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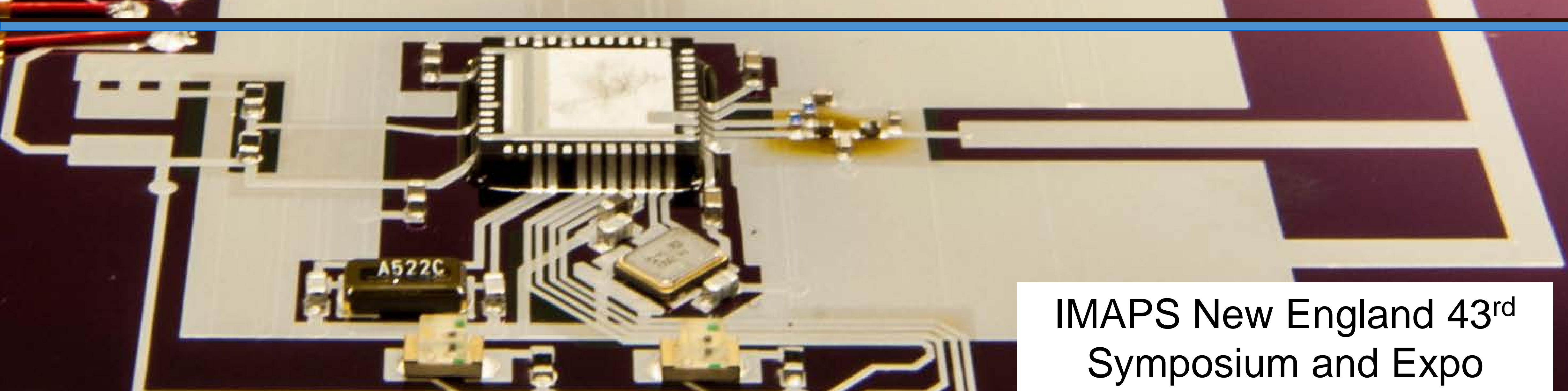
DRAPER

Printed Transceiver Circuit for System-on-chip Sensor and Processor



IMAPS New England 43rd Symposium and Expo

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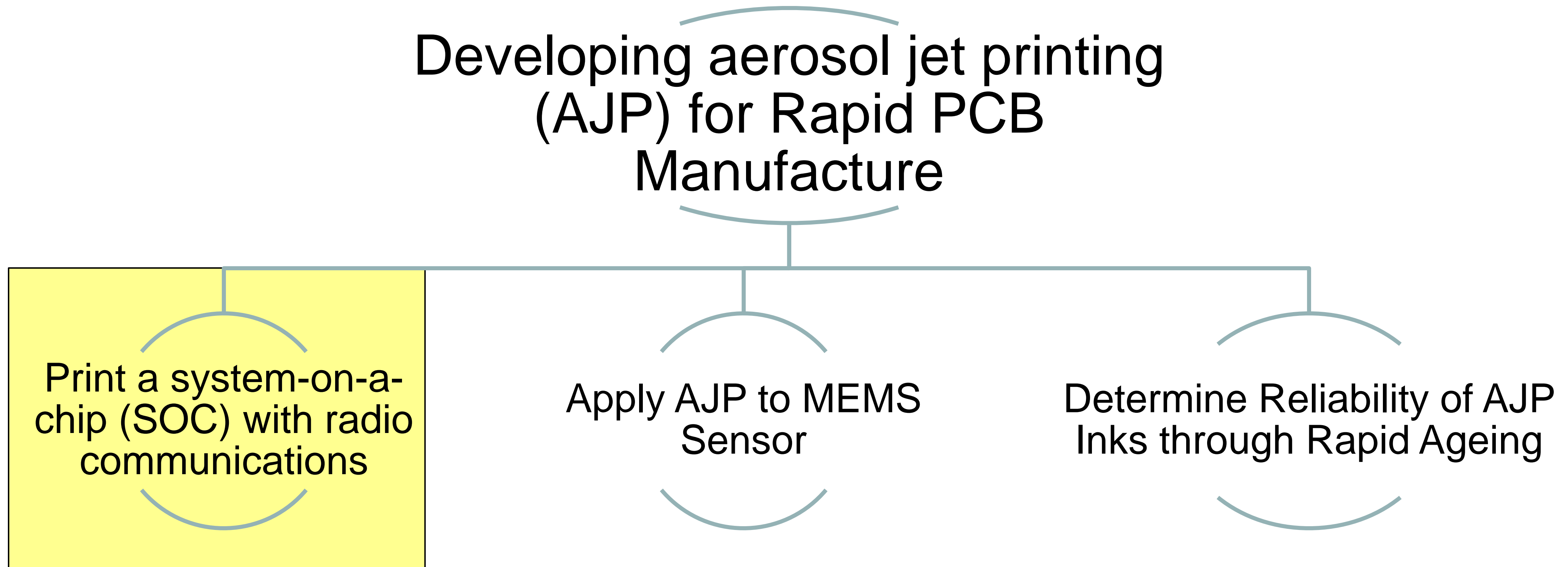
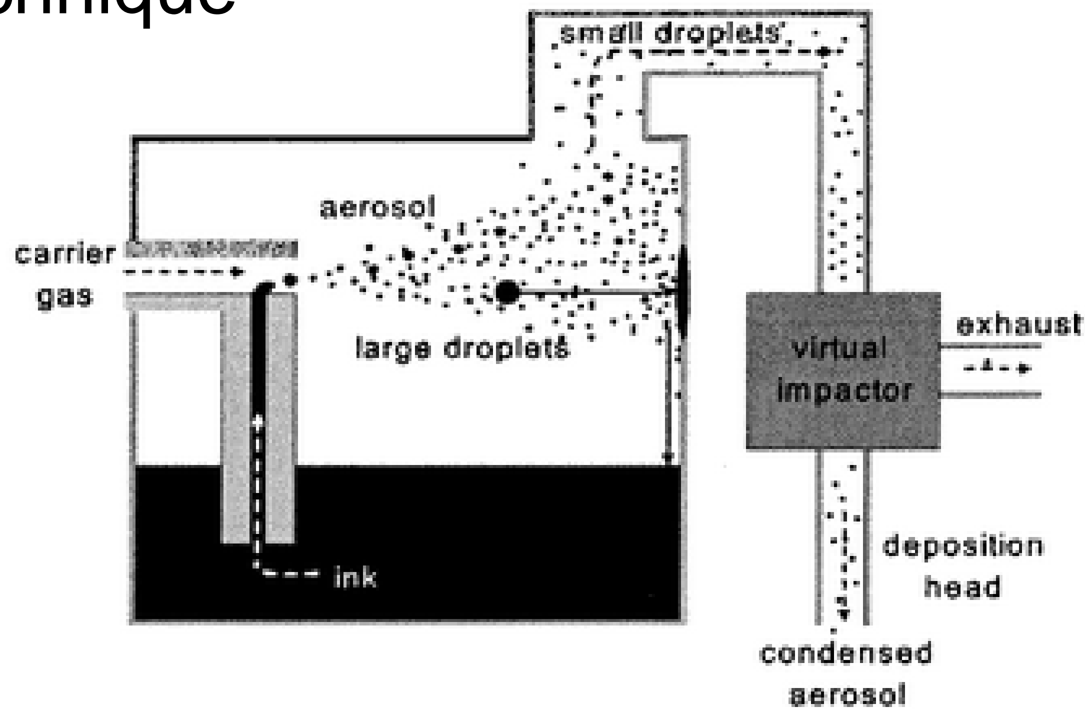
May 3rd 2016

