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Through Si Vias Using Liquid Metal Conductors for Re-workable 3D Electronics

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Outline

- History of liquid metals
- Motivation
- Current Work
- Electrical Characterization
- Challenges
- Summary
- Questions

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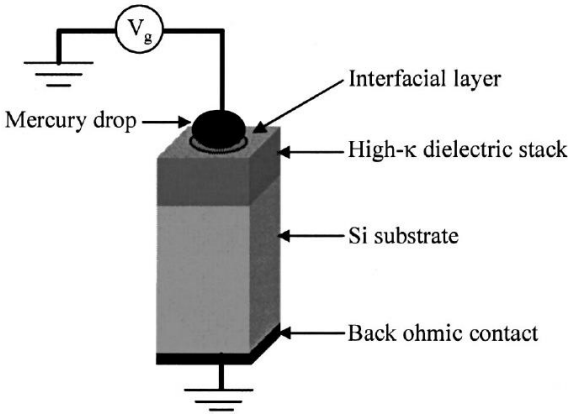
History of liquid metals

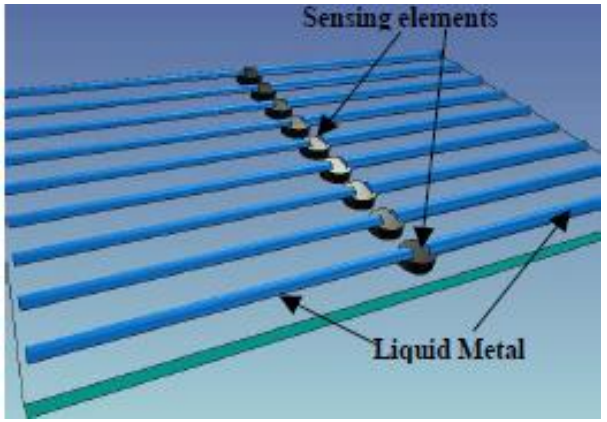
- Mercury used for rapid electrical characterization
  - Limited applications
- Eutectic alloys of Gallium
  - Eutectic Gallium Indium (EGaIn), GaSnIn (Gallinstan)
- Switches, cooling fluids, flexible electronics

Mercury contacts



Mercury Droplet for C-V measurements [1].

Gallinstan flexible electrodes



Flexible Sensor Skin [2].

[1]Garros, C. Leroux, and J.-L. Autran, "An Efficient Model for Accurate Capacitance-Voltage Characterization of High-k Gate Dielectrics Using a Mercury Probe," *Electrochemical and Solid-State Letters*, vol. 5, no. 3, p. F4, 2002.
[2] H. Hu, K. Shaikh, and C. Liu, "Super flexible sensor skin using liquid metal as interconnect," *2007 IEEE Sensors*, pp. 815–817, 2007.

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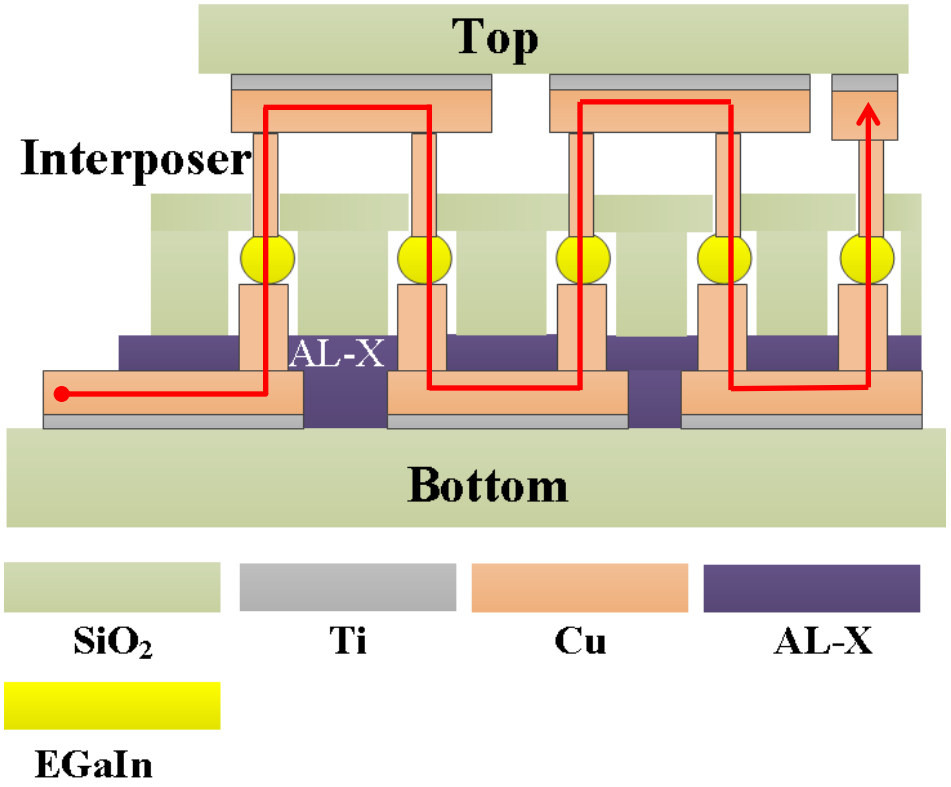
Motivation

