Lead-Free Fluxless Soldering below 120°C

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Outline/Agenda

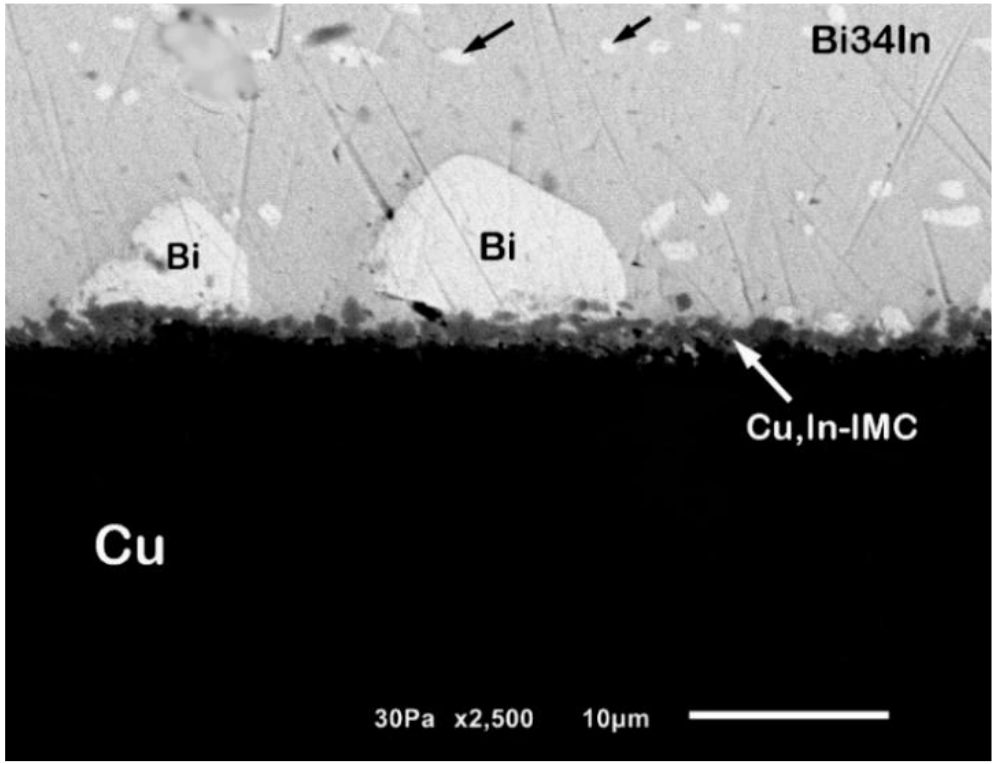
- Introduction
- Transient Liquid Phase bonding
- Ga-based paste
- Experimental
- Results and Discussion
- Conclusions
- Future Work

Introduction

- Low temperature soldering is vital for joining:
  - Heat sensitive materials & devices
  - Stress sensitive materials & devices
  - Piezo electrics with low Curie temperature
- Therefore, joining temperature should be kept as low as possible without limiting operational conditions.

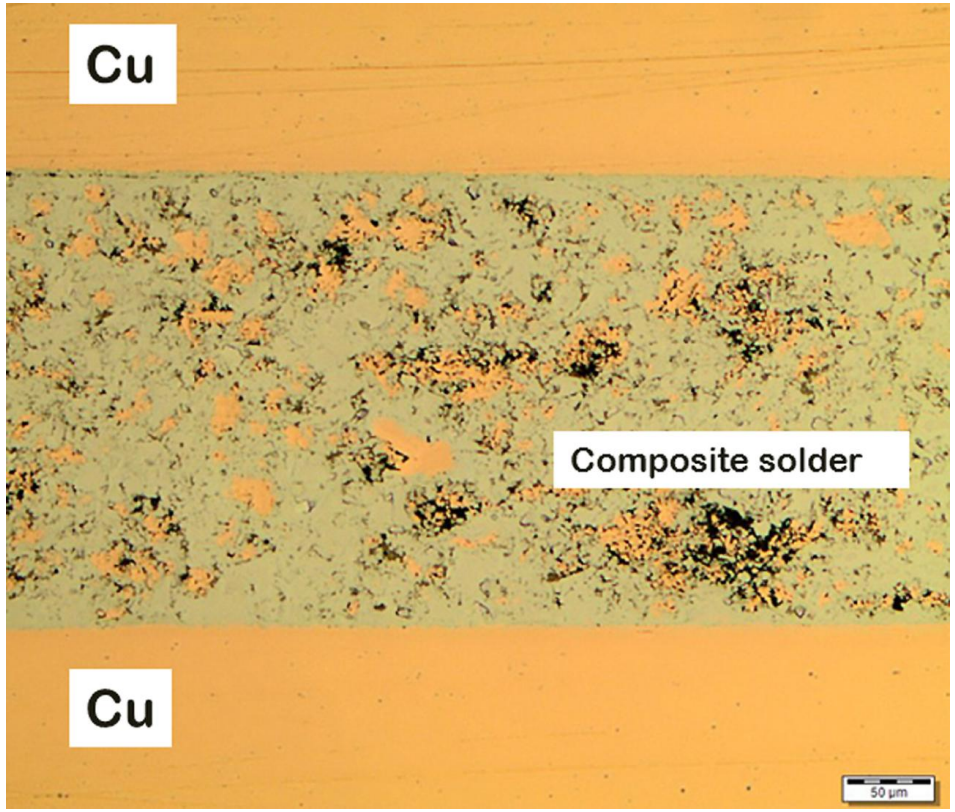
Introduction: Previous Publications

- Bi-In ordered alloys with 34 wt.% Indium can be used to join heat-sensitive electronic devices.
- Operating temperature was limited by low melting point of solder.