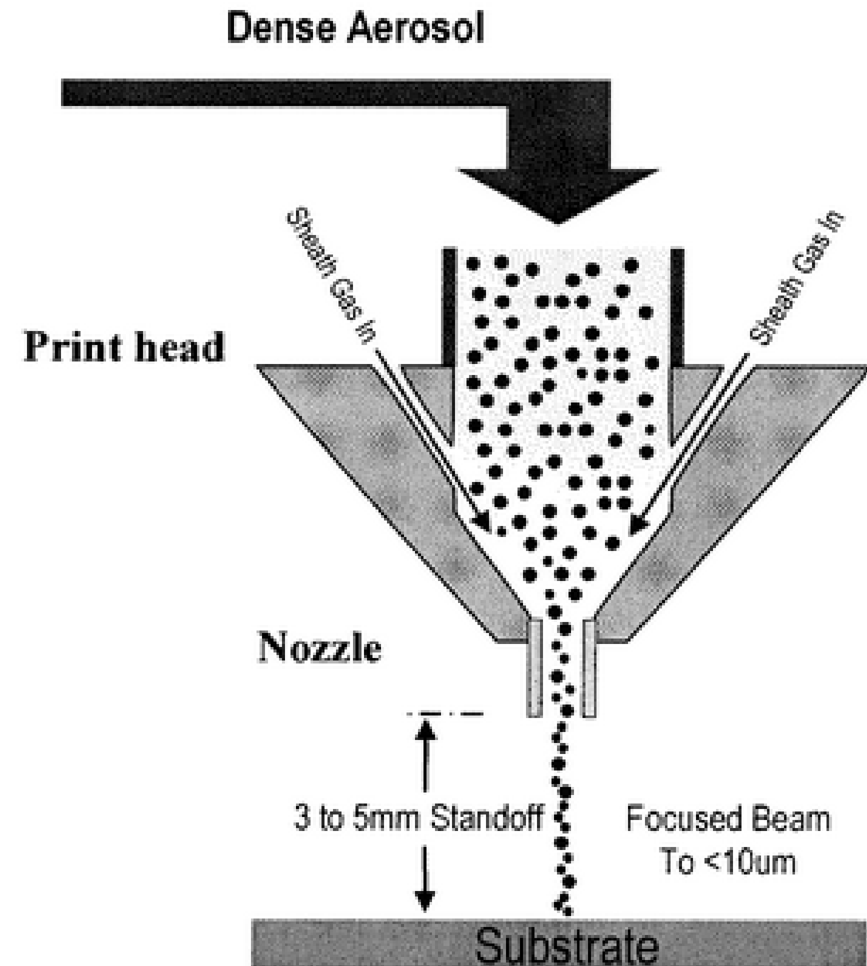
Research Goals



Background – Aerosol Jet

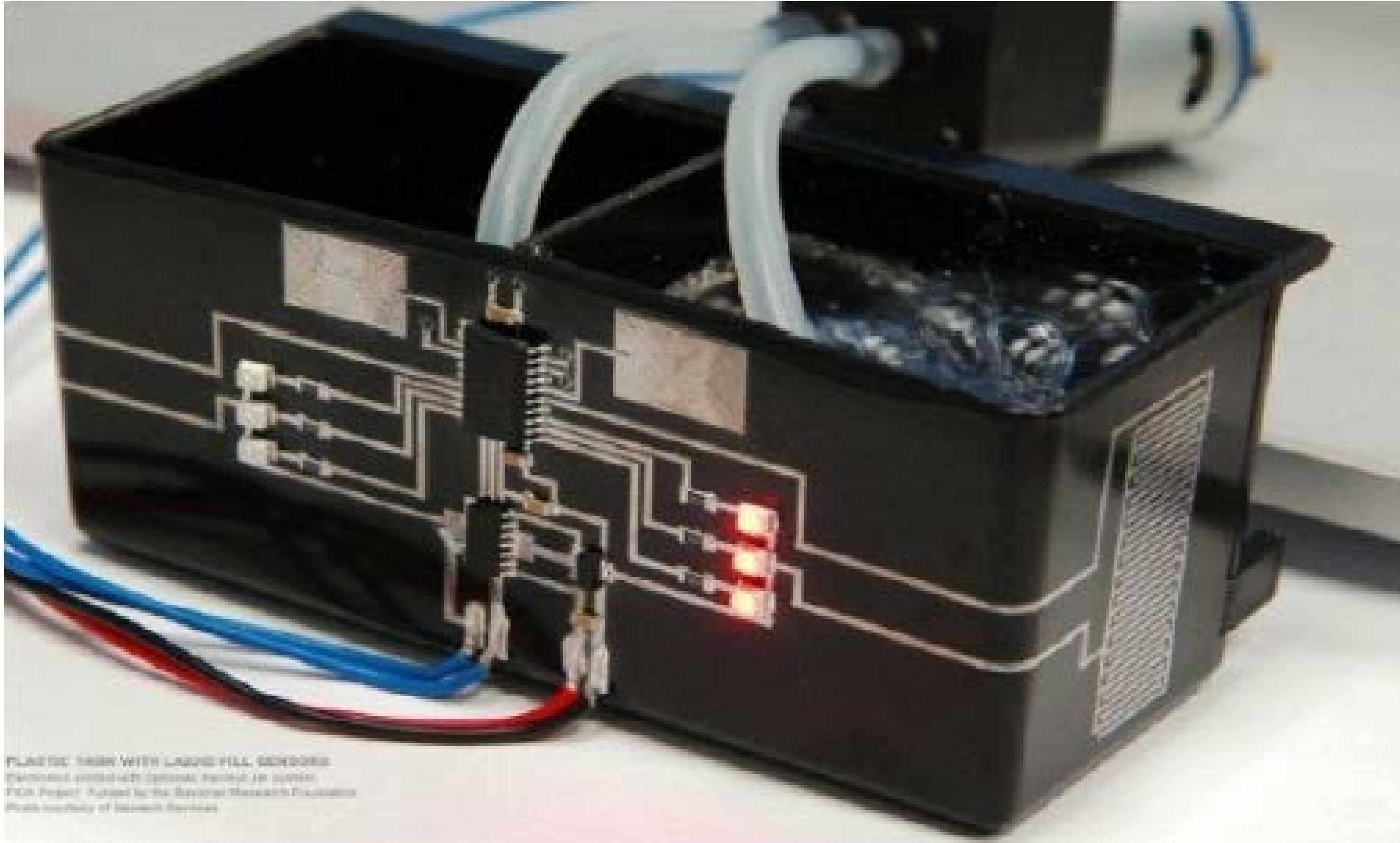
- The AJP Process [1]
- Advantages vs. Disadvantages to technique





[1] Chou et. al. Patent. 2014

Background – AJP Circuit Boards and Package Integration

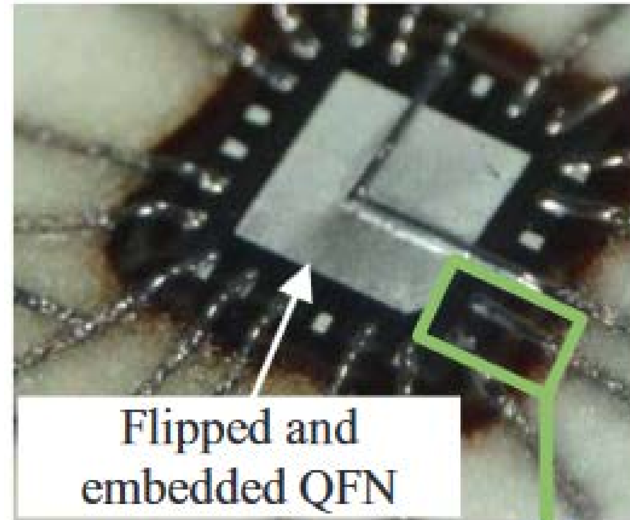


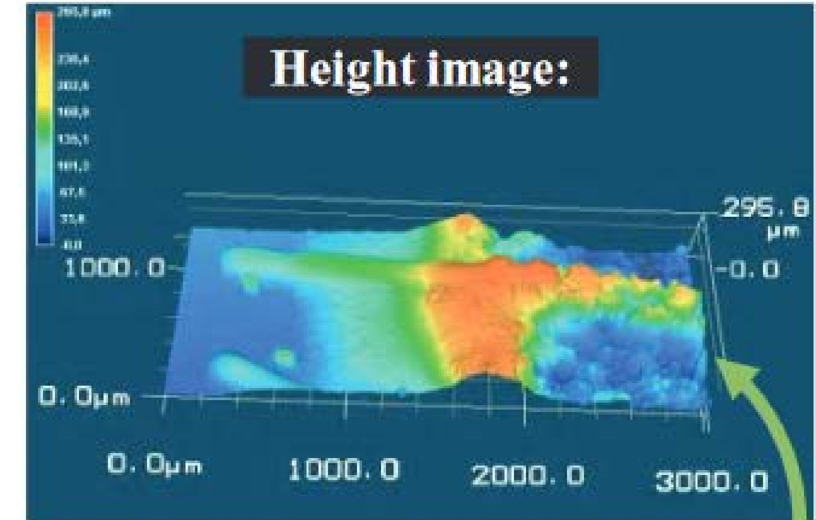
Functional circuit printed on the side of the tank is depicted [2].

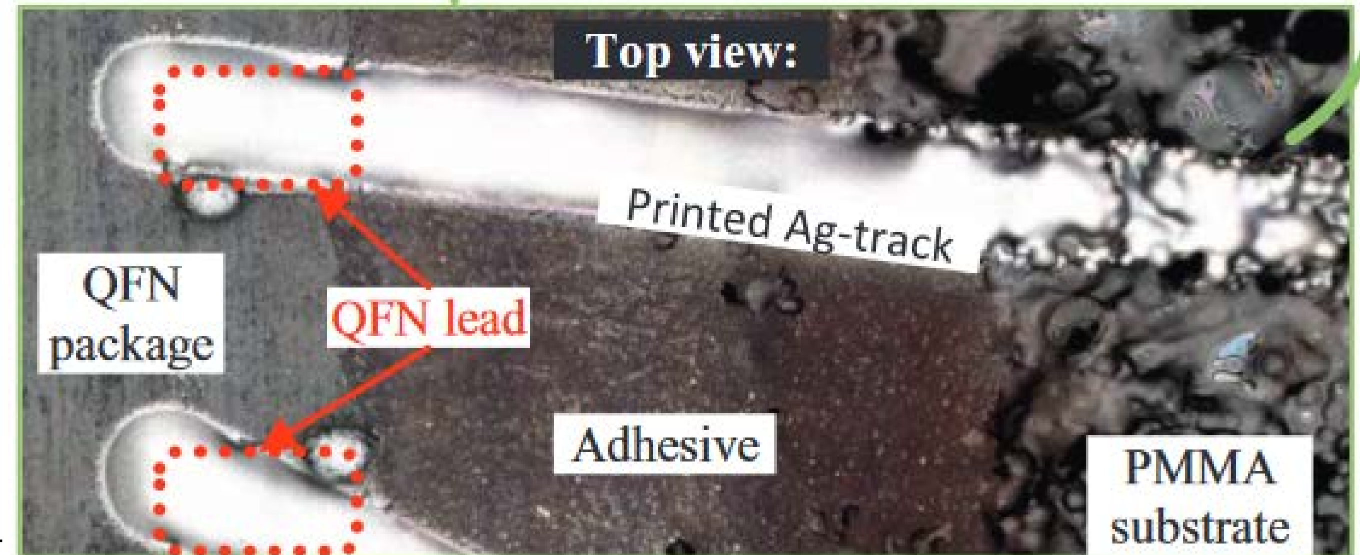
[2] Paulsen et. al. Future of Instrumentation International Workshop Proceedings, 2012

Background – AJP Circuit Boards and Package Integration

QFN24 package interconnected with silver to a circuit (not shown) on a PMMA substrate. The profilometry image on the top right shows the silver line going on to the QFN24 packages from left to right [3].