- Non-traditional materials in device integration (2.5D and 3D)
- Demonstrate feasible implementations
- Eutectic gallium indium safer than mercury
- Conductivity higher than mercury
  - 3.4×10^4 versus 1.0×10^4 [S/cm]
- Reasonable conductivity compared to copper 59.6×10^4 [S/cm]
- Liquid metal can better accommodate CTE of silicon
- **Provide re-workability**

Goal

Build re-workable test modules using liquid metal vias

Current work: Re-workable 2.5D integrated modules

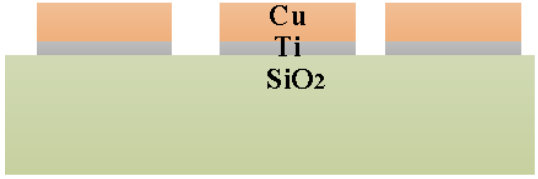


Implementation of liquid metal vias for re-workable modules

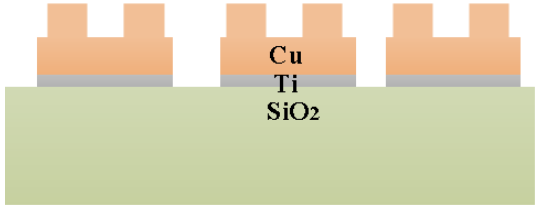
Current work: Fabrication details for a single replaceable die

Process flow for half-assembly

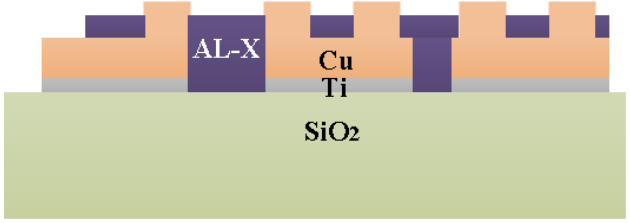
1. Pattern and lift-off bottom metal contacts.



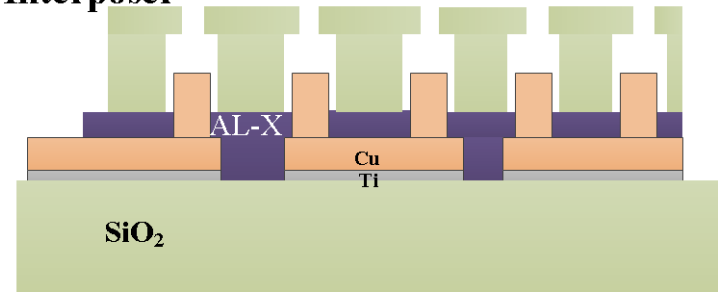
2. Electroplate copper pads.



3. Spin-on and pattern AL-X layer.



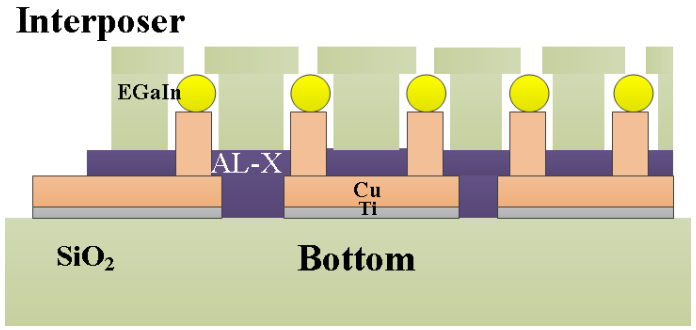
4. Mechanically bond interposer to bottom die.