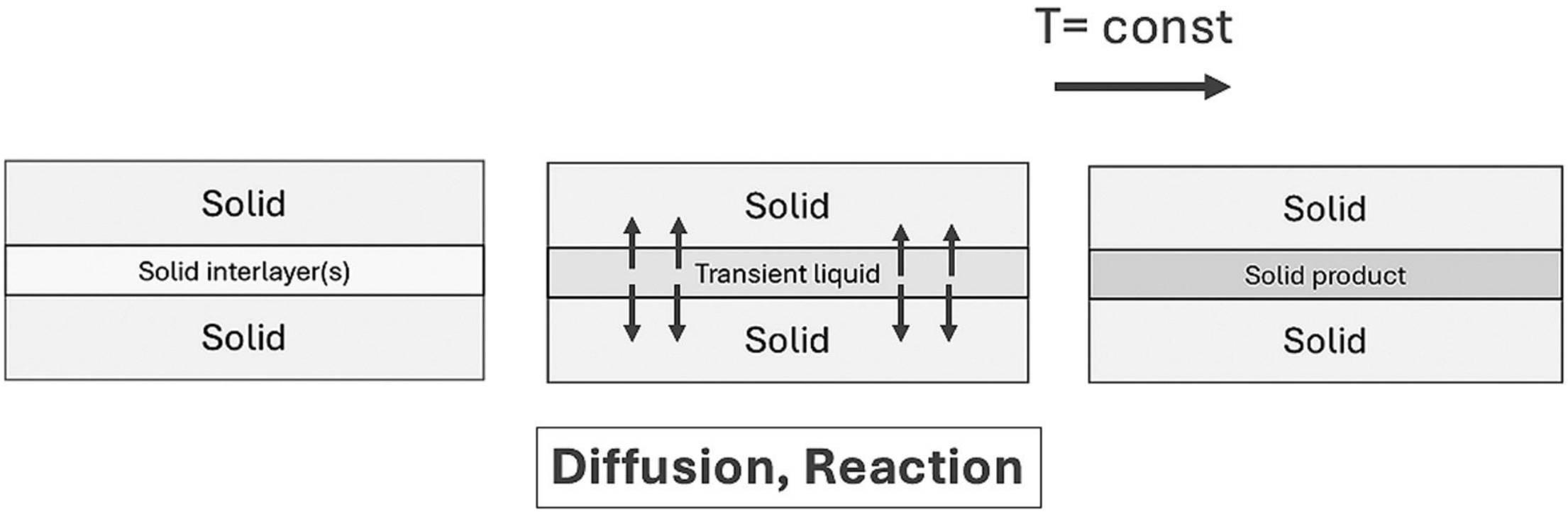
Introduction: Previous Publications

- Ga-Cu alloys made with dendritic Cu powder mixed into liquid Ga showed mixed results for joining Cu substrates
- Further investigation into Ga-Cu alloys was performed.

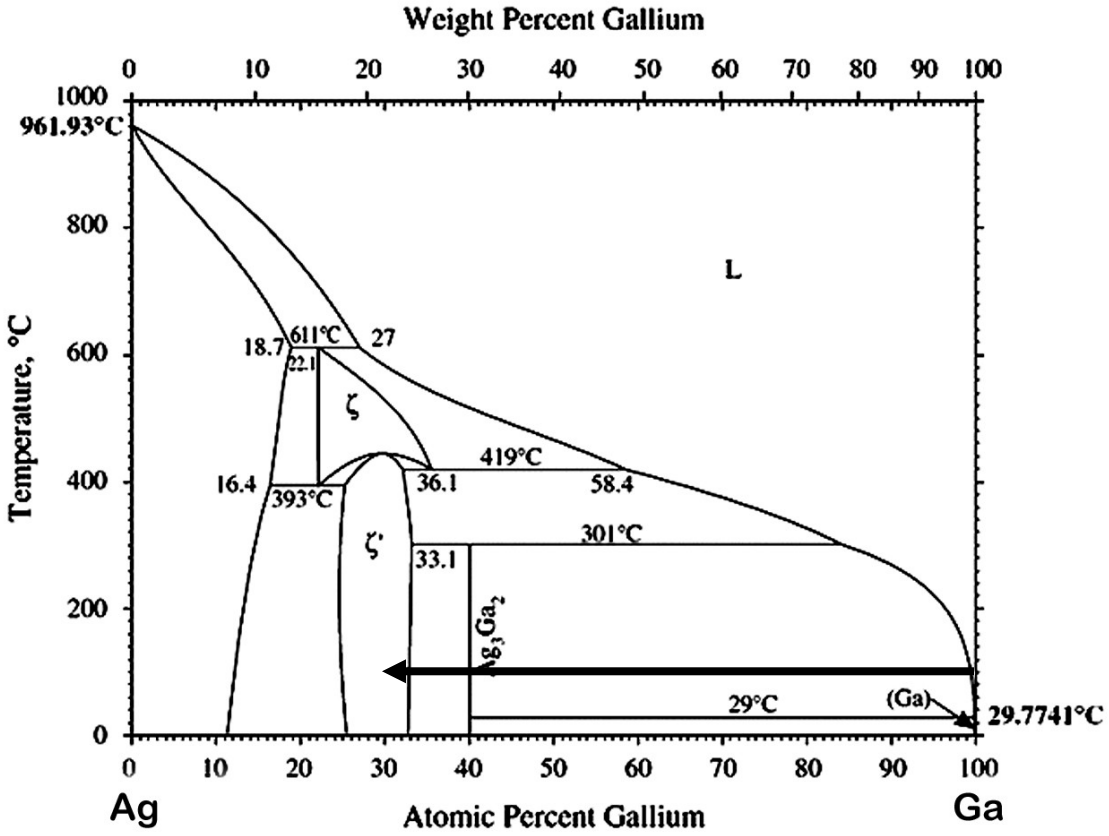


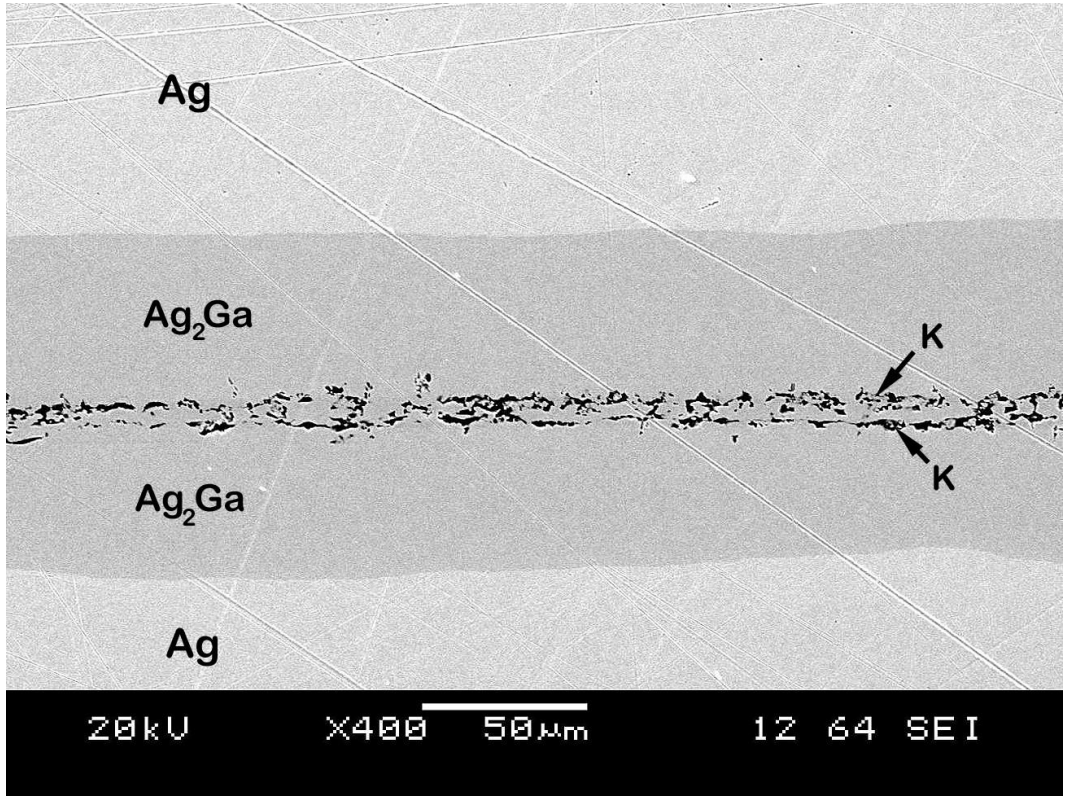
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Transient Liquid Phase Bonding