[3] Hoerber et. al. Procedia CIRP, 2014

Uniqueness

Multilayer circuit with most capability built with AJP

Flexibility in both substrates and inks

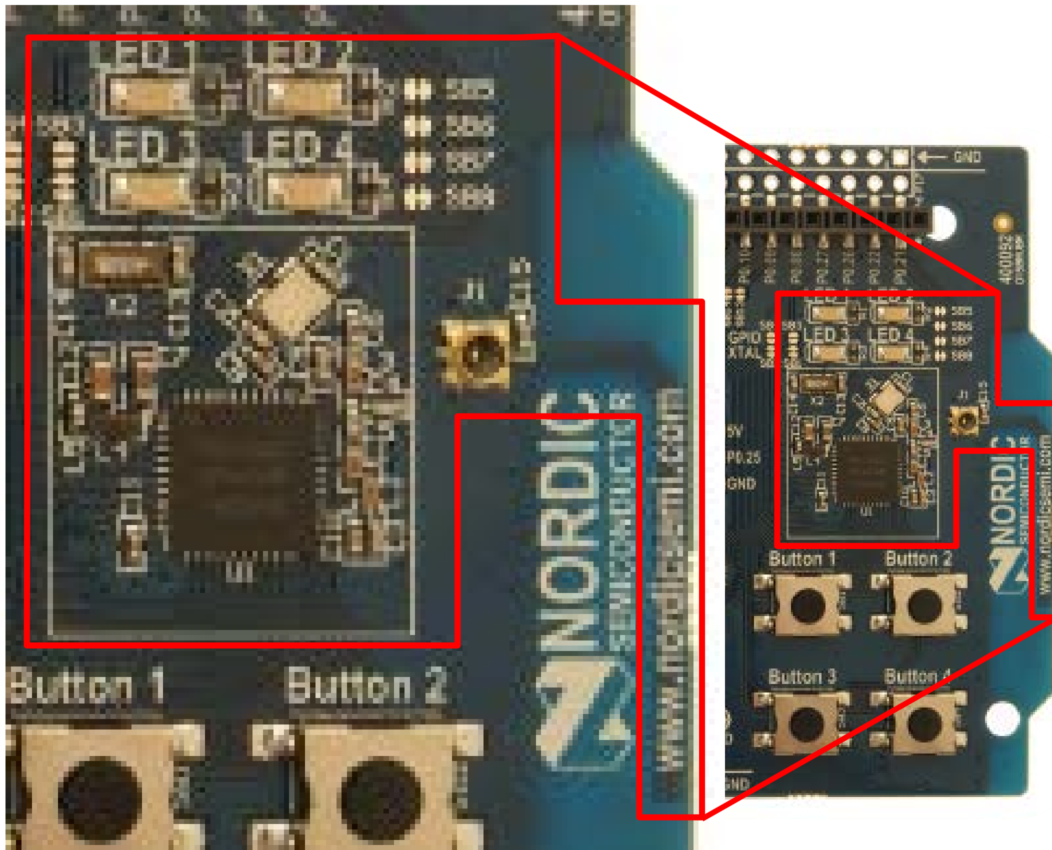
Integration of non-embedded components before the board fabrication

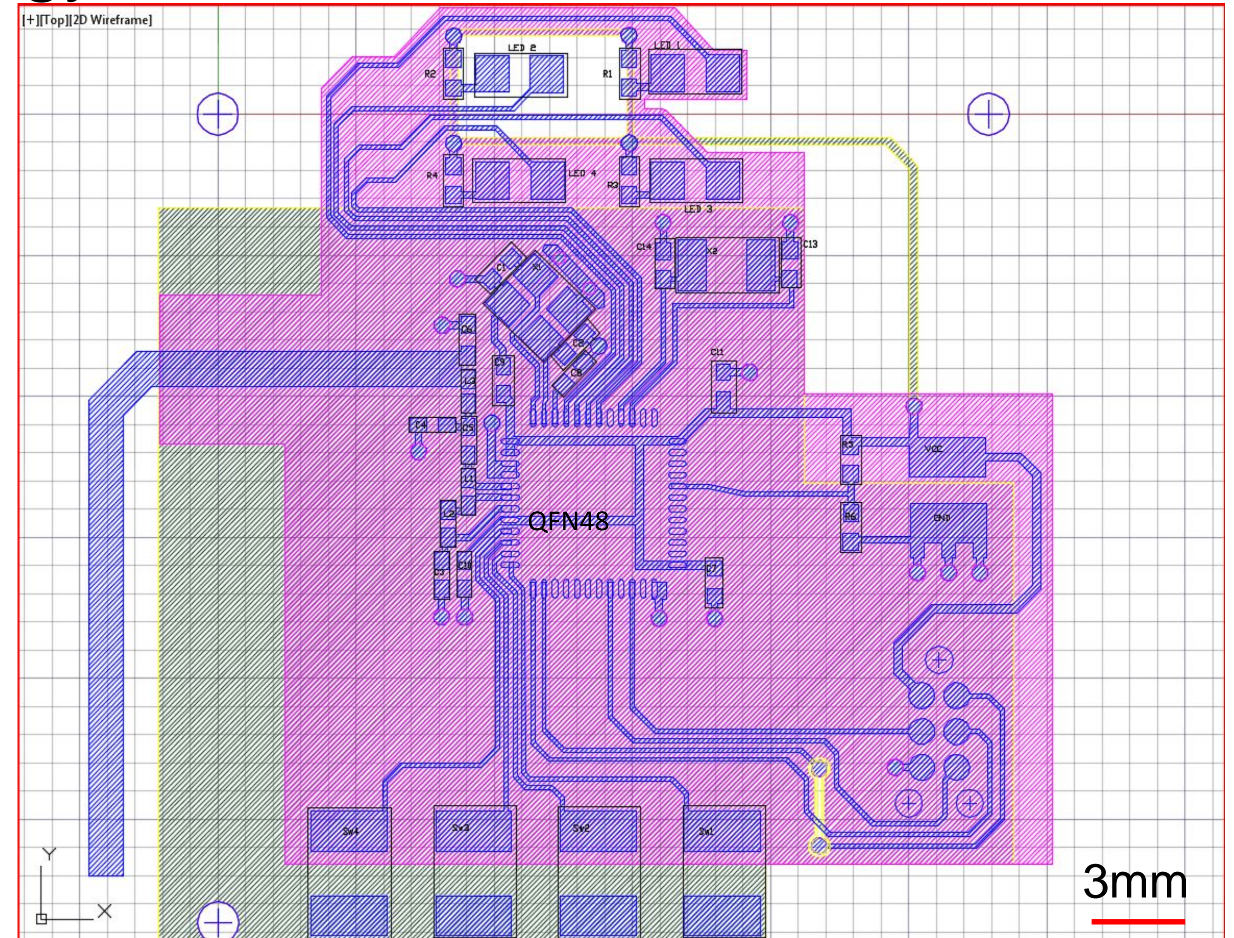
Avenue to reduce technology gap between SOC capabilities and flexible circuitry

Ageing testing done on multi-material structures

Transceiver Circuit Board Design

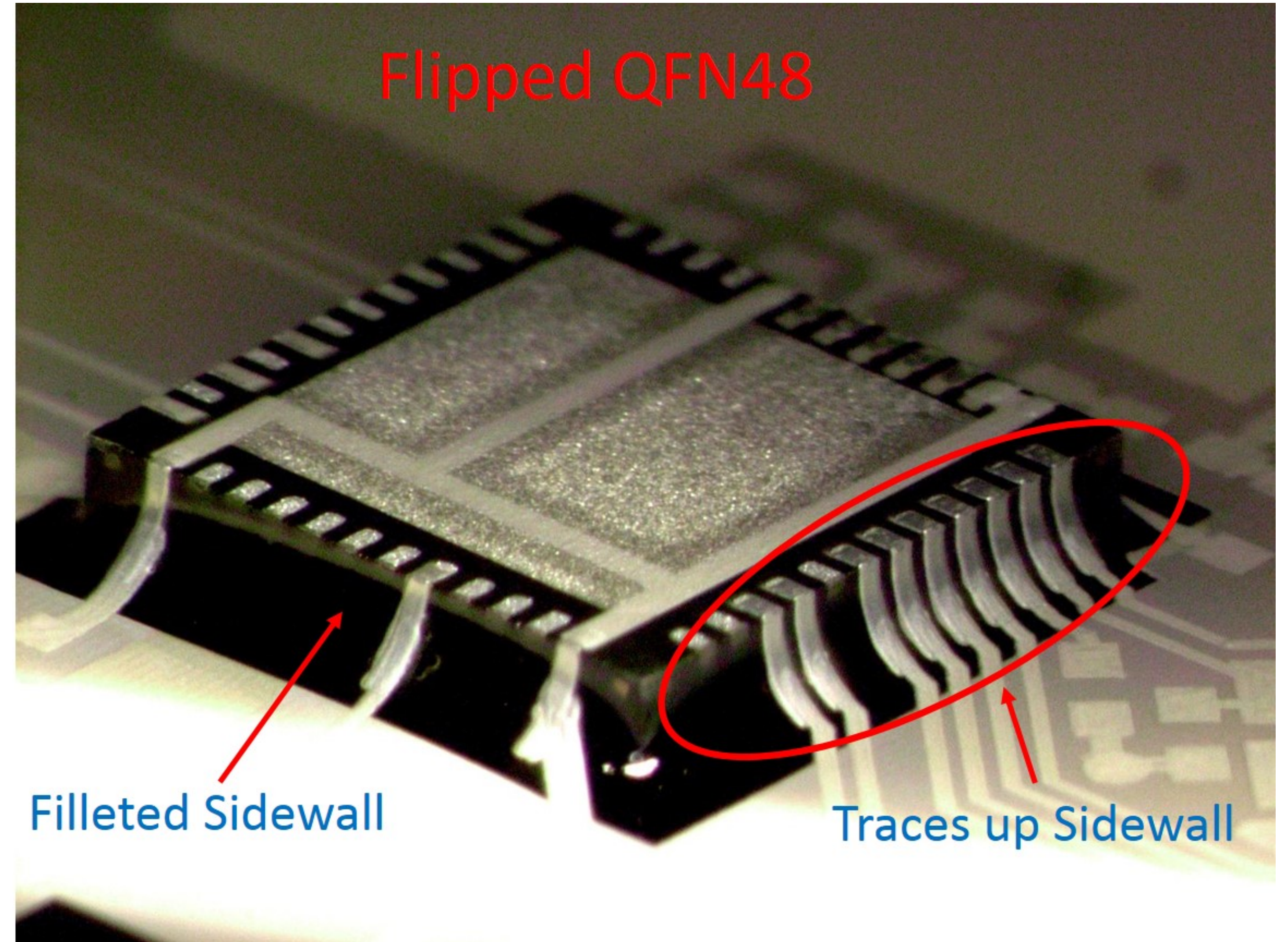
- Based off a commercial board Nordic Semiconductor nRF51822 Multiprotocol Bluetooth low energy/2.4 GHz RF SOC





