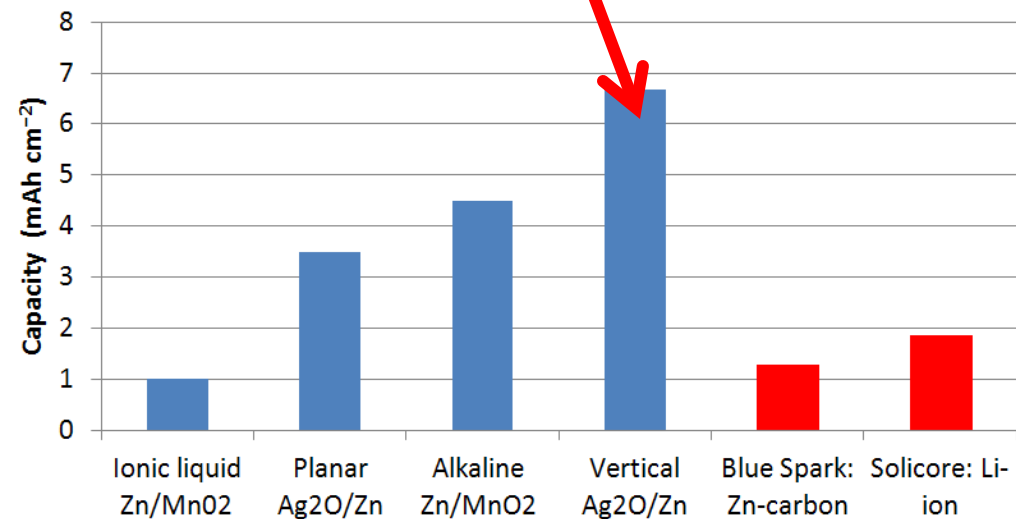
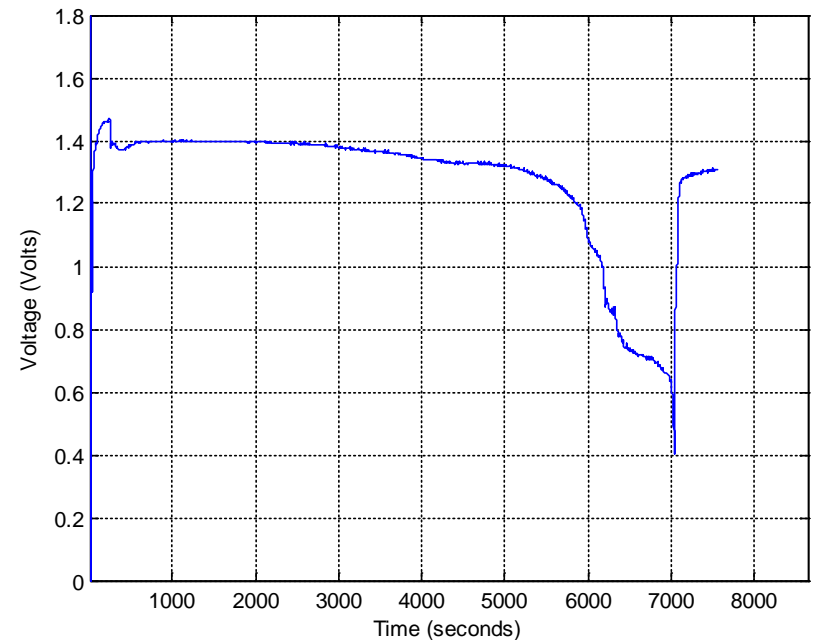


Printed Power Sources

- We've made printed batteries with energy density better than thin film Li.



Internal resistance: 24 Ohms
Silver oxide utilization: 94%



The coming convergence

- ◎ Novel Materials
- ◎ New Manufacturing Paradigms
- ◎ Ubiquitous systems integrating
 - Batteries
 - Computation / Communication
 - Sensing
 - Interaction