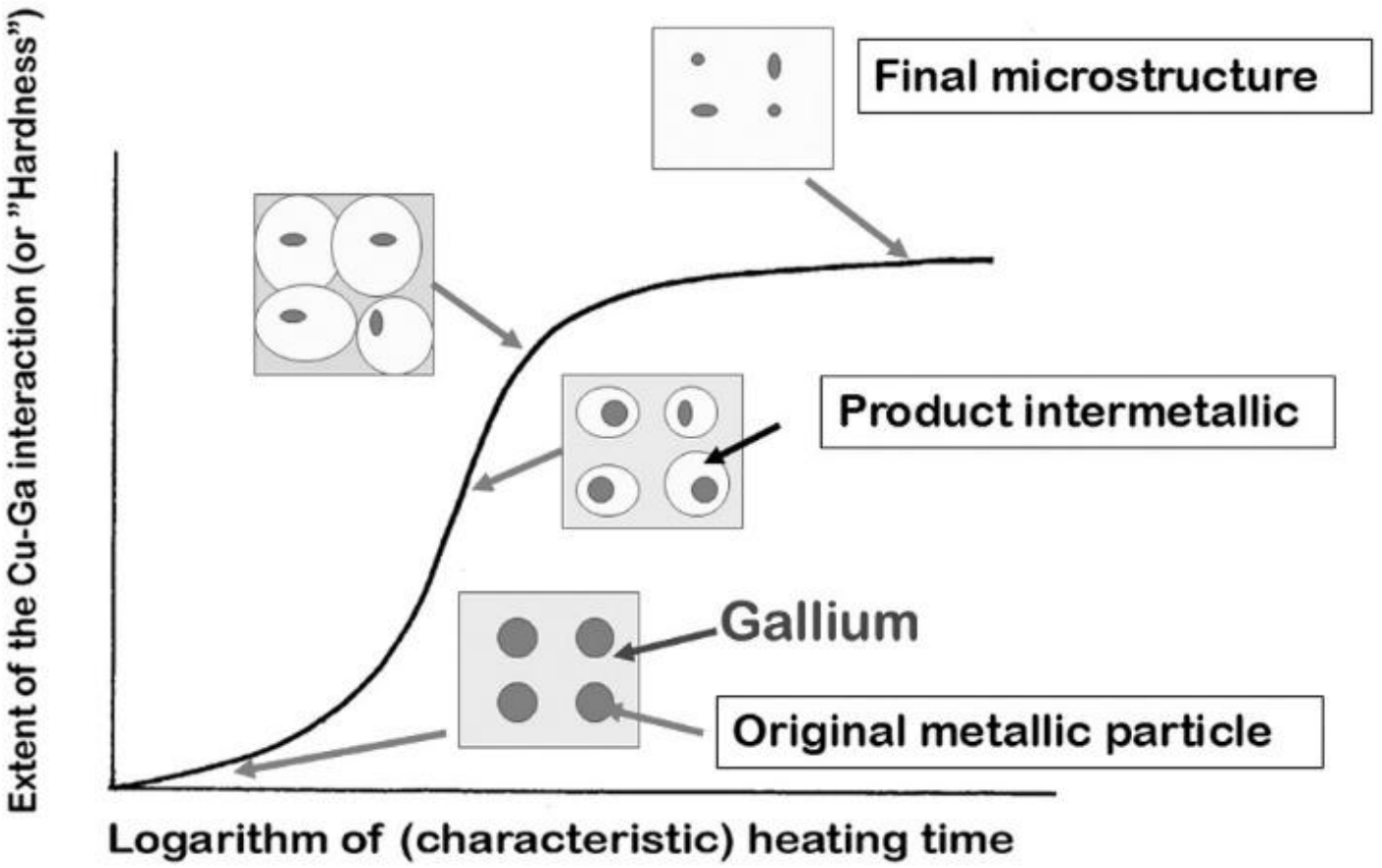


Example of TLP Bonding



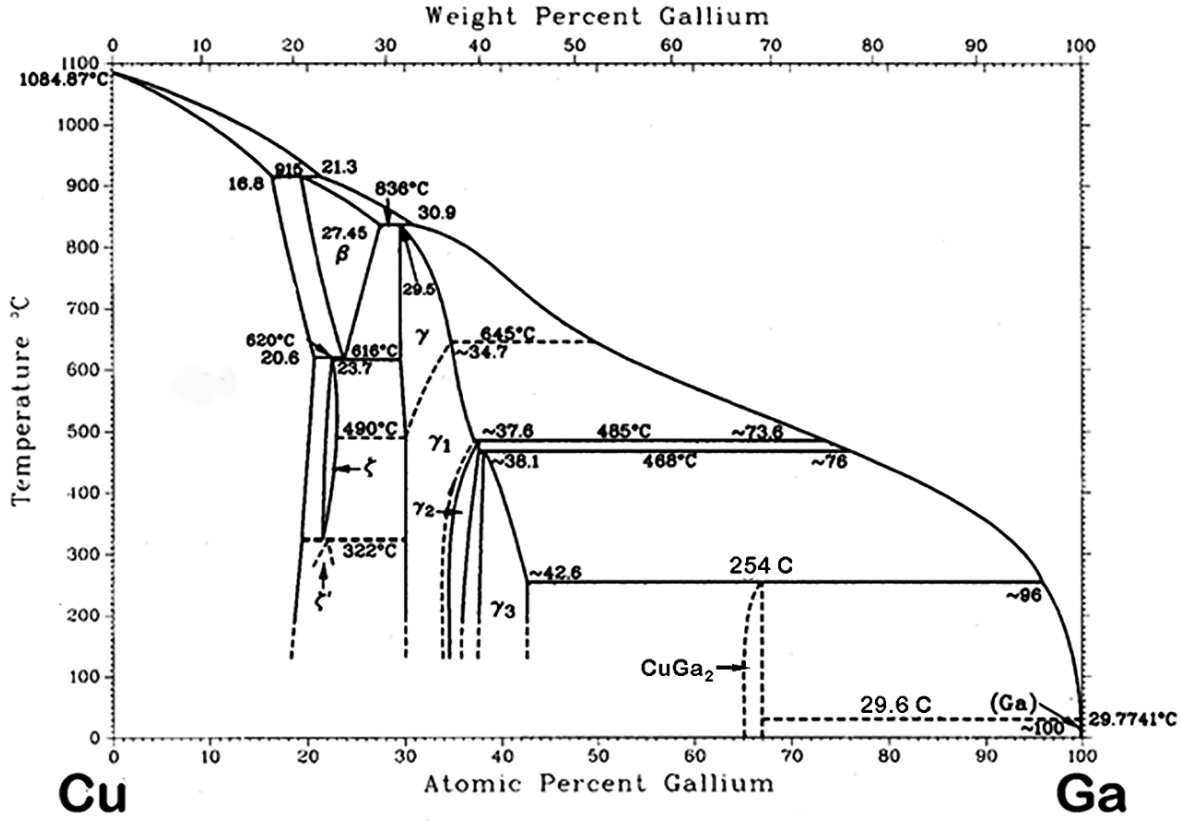


Ga-based alloy paste



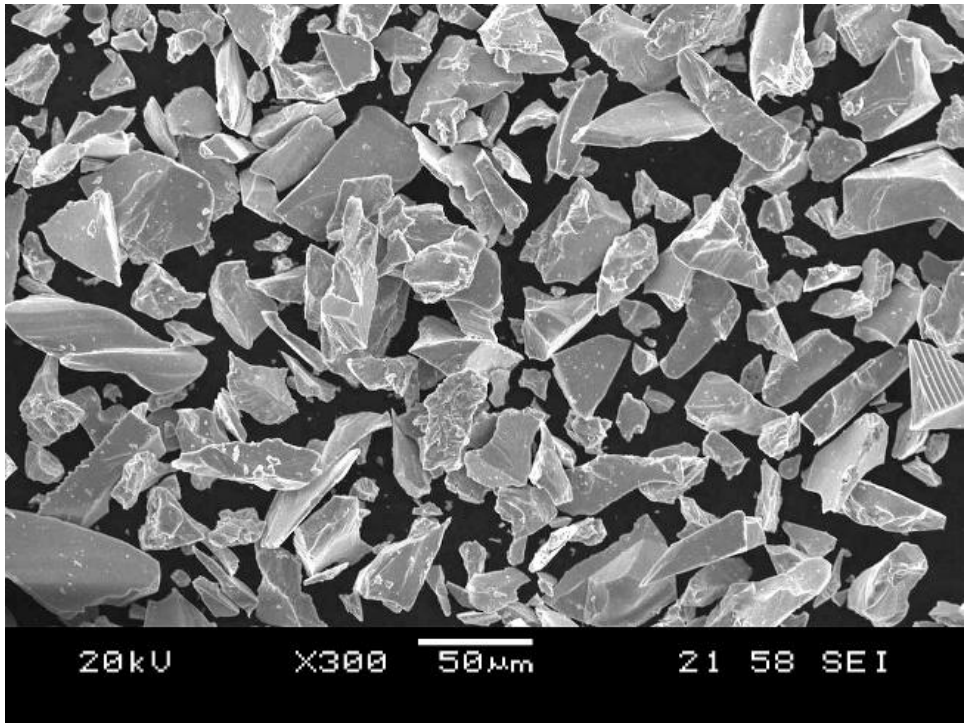
Objectives

- Produce joints below 120°C
- Joints which can withstand higher temperature (200°C)



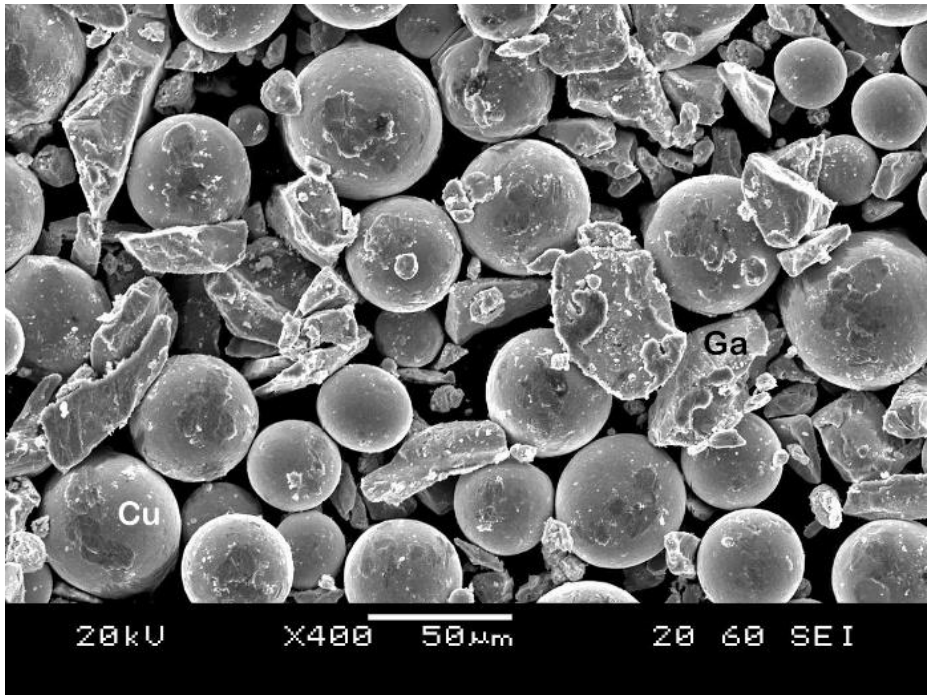
Experimental: Paste Preparation

- No commercial Ga powder available.
- Therefore cryo-pulverization of Ga necessary with liquid nitrogen.