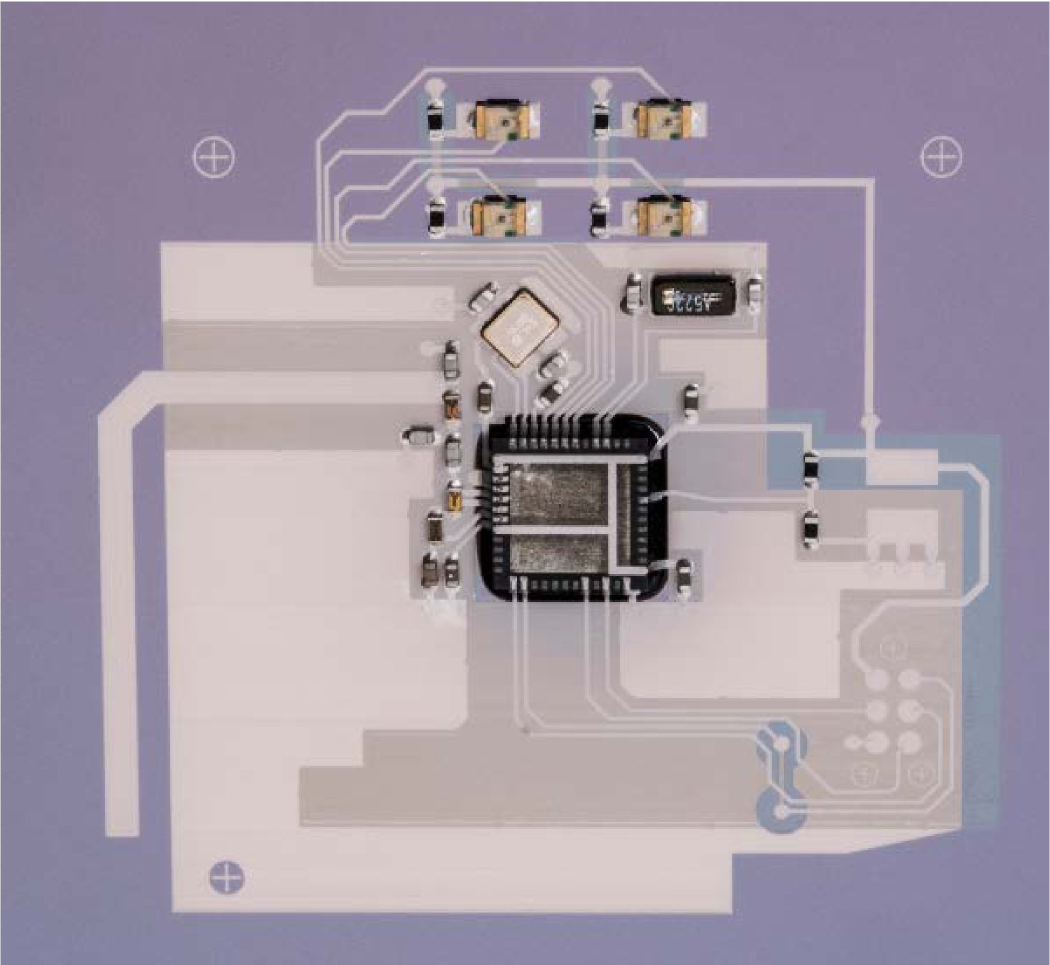
Design Analysis and Iterations

- COTS integration techniques: printed interconnect and assembly
- Flip component integration
- Enhance Printability – Ground, Dielectric, Vias
- Solder incompatibility→ Conductive epoxy
- Short reduction
- RF Circuitry