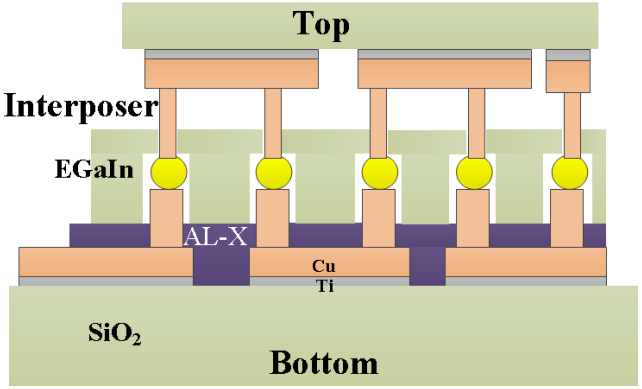
Current work: Fabrication details for a single replaceable die

Process flow for half-assembly continued.

5. Fill interposer vias with liquid metal.



6. Mechanically bond top die.



The top die is replaceable.

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Current work: Electrical contact to the liquid metal

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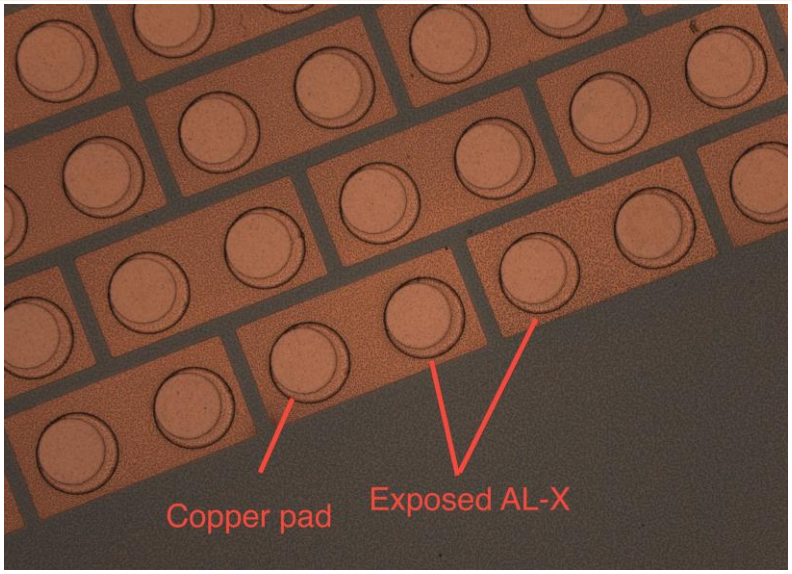
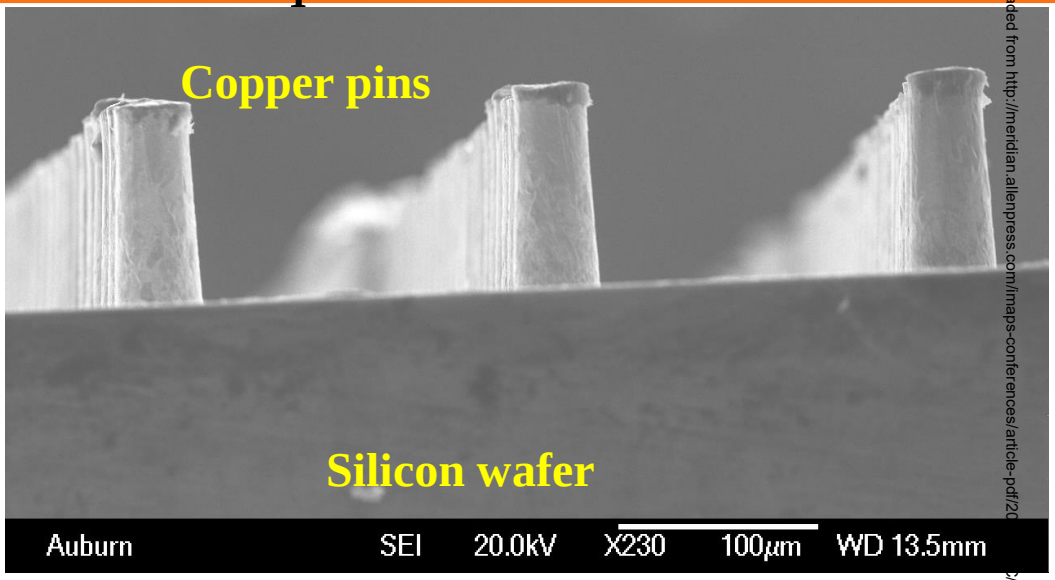
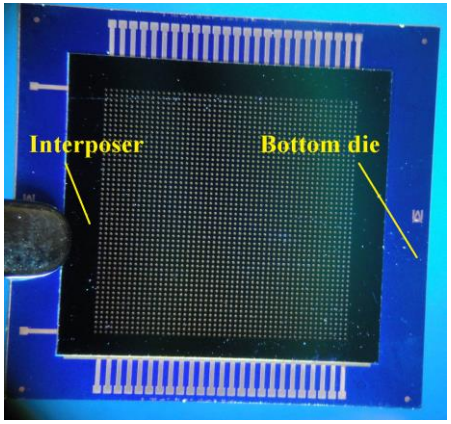