- Subsequently Sieving < 90 µm & < 32 µm.
- Creating flowable powder.



Experimental: Paste Preparation

- Mixed with spherical Cu-powder
- Two Solder alloys (66 wt.% Cu) tested:
  - Mixing in solid Ga powder @RT (powder-powder)
  - Blending in liquid Ga @70°C (powder-liquid)
- Tested on Ag & Cu substrates & wire



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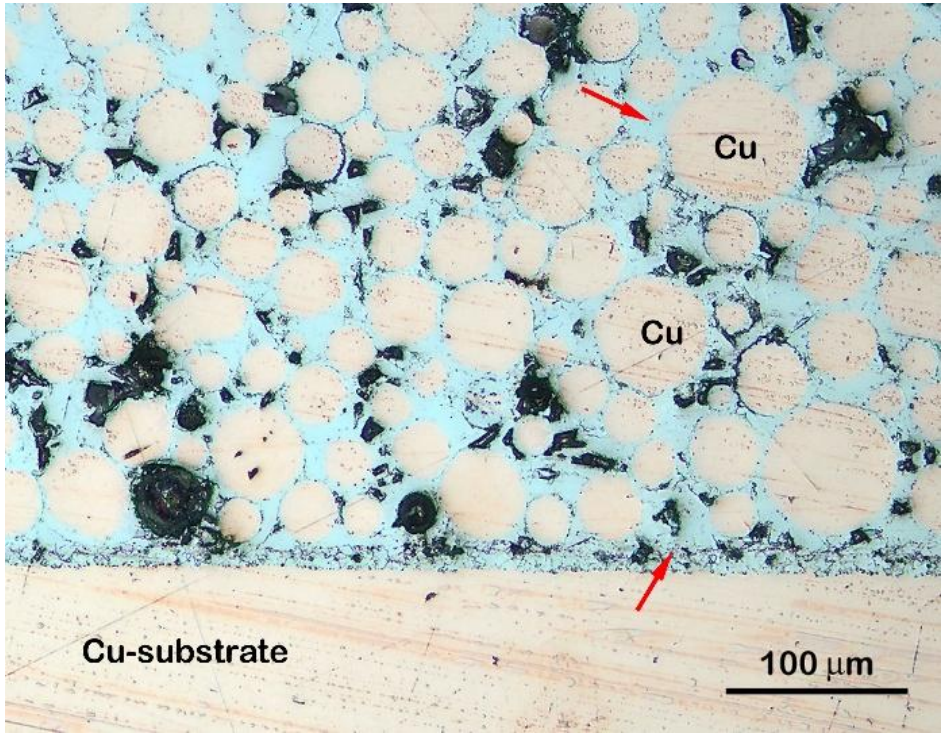
Experimental: Process

