Atomic Layer Deposited Al_2O_3 Passivation for the Silicon Interconnect Fabric

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Introduction

- Silicon interconnect fabric (Si-IF) is a heterogeneous integration platform
- Fine bump (pillar) pitches (<10 µm) and inter-dielet spacing (<100 µm)
- Relies on metal-metal thermocompression bonding
- Eliminates solder , underfill and overmold
- Advantages: high bandwith, low power dissipation, BEOL technology
- Challenges: need for a robust passivation

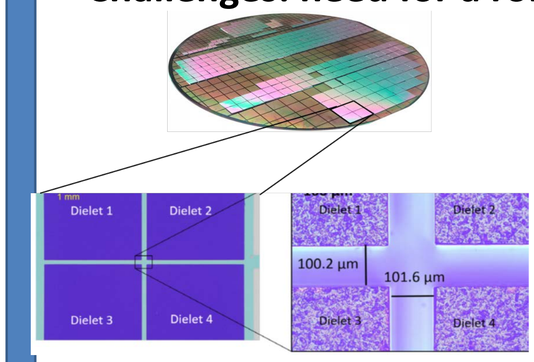

Figure 1. Si-IF assembly [1]

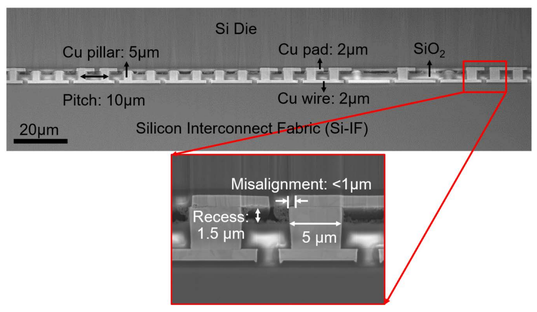

Figure 2. Si-IF cross section showing Cu pillar and pads

ALD Al_2O_3 for Passivation

- Advantages: uniformity, high quality thin film, precise thickness control, low (≤200°C) deposition temperature
- Equations (1) and (2):the growth of Al2O3 from trimethyl-aluminum (TMA) precursor [2]:

$$Al - OH^* + Al(CH_3)_3 \rightarrow AL - O - Al(CH_3)_2{}^* + CH_4 \quad (1)$$

$$Al - CH_3{}^* + H_2O \rightarrow AL - OH^* + CH_4 \quad (2)$$

- Cu samples passivated with different Al_2O_3 thicknesses.
- Humidity testing up to 216 hours (85%RH/ 85°C).
- XRD showed no Cu oxide peaks even after 216 hrs of testing

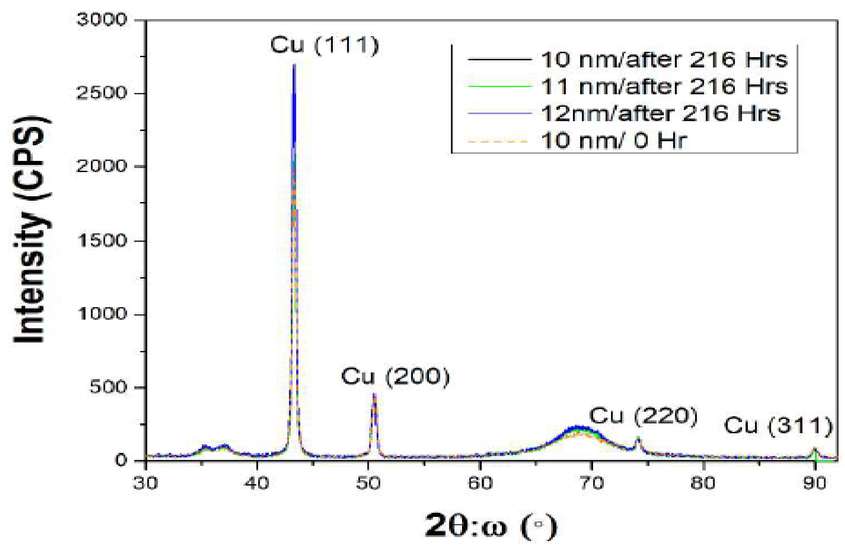

Figure 3. XRD scan of the blanket Cu samples passivated after 216 hours of humidity testing and a pristine sample [3].

Experimental Results for Bonded Samples

- ALD recipe optimized to achieve large step coverage.
- A bonded sample is coated with 20nm of Al_2O_3.
- Die is sheared off.
- FIB cross sectioning of the pillars under the die to investigate Al_2O_3 thickness.