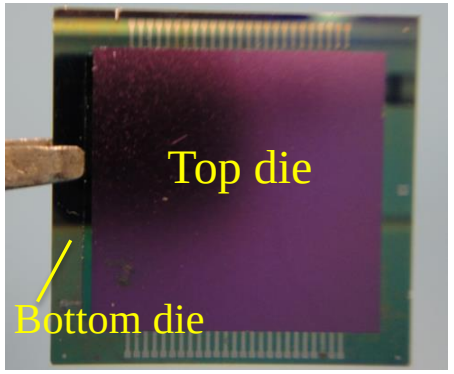
Bottom die contact pads.



Top die copper pins.



Half-assembly showing die stack up.



Fully assembled die.

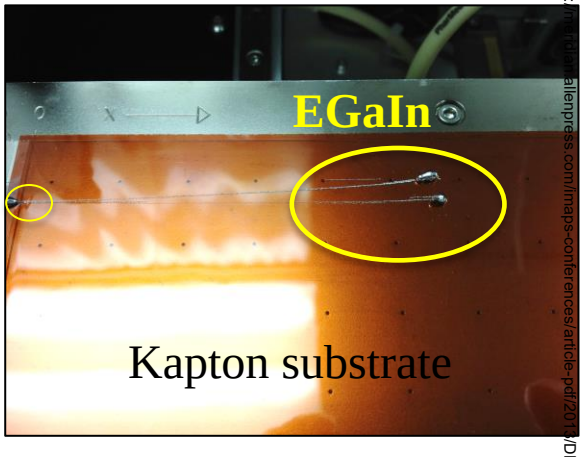
Current work:
Filling hollow vias with liquid metal

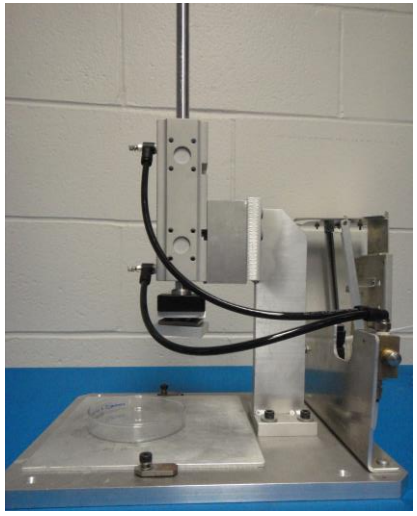
Methods Explored:

Inkjet printing of liquid metal

→

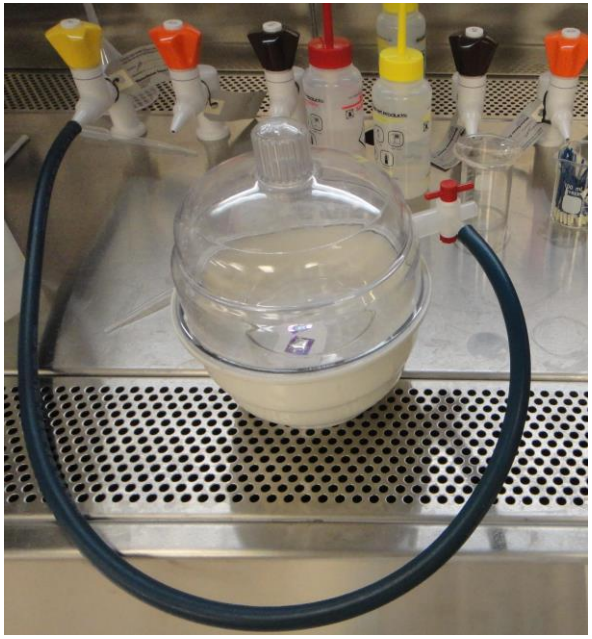
Controlling volume difficult

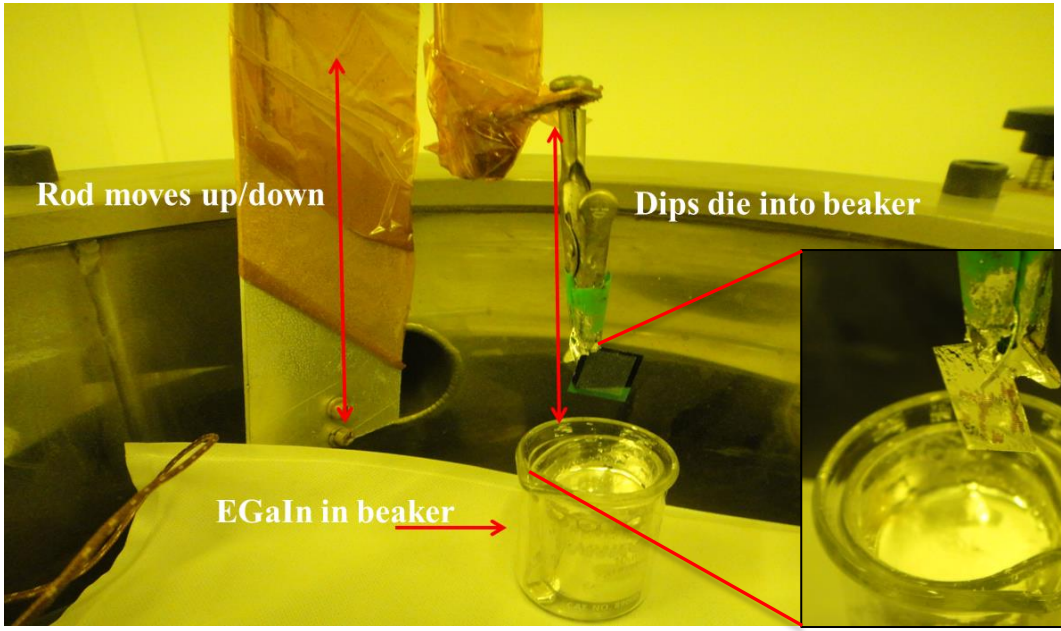




Compressing liquid metal into via openings

Current work:
Filling hollow vias with liquid metal contd.