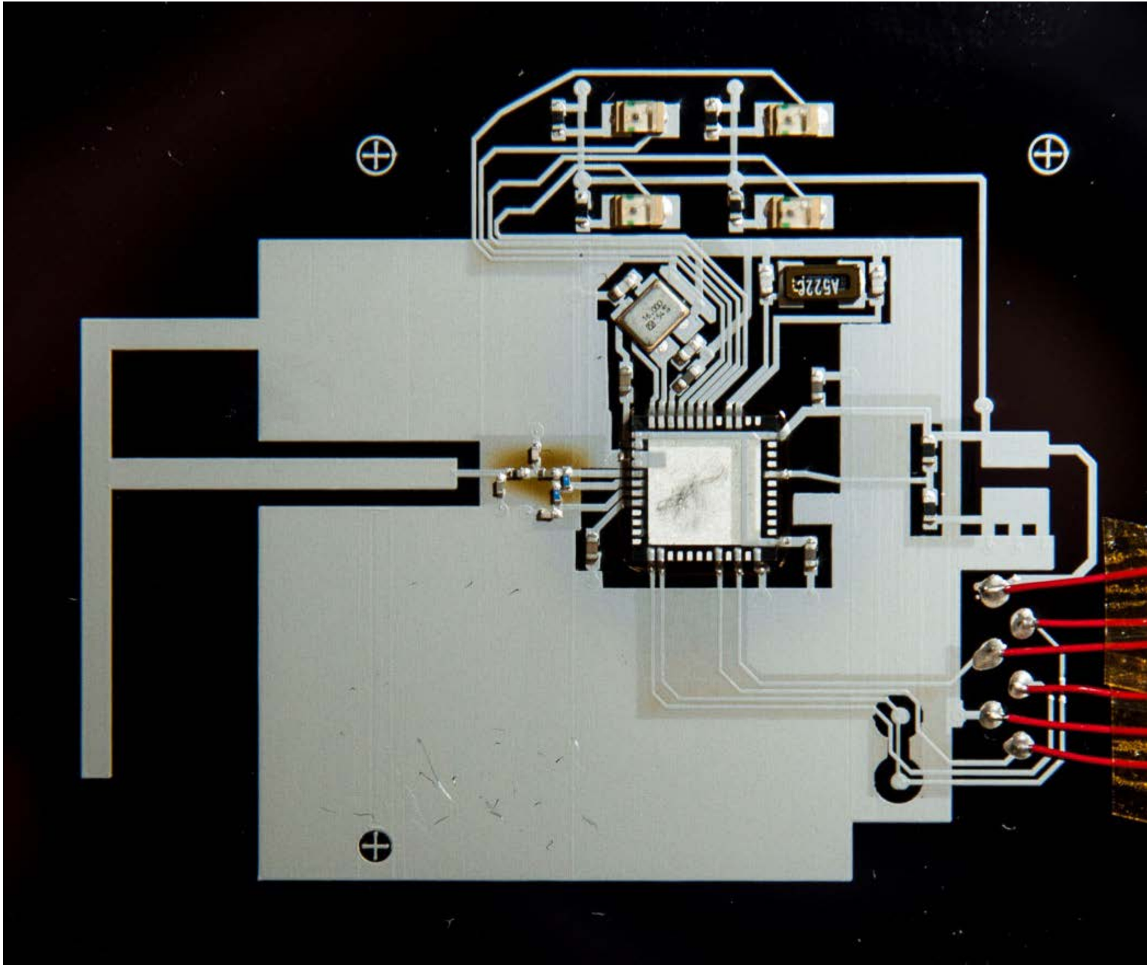


Design Iterations

Original Design

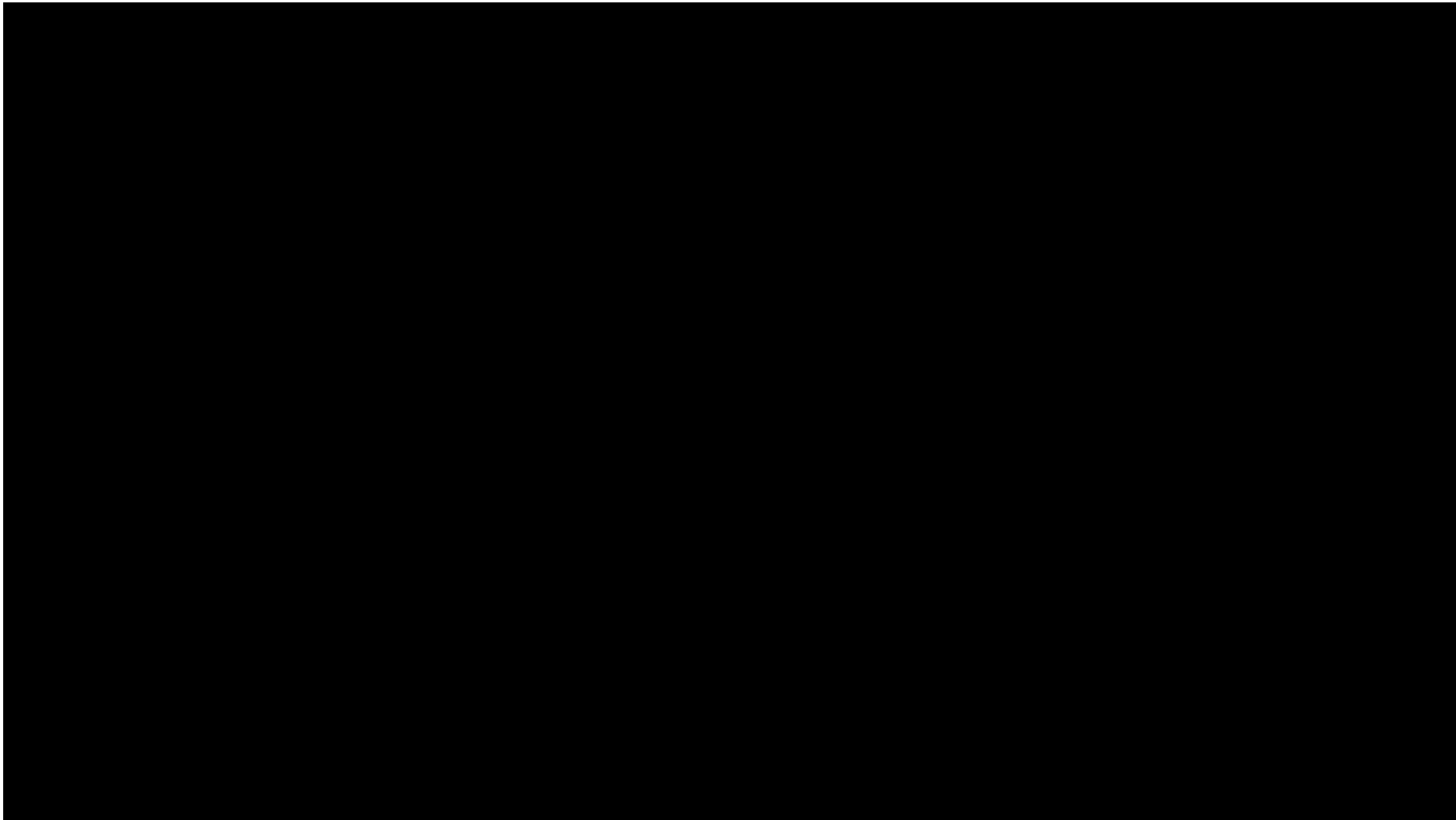


Final Design



Programmability

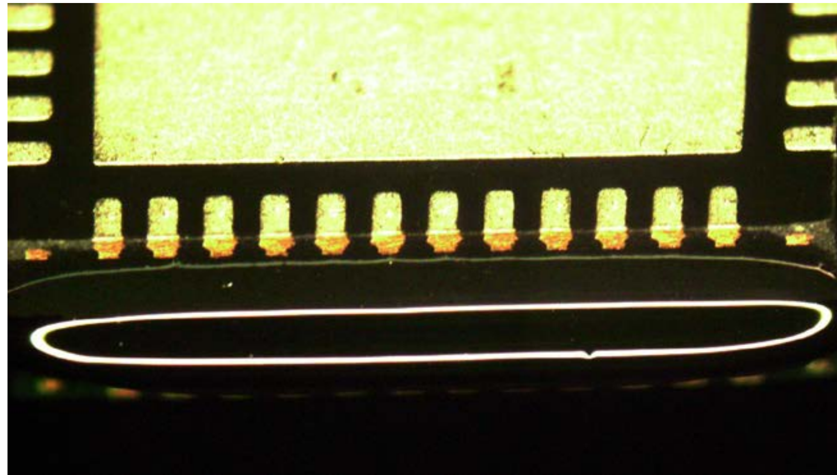
- "Blinky" successfully programmed and executed
- Does not require RF circuitry
- Post-programmed circuit only needs a power supply



Mounting of Microprocessor and Printing of Interconnect Traces

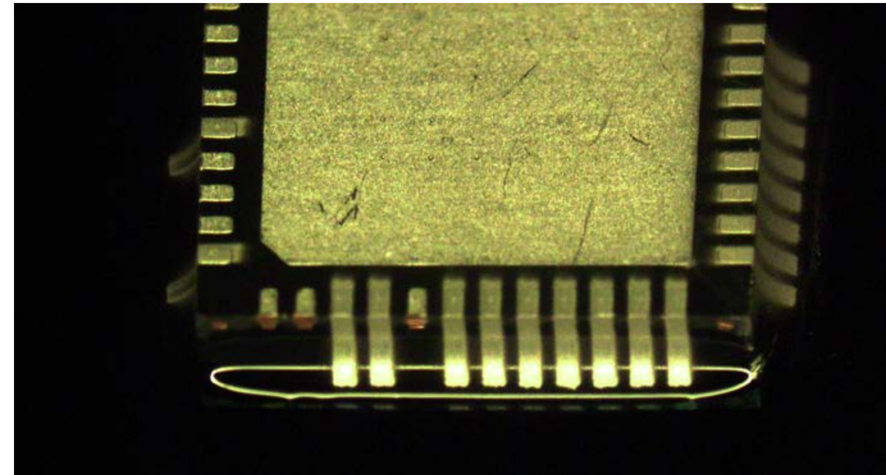
QFN48 Mounting

- Armstrong C-7/W epoxy
- Fillet concave corner
- Remove airgap
- 1 hour for placement & cure at 100˚C



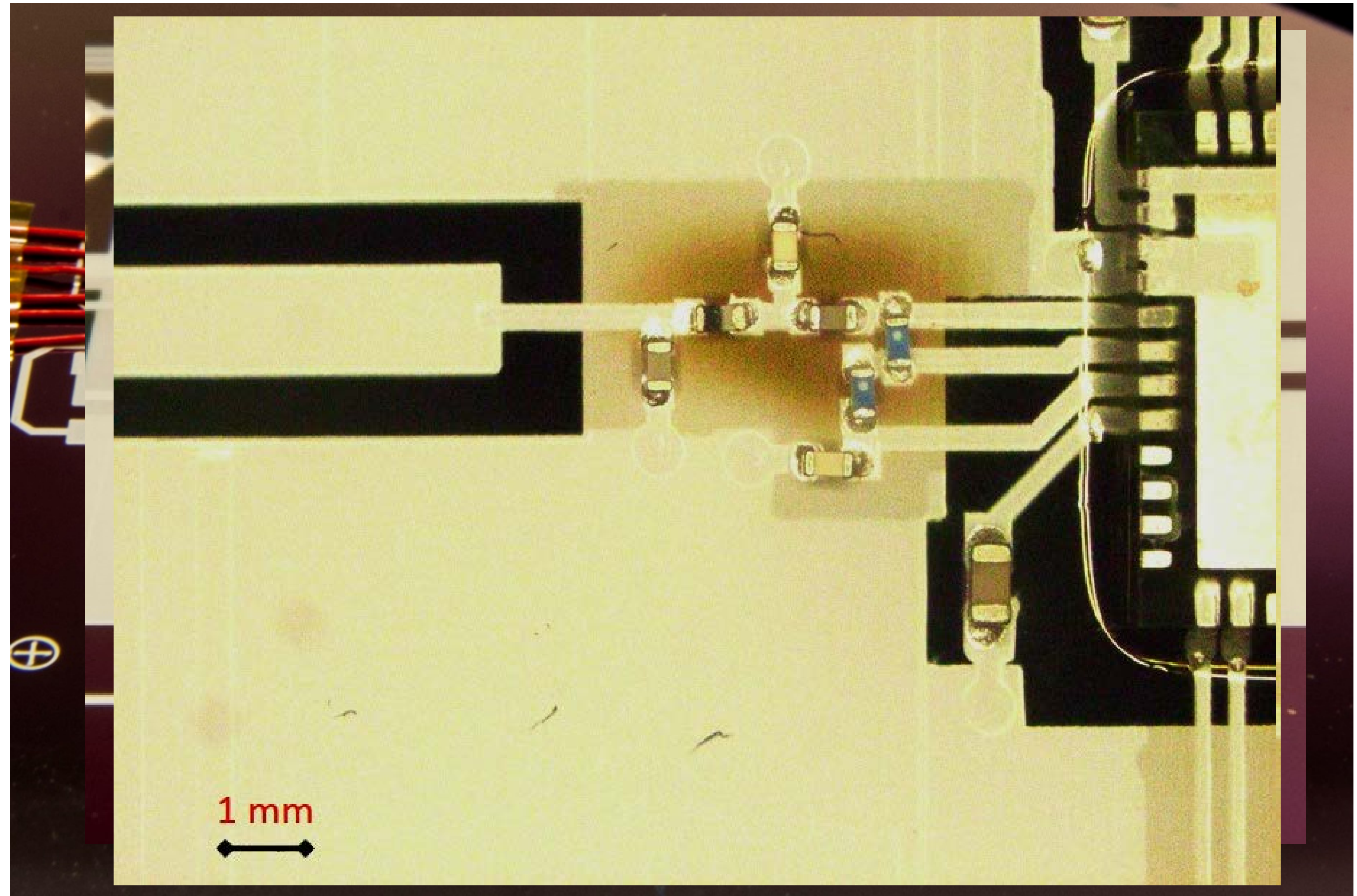
Integration Lines

- NovaCentrix HPS-030AE1 Silver Flake Ink
- Subsequently connected to PCB
- 20-50 μm print width
- 30 min print for 5 passes on 4 sides



COTS and Wire Placement

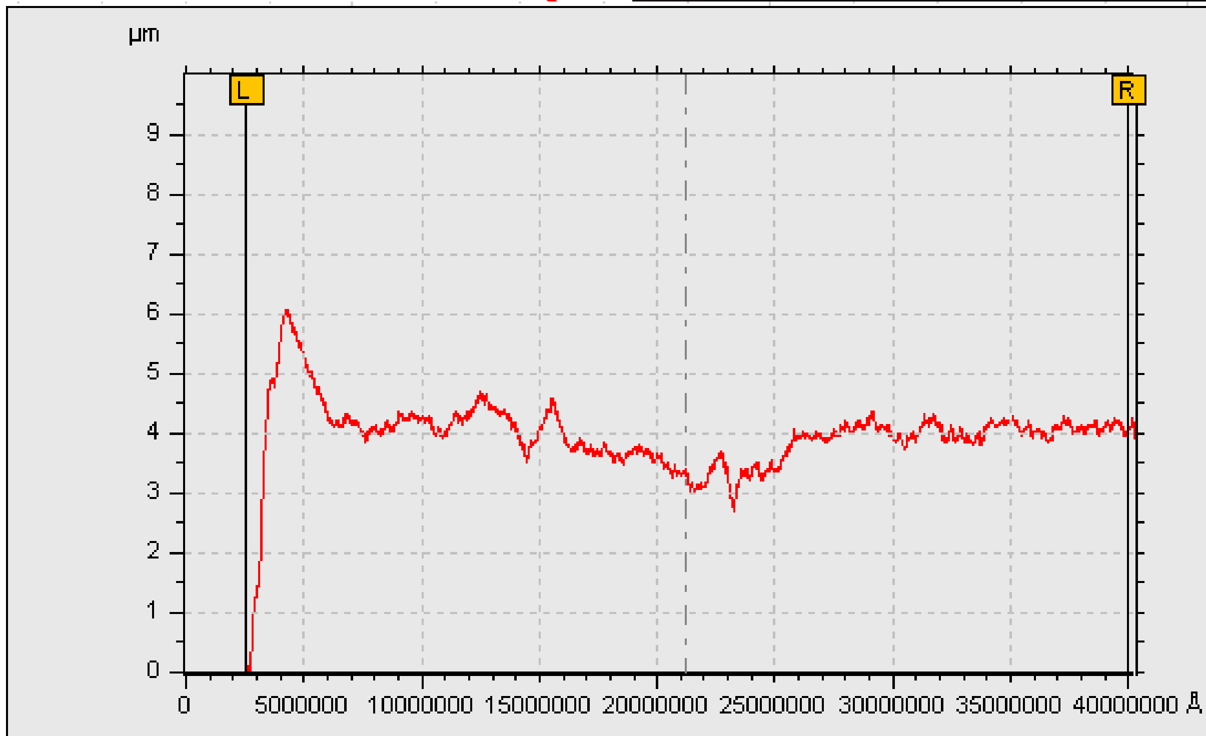
- EPO-TEK® H20E
- Caps, inductors, resistors, oscillators hand placed
- Breakout wires
- Cure 30 min at 100°C several times throughout placement
- 3+ hours