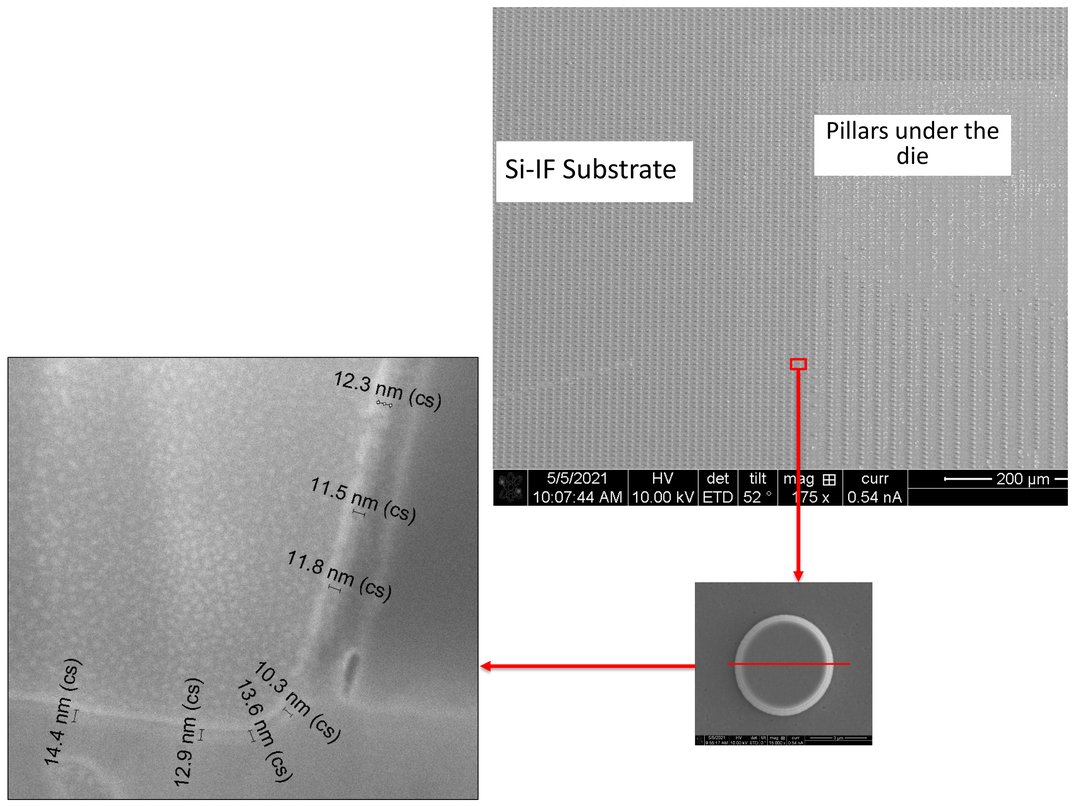

Figure 4. (a) SEM image of the Si-IF showing the area under a sheared die. (b) FIB image of a sidewall of a pillar under the die showing the thickness of the Al_2O_3.

- Humidity testing (85%RH/85°C) for 564 hours on bonded and passivated samples
- Electrical resistance measurement every 594 hours.
- Maximum change in electrical resistance of the daisy chain<3%

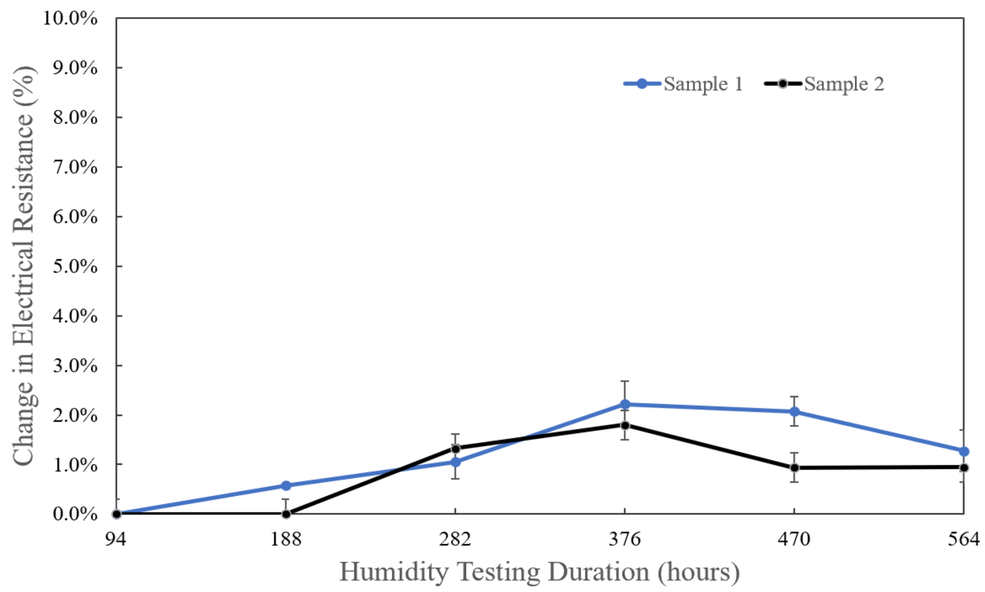

Figure 5. Electrical resistance of two samples with daisy chain structure and passivated with 20 nm of Al_2O_3 during 594 hrs of humidity testing

Conclusion

- ALD Al_2O_3 is a robust passivation for Si-IF.
- ALD recipe optimization to achieve high step coverage.
- Max. change in electrical resistance of the bonded samples after 594 hrs of humidity testing was <3%

References

1. Adeel A. Bajwa, S. C. Jangam, S. Pal, N. Marathe, T. Bai, T. Fukushima, M. Goorsky, and S. S. Iyer, "Heterogeneous Integration at Fine Pitch (≤ 10 µm) using Thermal Compression Bonding", Proc. of 67th IEEE Electronic Components and Packaging Technology (ECTC) 2017.
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3. N. Shakoorzadeh Chase, R. Irwin, Y. T. Yang, H. Ren and S. S. Iyer, "Reliability Considerations for Wafer Scale Systems," 2021 IEEE 71st Electronic Components and Technology Conference (ECTC), 2021, pp. 84-89