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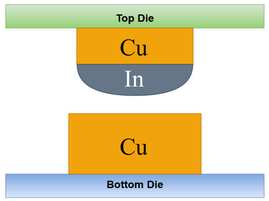
Investigation of Low Temperature Bonding Process based on Cu/Ni/In Solid Liquid Interdiffusion

Adil Shehzad[1], Steffen Bickel[2], Iuliana Panchenko[1,2], Jürgen M. Wolf [1], Wolfram Steller[1],
Benedikt Wolfram[3], Maksym Myndyk[3]
1) Fraunhofer IZM (ASSID), 01468, Dresden, Germany 2) IAVT, TU Dresden, 01062, Germany
3) Semsysco GmbH, 01468, Dresden, Germany

Fraunhofer IZM
ASSID – All Silicon System Integration Dresden

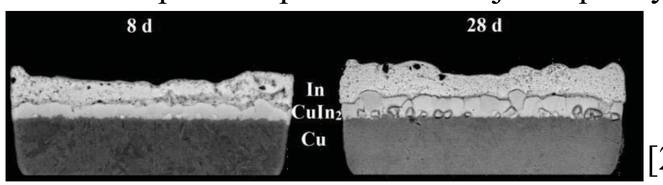
Introduction to Low T (SLID) bonding

- Interdiffusion of elements in material system with two or more components [1]
- Cu/In system is among best approaches for low temperature bonding below 200ºC
- In provides lower melting Temp (~156ºC) compared to typical solders like Cu/Sn and Cu/SnAg



Challenges

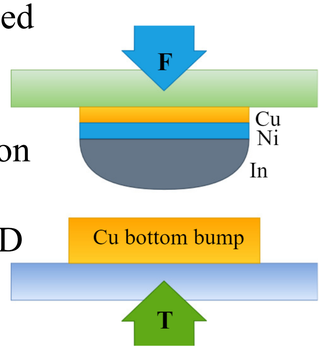
- Cu/In as a joining material exhibits greater challenge during storage time
- Formation of $CuIn_2$ IMC at room Temp [2]
- Consumption of pure In affects joint quality



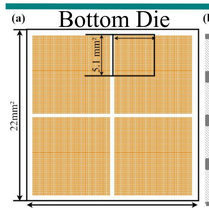
[2]

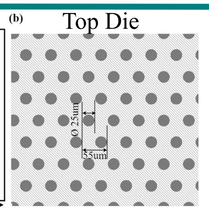
Proposed Solution

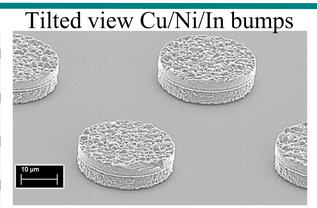
- Ni barrier layer is introduced to suppress the growth of $CuIn_2$ IMC
- Based on slow interdiffusion between Ni and In
- Spare pure In for later SLID process and allow good wetting



Fabrication & Characterization of wafers

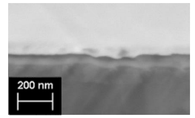






•1µm Ni plated b/w Cu & In to limit $CuIn_2$ IMC growth

- Array of bumps
- Bump pitch: 55um
- Bump Ø Top: 25µm, Bottom 35µm
- Bonded area: 4.4 mm²



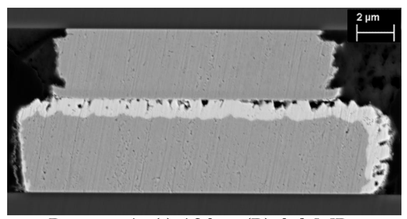
- RT storage has shown the growth of NiIn IMC ($Ni_{28}In_{72}$)
- Very slow growing IMC
- Not very stable

Design of Experiment

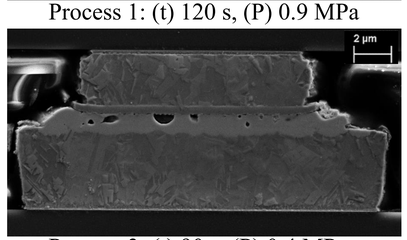
Process	Process parameters varied: Applied T, °C	Pressure, MPa	Time, s	Interface T measured, °C
1	225	0.9	120	~169
2	221 ↓	0.4 ↓	120	~162 ↓
3	221	0.4	90 ↓	~162
4	221	0.4	30 ↓	~162
5	221	0.4	10 ↓	~162

- Mainly bond time (s) and bond pressure (MPa) were modified
- Suitable interface temperature was provided
- Investigation of bond region after introduction of Ni barrier layer
- Influence of Ni barrier layer in joint quality following executed bond processes

Microstructure analysis



Process 1: (t) 120 s, (P) 0.9 MPa



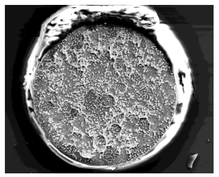
Process 3: (t) 90 s, (P) 0.4 MPa

- Cross section analysis was done
- Analysis of the bond interface
- Results demonstrated voids along Ni layer
- 90s bond time and lower pressure provided the interface with less voids
- Very fast formation of $Cu_{11}In_9$ IMC phase close to Cu (bottom bump)
- Too slow IMC formation at Ni/In interface, expected as ($Ni_{28}In_{72}$)
- Inhomogeneous distribution during phase growth, volume shrinkage causing voids [1]

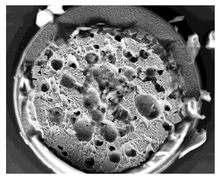
Shear test analysis

Process	Min Shear strength, MPa	Max Shear strength, MPa
2	16.29	44.47
3	13.69	29.35
4	9.63	18.06
5	9.10	12.94

- Shear tests of bonded samples were carried out to analyze bond strength
- Shear mode was investigated
- Macroscopic inspection demonstrated shear mode at Ni/In interface
- Shear results correspond to results of microstructure analysis
- Longer bond times have shown the higher bond strengths



Sheared Top bump



Sheared bottom bump

Conclusion and Outlook

Conclusion

- Process parameters were reported for Cu/Ni/In bonding
- Successful bonding results were achieved
- Microstructure confirmed the fast growth of $Cu_{11}In_9$ IMC and slow growth of NiIn IMC on bottom and top interfaces respectively
- Initial results have shown more voids at phase boundary Ni/$Cu_{11}In_9$ IMC
- Shear mode at the same phase boundary
- Max shear strength of 29.35 MPa was obtained for best bonding results

Outlook

- To improve the joint quality, much thinner Ni layer is proposed
- Two sided Ni barrier configuration can be used
- In plated on both sides for the formation of In-In SLID joint
- Joint strength can be enhanced mechanically

[1] Larsson, A., Tollefsen, T. A., & Aasmundtveit, K. E. (2016, September). Ni-Sn solid liquid interdiffusion (SLID) bonding—Process, bond characteristics and strength. In 2016 6th Electronic System-Integration Technology Conference (ESTC) (pp. 1-6). IEEE.

[2] Bickel, S., Sen, S., Meyer, J., Panchenko, I., & Wolf, M. J. (2018, September). Cu-In fine-pitch-interconnects: influence of processing conditions on the interconnection quality. In 2018 7th Electronic System-Integration Technology Conference (ESTC) (pp. 1-6). IEEE.