- Processed at 120°C
- Cured for 16 hours on substrate
  - After 4 hours: all Ga → $CuGa_2$-intermetallic
- Investigation was done by:
  - Optical microscopy
  - Scanning electron microscopy
  - Electron-probe microanalysis

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Results & Discussion

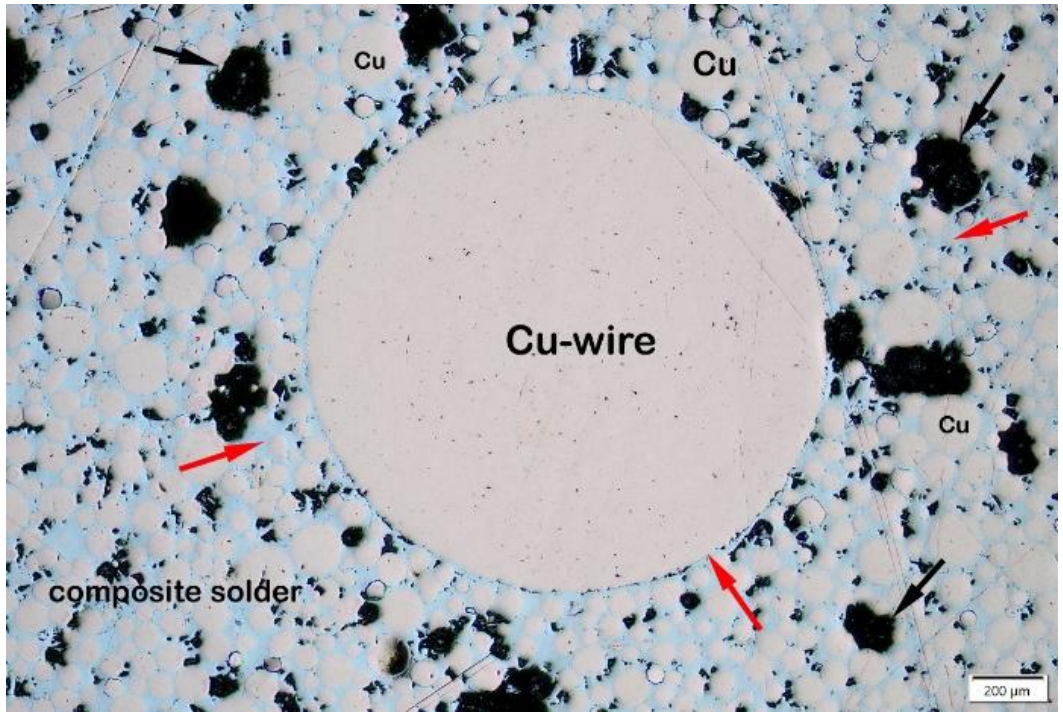
- Sample: Ga powder mixed with Cu powder on Cu substrate.
- Clear intermetallic formation in light blue
- Problematic voids appear



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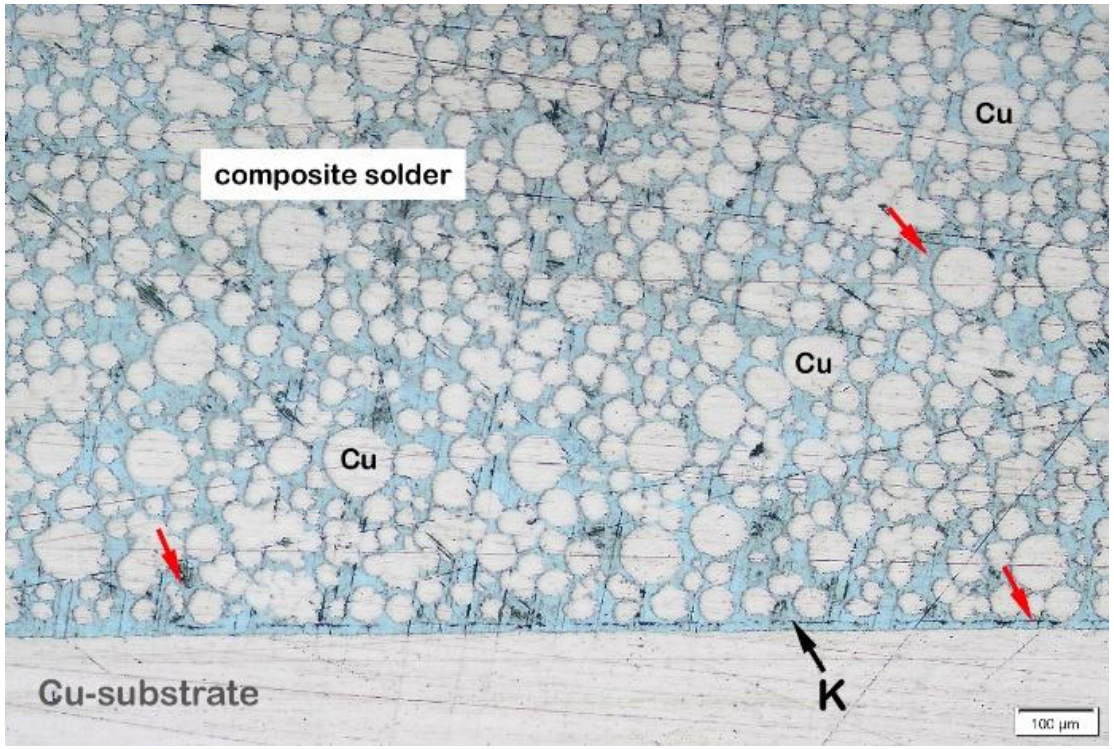
Results & Discussion

- Sample: Ga powder mixed with Cu powder on Cu wire.
- Similar results as on the Cu substrate
- A successful interconnection can be accomplished