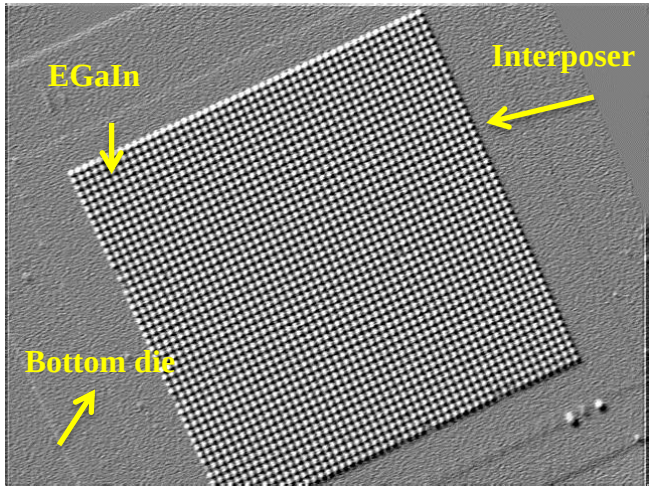




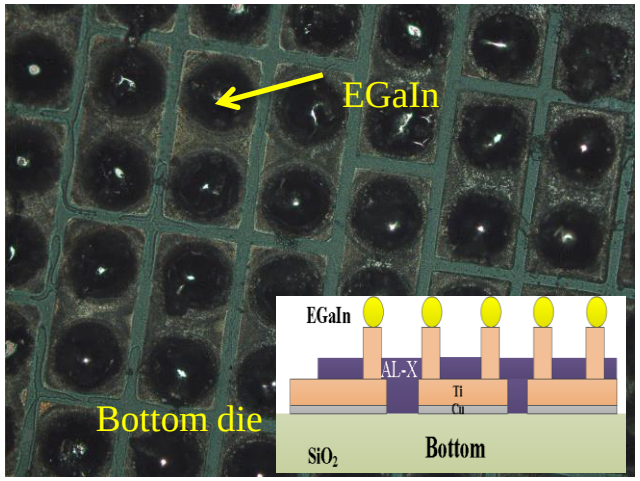
(a) Chamber for filling half-assembled die (b) for filling single interposer die.

Successful methods of filling hollow vias on a silicon interposer.

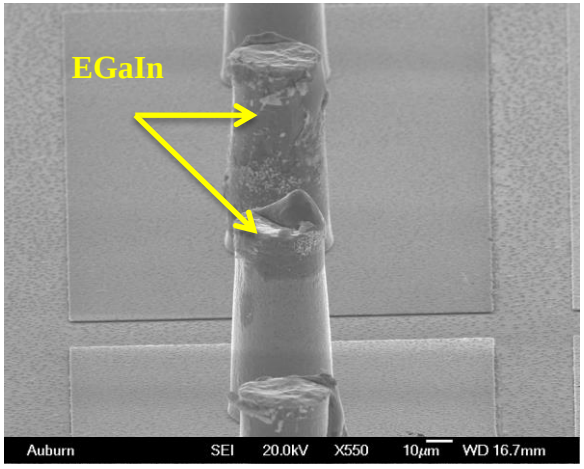
Current work: Confirmation of via filling

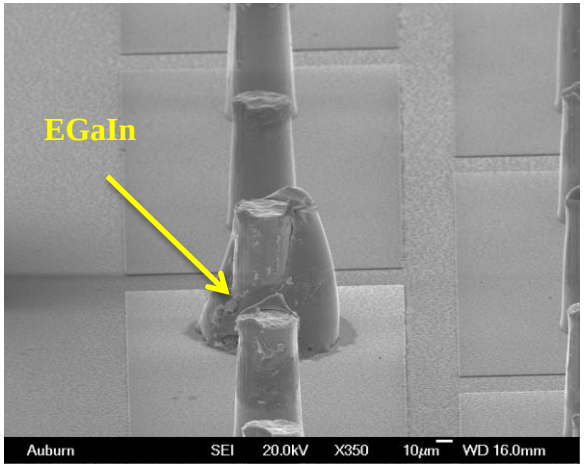


X-Ray Confirmation.



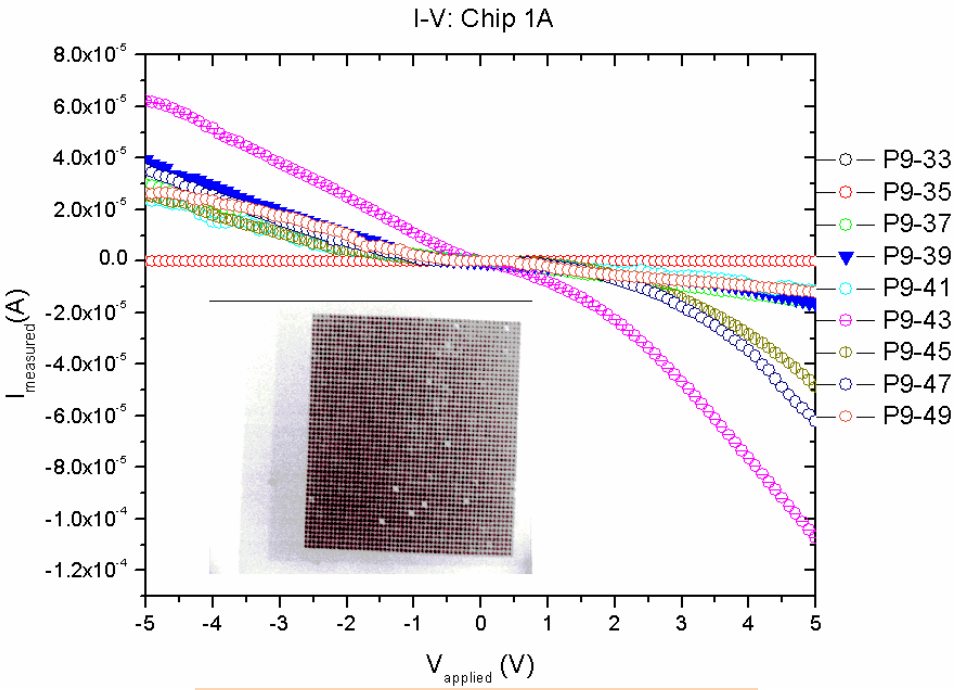
Bottom die (interposer removed).