Profilometry of Ground and Dielectric layers

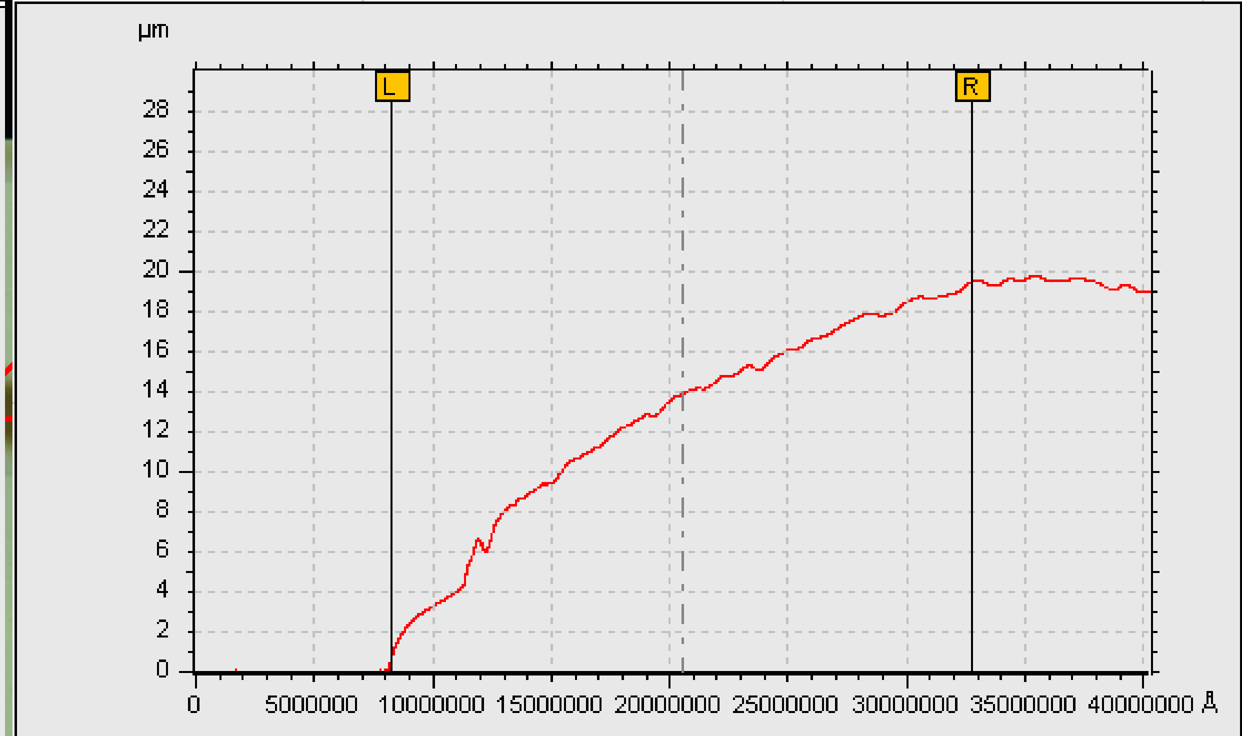
Ground Silver

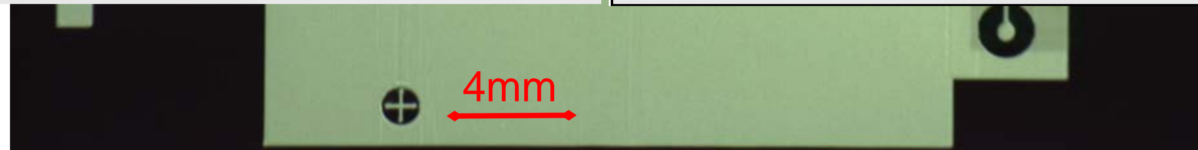
- Height of the antenna



Dielectric layer

- Height of the RF dielectric area

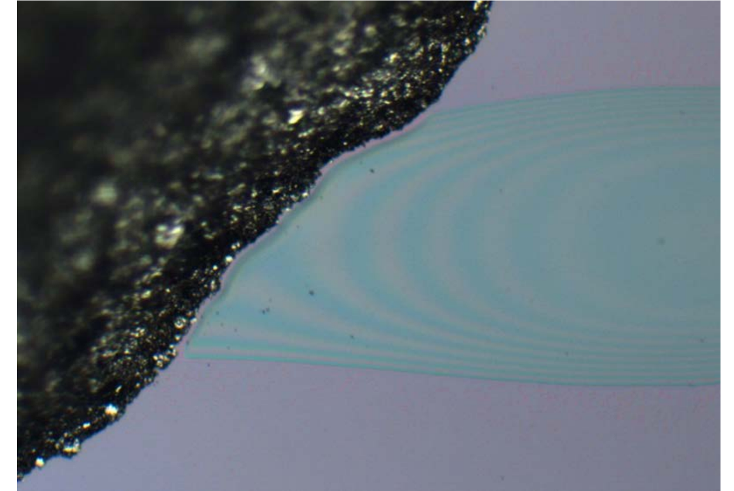


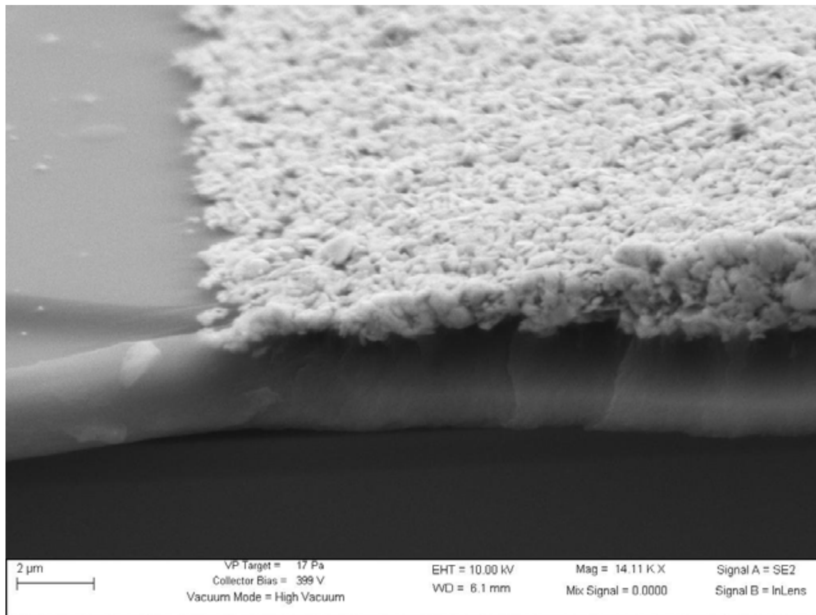


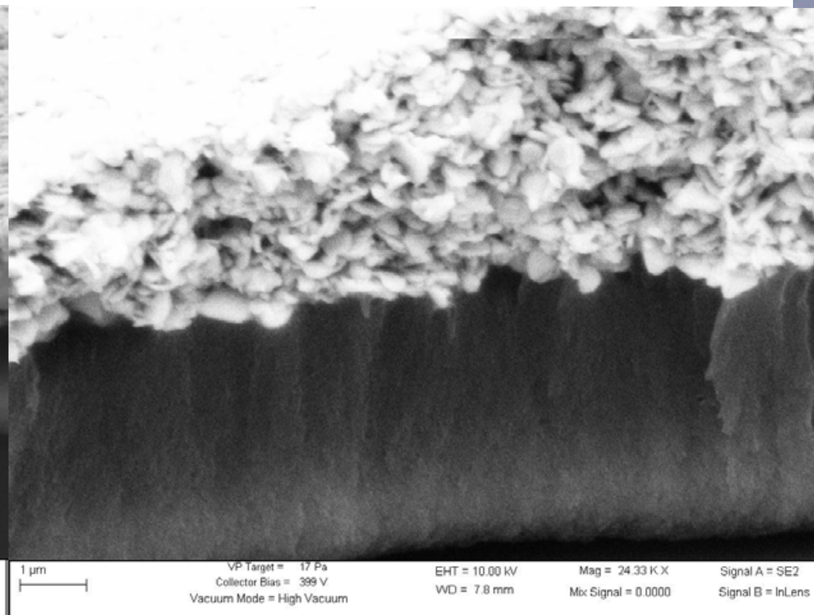
*Antenna measurement is mirrored

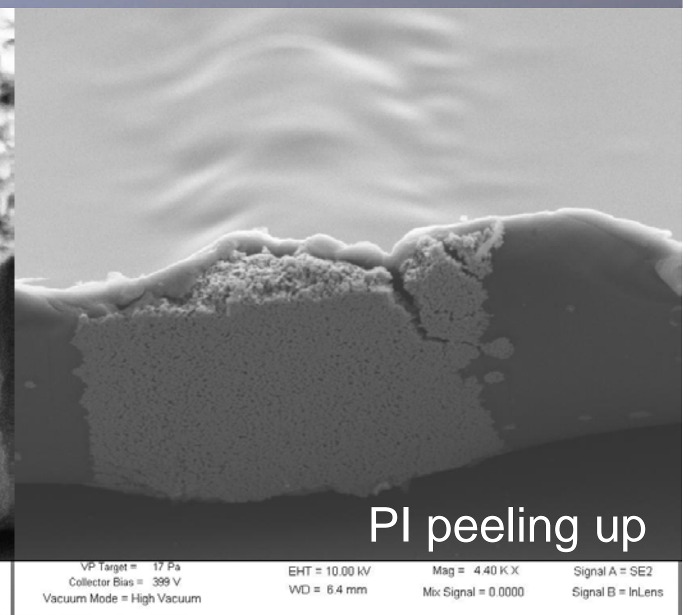
Ink Analysis – Ag/PI Compatibility

- Cross-sections of Ag/PI structures
- Ag/PI SEMs
- Fragility of Ink to soldering/wirebonding
- Conductive Epoxy/PI tests