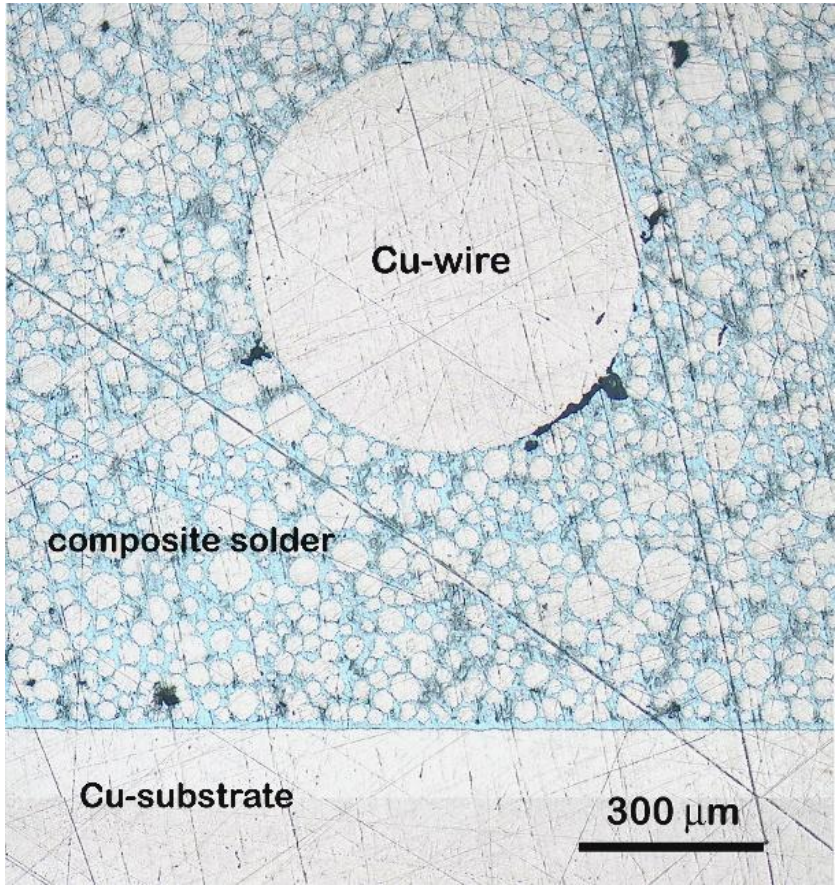
Results & Discussion

- Sample: Cu powder mixed with liquid Ga cured on Cu substrate.
- Less voids visible compared to powder-powder mixture.
- From the Kirkendall plane there is a reaction with the substrate as well.



Results & Discussion

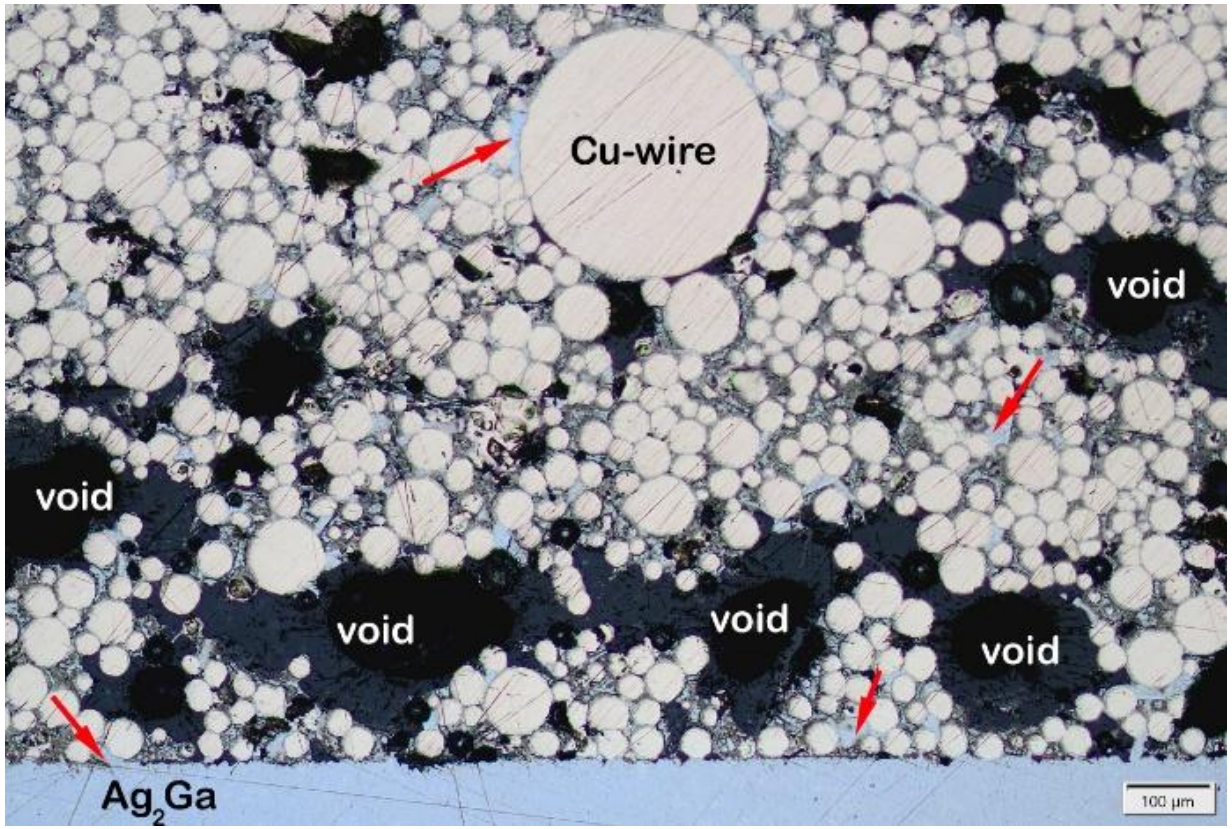
- Sample: Cu powder mixed with liquid Ga interconnecting Cu wire to Cu substrate.



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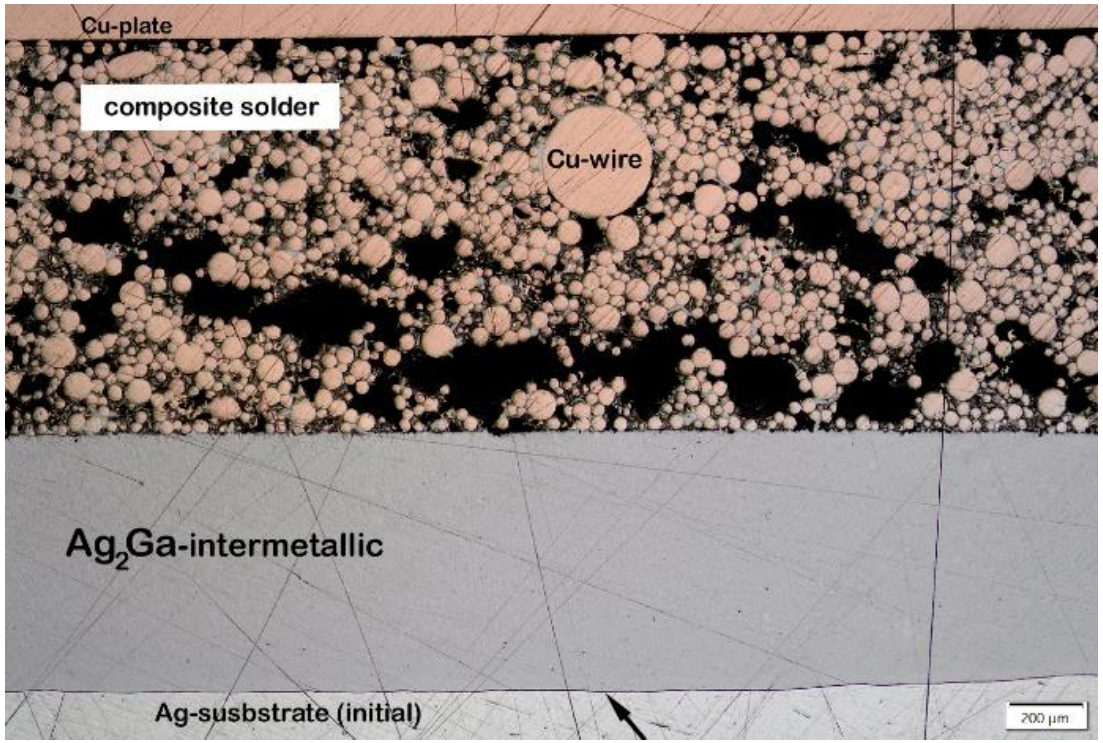
Results & Discussion