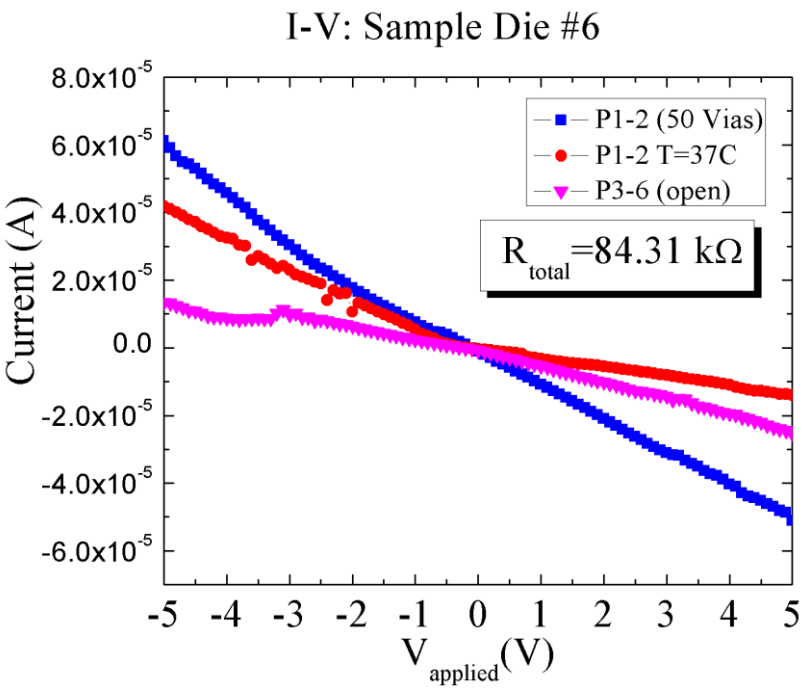


EGaIn on the top die copper pins.

Current-Voltage measurements



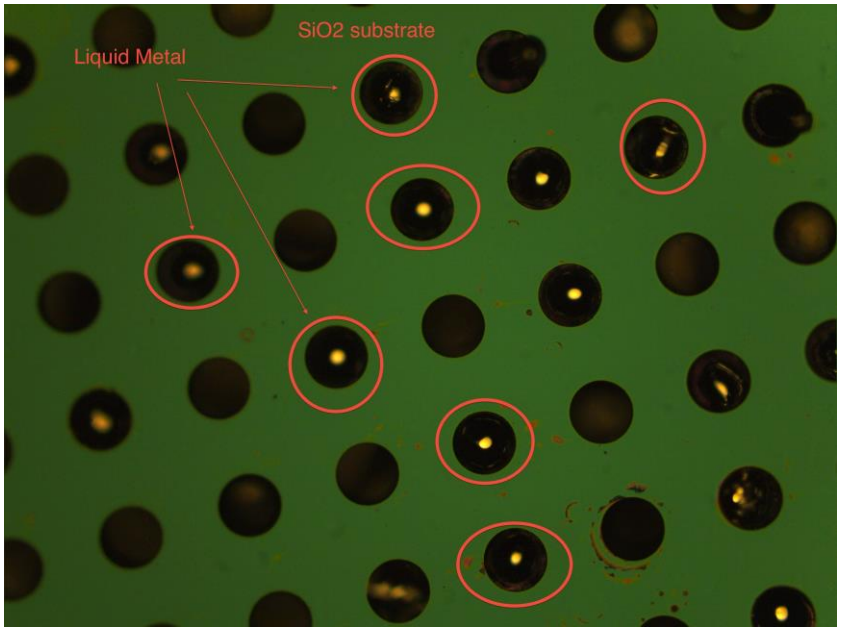
Current measured through ~ 500 vias, 250 transitions