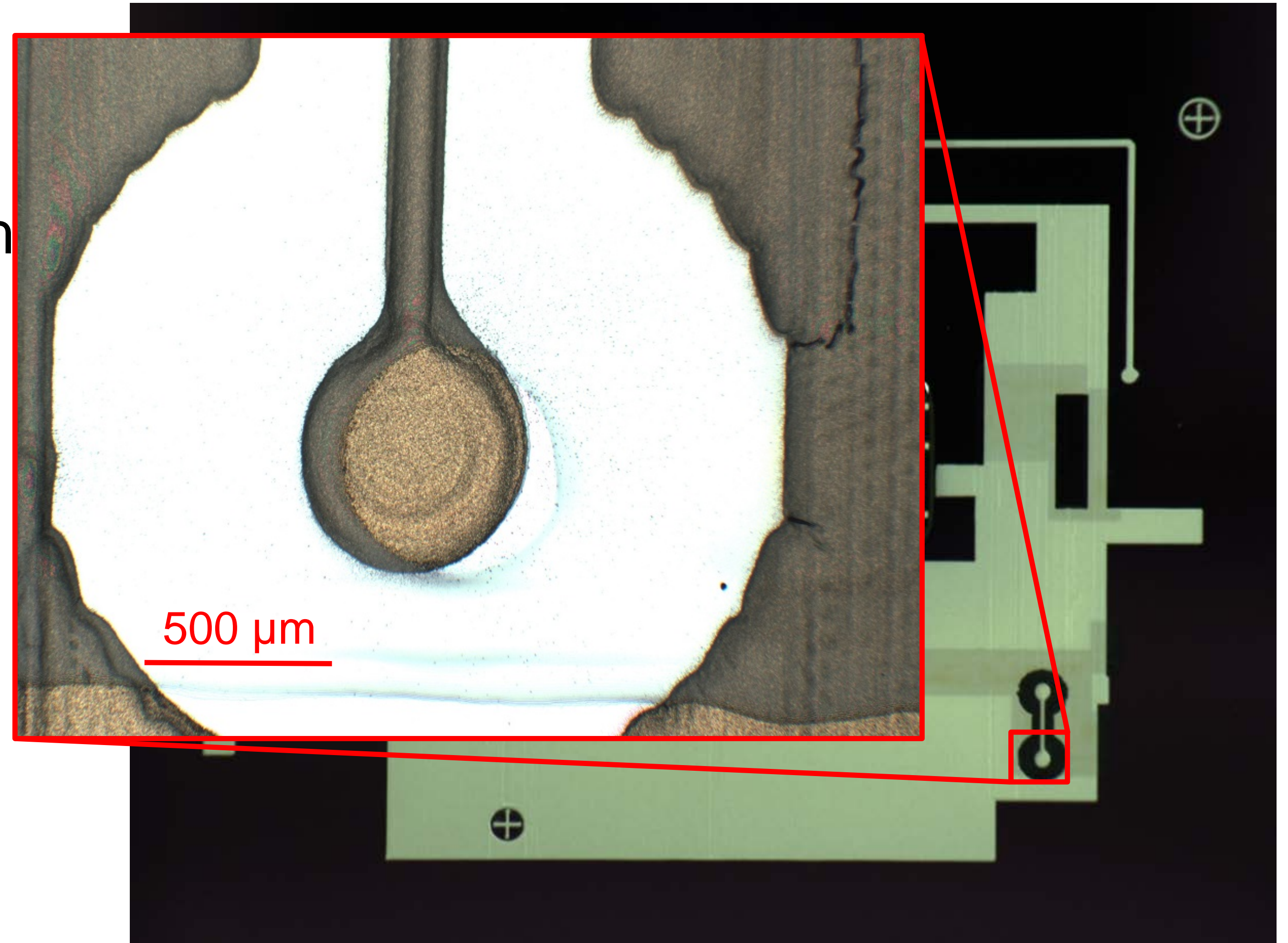




Printing of the Dielectric Layer

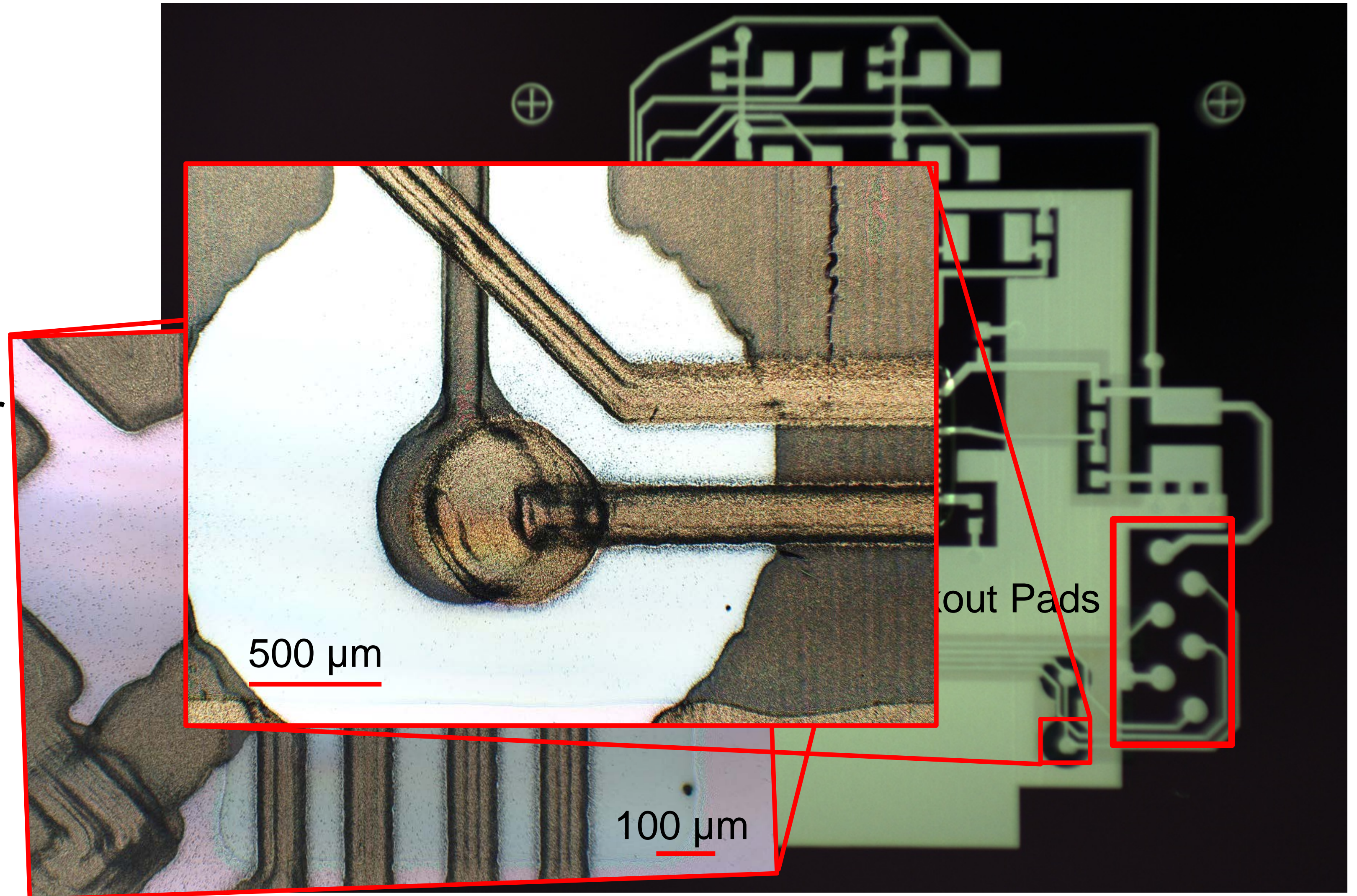
Dielectric Layer Print

- NeXolve Corin XLS Polyimide
- Designed with 120 µm spacing
- Printed at 170-200 µm line width
- 30-40% trace overlap
- Platen 40°C
- Matching network design 10 µm
- If 7 µm reflection coef. 0 dB
- 3 passes main, 7 passes RF
- 30 min print



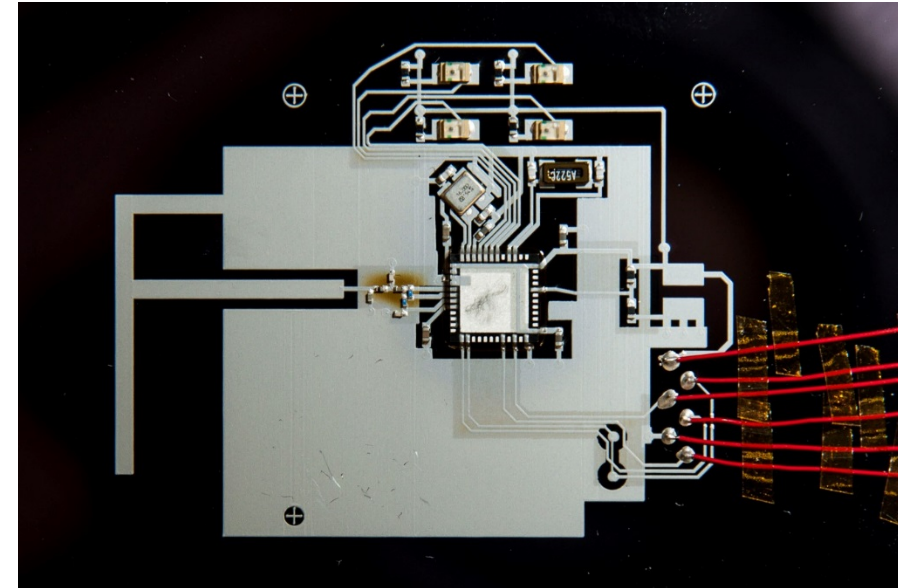
Silver Routing Layer

- NovaCentrix HPS-030AE1 Silver Flake Ink
- RF printed separately
- Print 1 hour
- Pictures of two multilayer locations