- Sample: Cu powder mixed with liquid gallium cured on Cu wire and Ag substrate.
- Ag are common electrodes
- Considerably more voids visible
- Still a good contact between solder and substrates

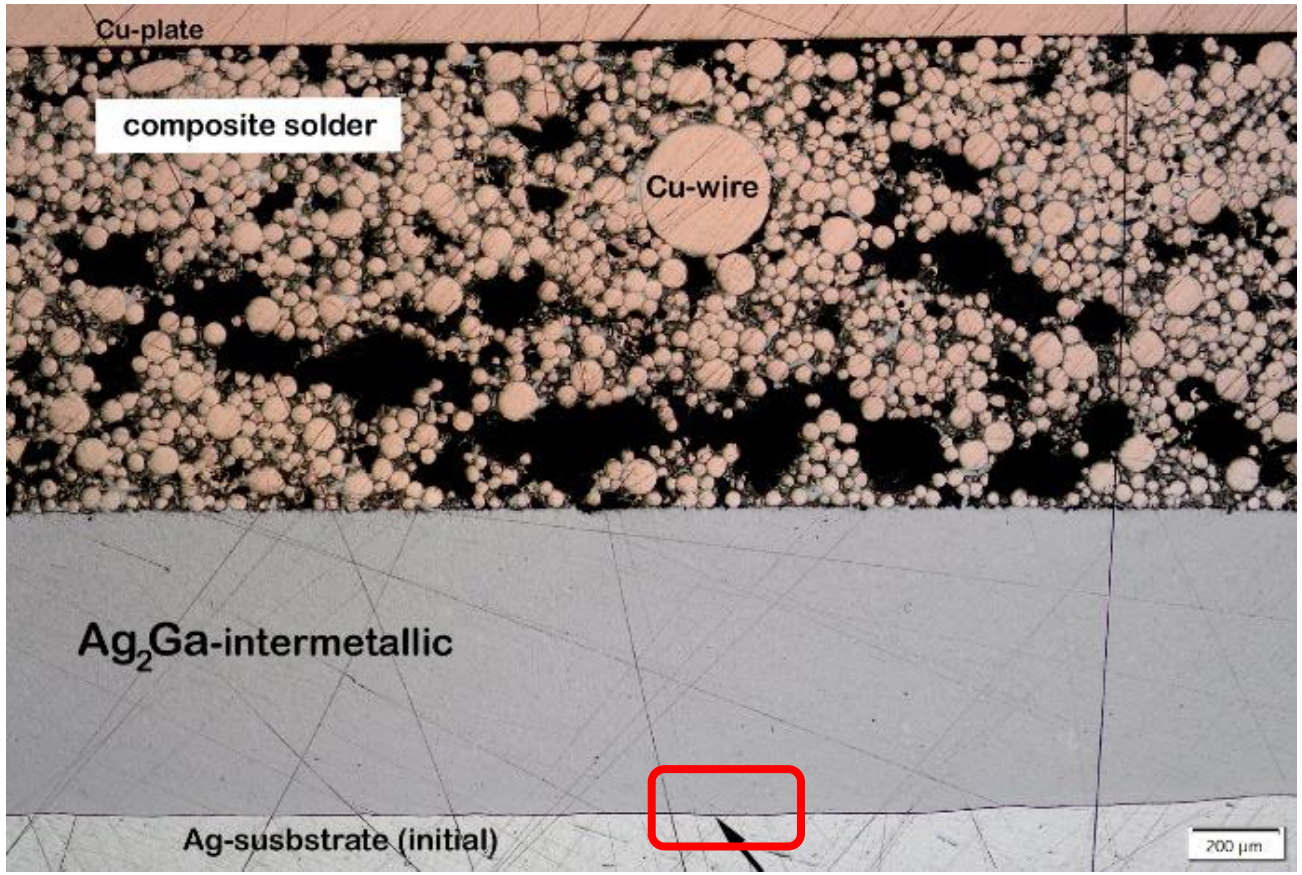


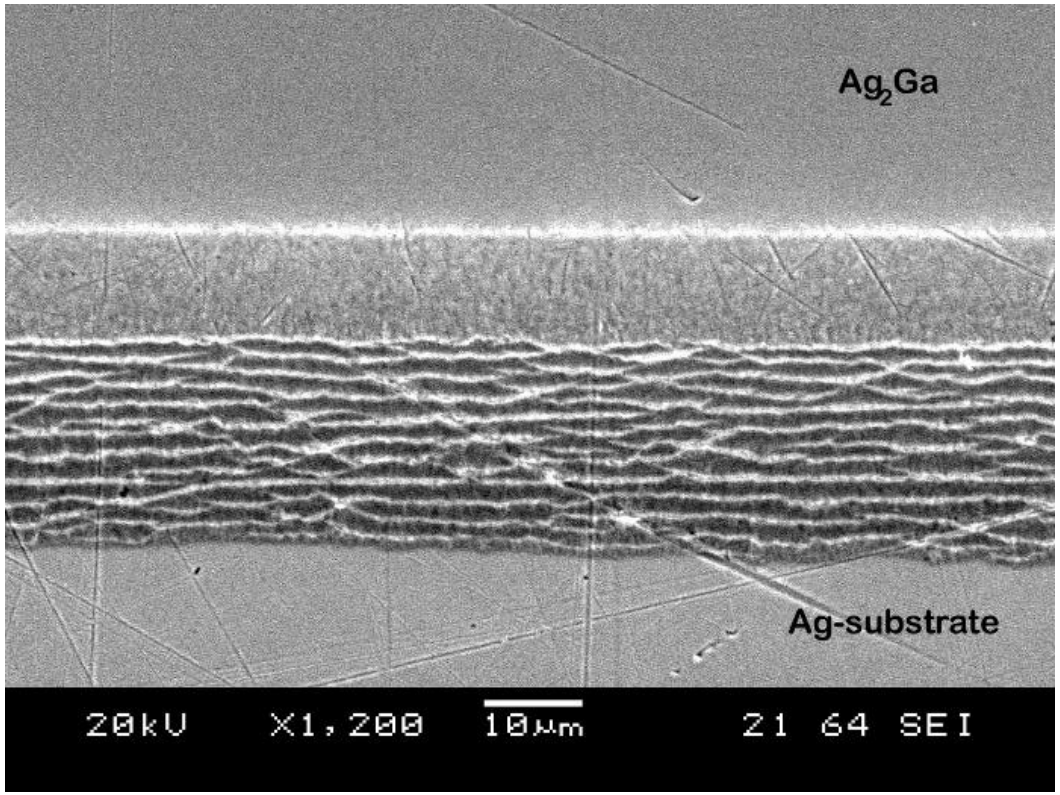
Results & Discussion

- Sample: Cu powder mixed with liquid Ga cured on Cu wire and Ag substrate.
- Huge Ag_2Ga intermetallic visible
- Ga reacts much faster with Ag then with Cu