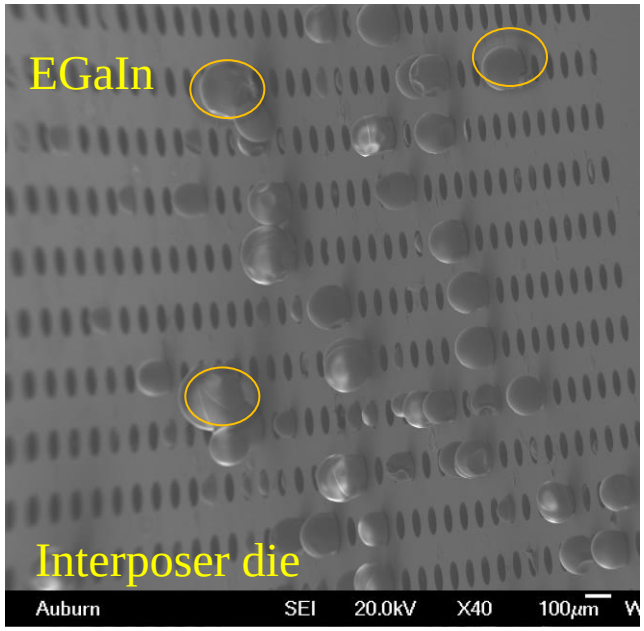
Current measured through ~ 50 vias, 25 transitions

Non-linearity present in I-V. Likely due to work function difference. Working on improving contacts.

Challenges



Liquid metal inside via openings.



SEM of liquid metal outside via openings.

- Wetting properties of EGaIn can be altered [3]
- Electrical contact to the liquid metal
- Investigate and incorporate containment structures

[3] Q. Xu, N. Oudalov, Q. Guo, H. M. Jaeger, and E. Brown, "Effect of oxidation on the mechanical properties of liquid gallium and eutectic gallium-indium," *Physics of Fluids*, vol. 24, no. 6, p. 063101, 2012.

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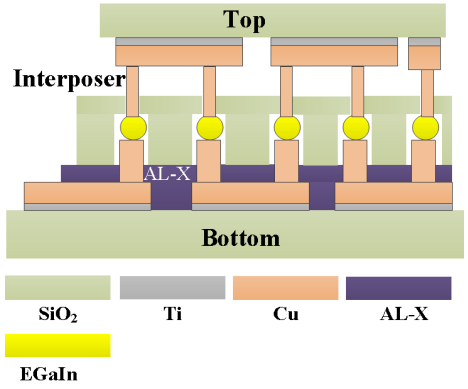
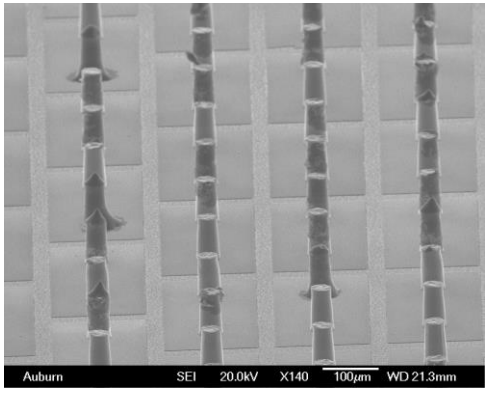
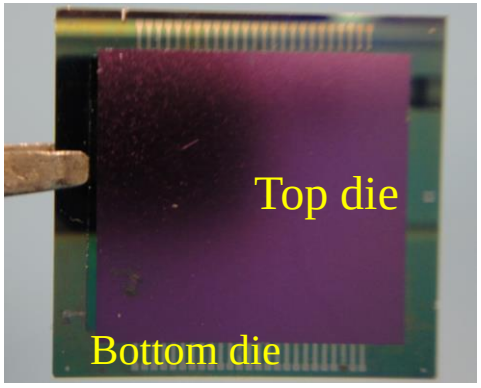
Summary

- Hollow vias filled
- Re-workability concept shown
- Electrical testing results are promising
- Exploring containment structures







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Questions?

Thank You