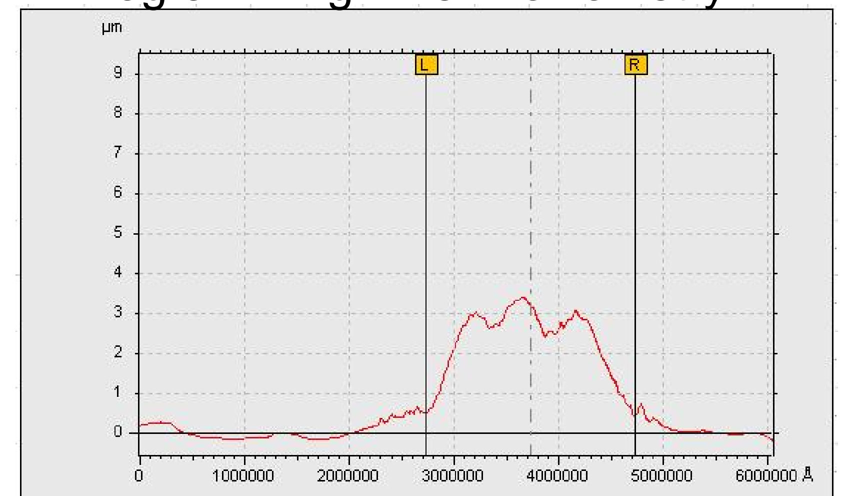


Transceiver Circuit Functionality Results

- Resistivity programming lines 3-6x bulk
- Manufacturability
  - Fabrication approximately 10 hours
  - Potential to reduce it by > 4 hours
  - Design alterations to machine code ~1 hr
  - Correctible during early stage prints
- Reproducibility
  - Shorting issues – primary failure mechanism
  - Trace width and height variability
  - Manual epoxy method on 0201 pad size
  - 2/8 completed modules programmable, 0/8 functional RF



Programming Line Profilometry



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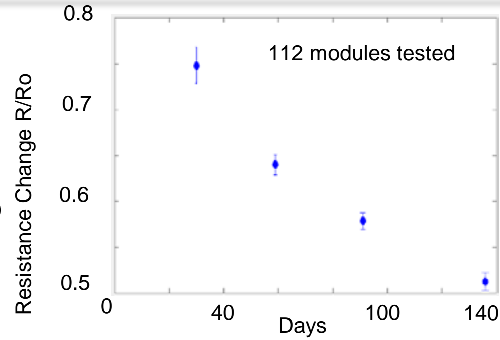
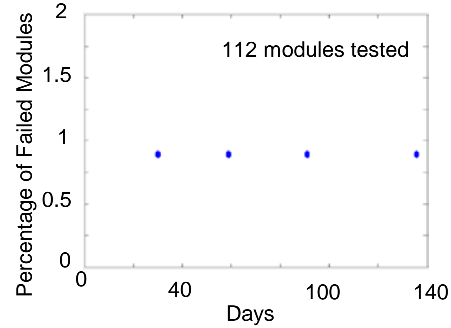
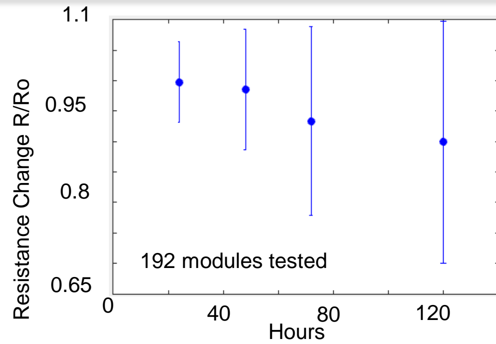
Rapid Ageing of AJP Inks

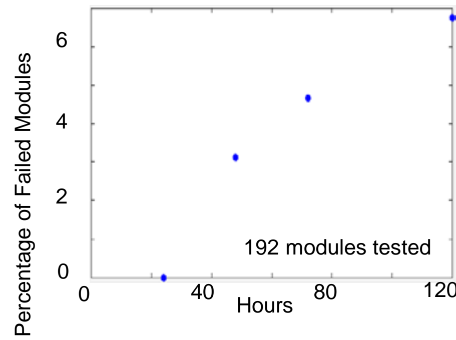
Elevated temperature ageing (60^oC)



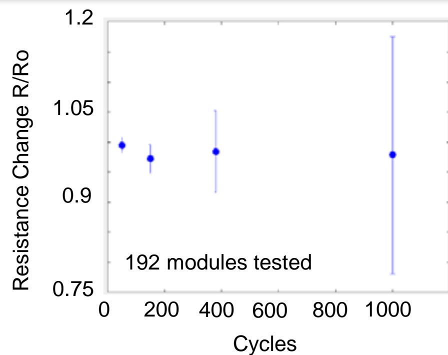


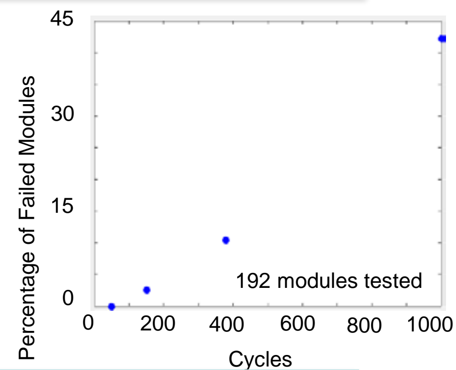
Moisture/ humidity Resistance (50^oC/85%RH)

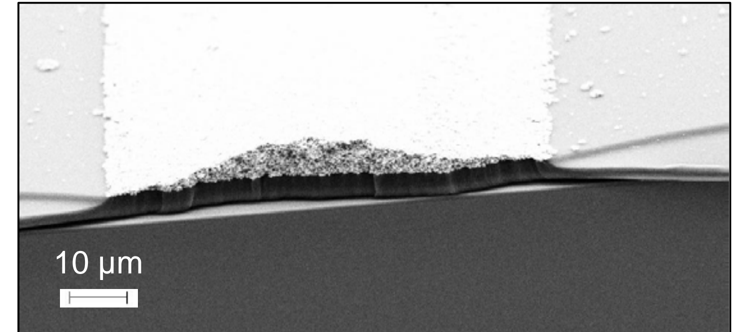


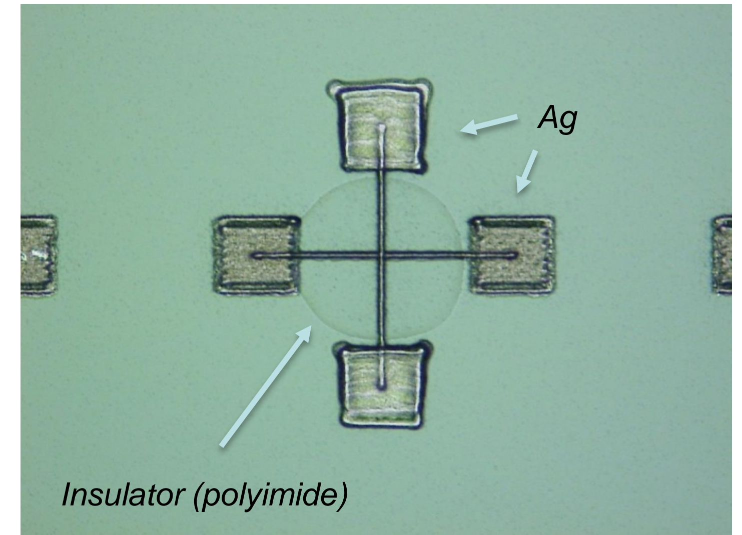


Thermal Shock (-55^oC/125^oC)









6% uncertainty due probe placement not included

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CONCLUSIONS AND FUTURE WORK

Conclusions

Transceiver Circuit	Flexible Process Developed for Complex PCB Manufacture
	Suitable when near bulk resistivity is not essential
	Fabrication time reduced from weeks and months to days
	Hand-placing components works for majority of circuit
	Successful programming and execution of microprocessor
	RF not functional – dielectric variation and 0201 components
	Currently not very repeatable process, can be improved with design

Future Work

Apply circuit building process to variety of inks and substrates

Photonic annealer integration

Automated COTS placement

Redesign circuit to reduce conductive epoxy

Functionalize RF portion of circuit

Acknowledgments

Those who have contributed to the research:

Yen Wah Ho, Pat Barry, Abbie Spencer, Else Vedula, Jon O'Brien, Matt Griffin, Greg Fritz

Tufts University

Draper

References

1. J. Chou, M. McAllister, and P. Schottland, "Aerosol Jet Printable Metal Conductive Inks, Glass Coated Metal Conductive Inks and Uv-curable Dielectric Inks and Methods of Preparing and Printing the Same," 2014.
2. J. A. Paulsen, M. Renn, K. Christenson, and R. Plourde, "Printing conformal electronics on 3D structures with Aerosol Jet technology," in 2012 Future of Instrumentation International Workshop (FIIW) Proceedings, 2012, pp. 1-4.
3. J. Hoerber, J. Glasschroeder, M. Pfeffer, J. Schilp, M. Zaeh, and J. Franke, "Approaches for Additive Manufacturing of 3D Electronic Applications," Procedia CIRP, vol. 17, pp. 806-811, 2014.