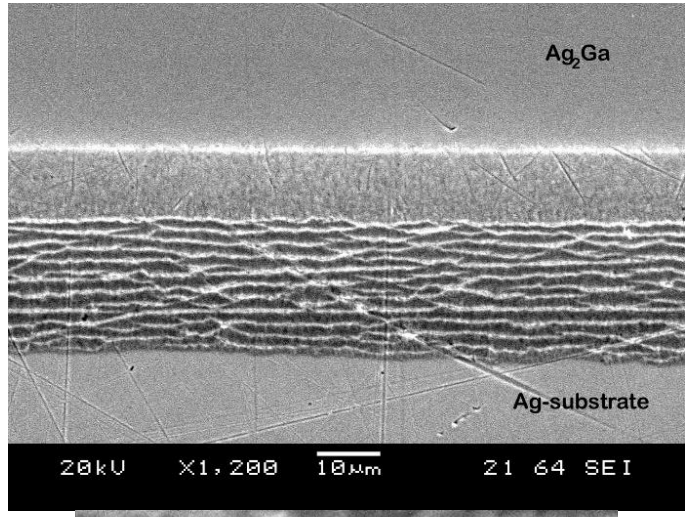
Results & Discussion

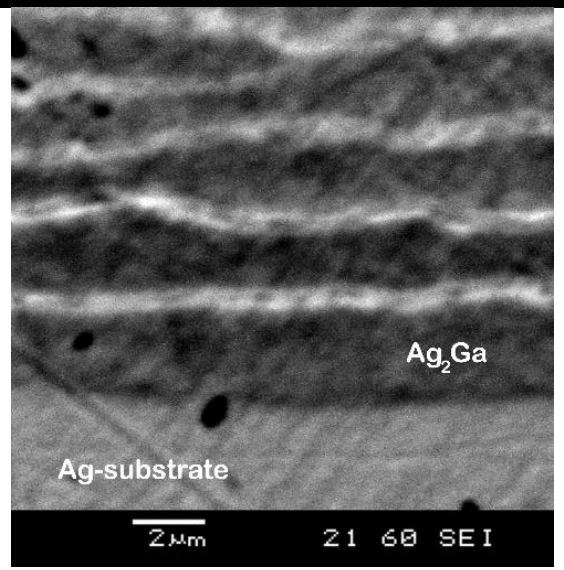




Results & Discussion

- Sample: Cu powder mixed with liquid gallium cured on Cu wire and Ag substrate.
- Periodic pattern formation is visible on Ag/Ag_2Ga interface
- White band is not single phase it is an agglomeration of particles
- So far, no explanation for this peculiar phenomenon





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Conclusion

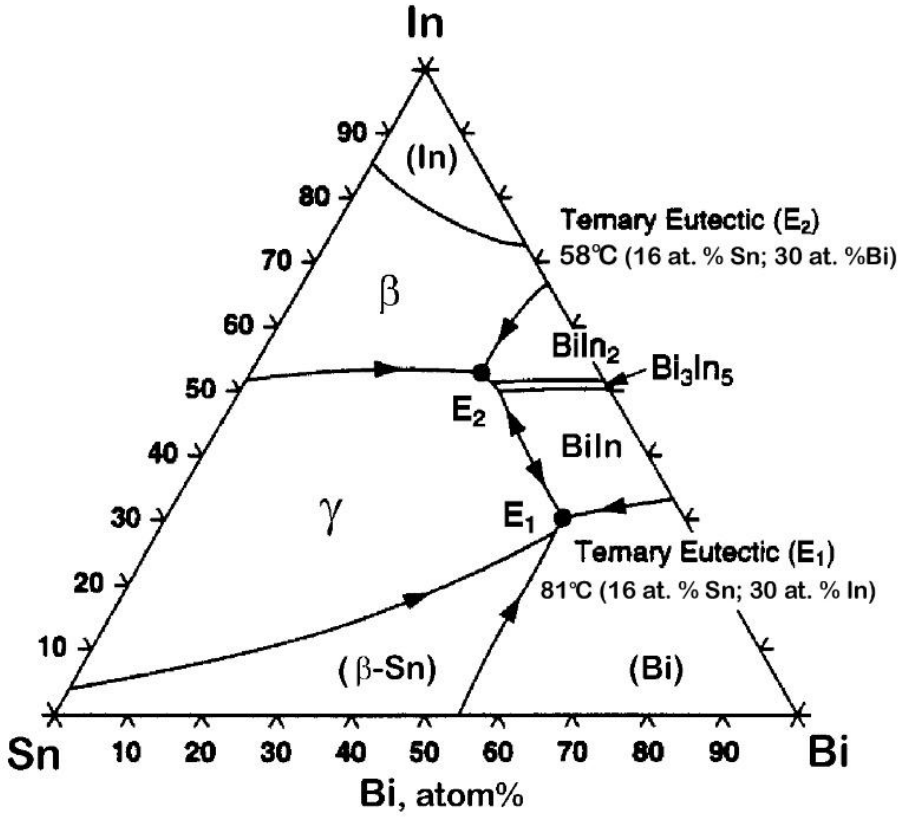
- Possible to join Cu & Ag substrates below 120°C using Ga-Cu alloy paste.
- Product joints can withstand higher temperature.
- Powder-liquid shows currently better results for joints.
- Ga has a higher reactivity to Ag substrate than Cu substrate.

Conclusions

- Flowable powder of Ga can be prepared.
- Powder based Ga-Cu Solder alloys can be formulated @ RT.
- Powder-Liquid Ga-Cu Solder alloys can be formulated @ 70°C.
- Ga-Cu alloys can be used to join Cu substrates.
- Ga-Cu alloys can also be used to join Ag substrates.
- Reaction barrier required for joining of Ag with Ga-Cu alloys.

Future Work

- Compaction of Ga & Cu Powder prior to paste application
- Add Reaction Barrier when joining Ag
- Smaller Cu particle size as powder
- Vapor pressure soldering with acetic acid
- Investigate Sn-In-Bi



Thank You!

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