Thermomechanical Behaviour of Copper at Nanoscale by Laue Microdiffraction

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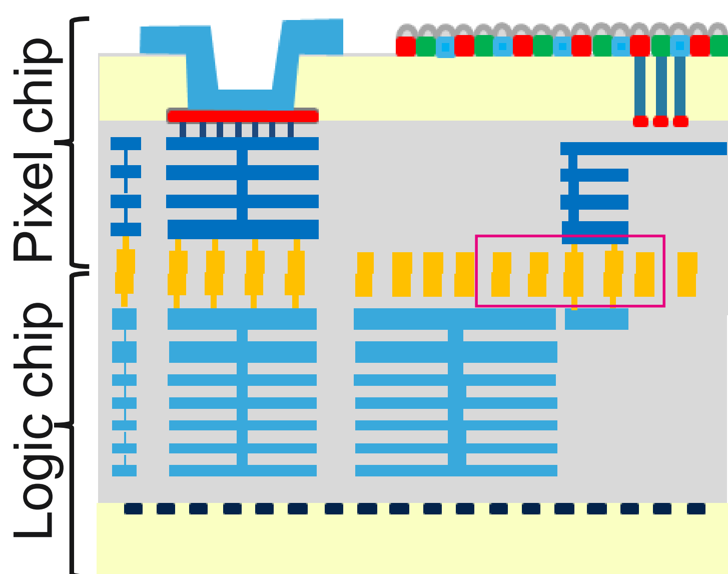
The investigation of copper microstructure at nanoscale using synchrotron-based Laue microdiffraction technique is presented. Based on the experimental findings, FEM simulations allow to extract the plastic behaviour dependence on the orientation for the single crystals. The results obtained are used to achieve Cu/SiO_2 hybrid bonding with 300 nm Cu pads.

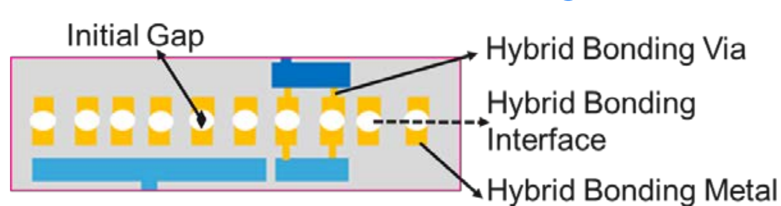
INTRODUCTION AND PROBLEMATIC

Image sensor could benefit from pad size reduction which bonding is driven by copper thermomechanical behaviour.

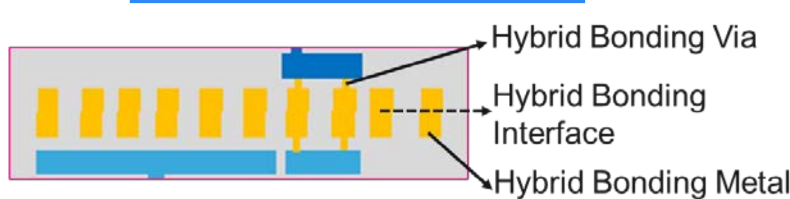
3D Stacked Image Sensor



Post bonding: gap separating Cu-Cu due to initial Cu dishing

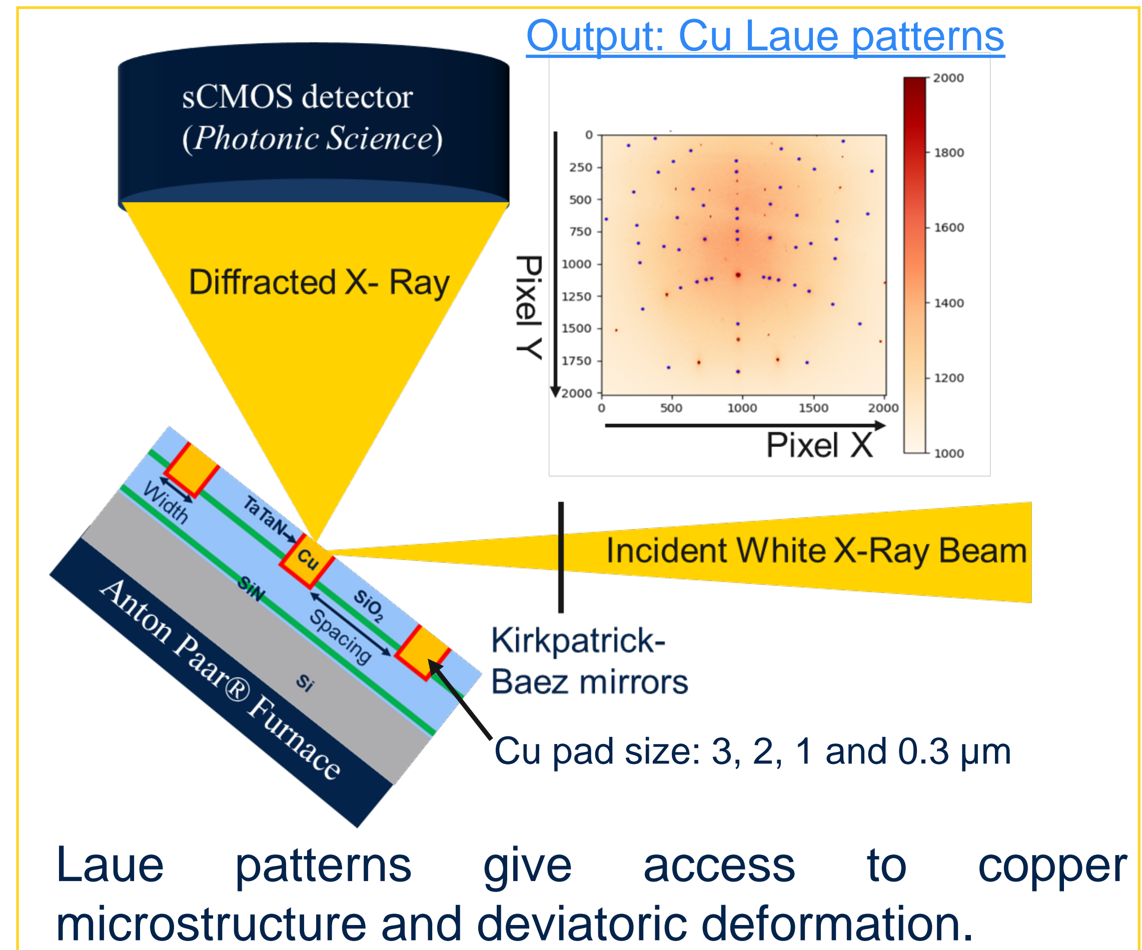


Post anneal at 400°C – 2h: Cu-Cu connections established



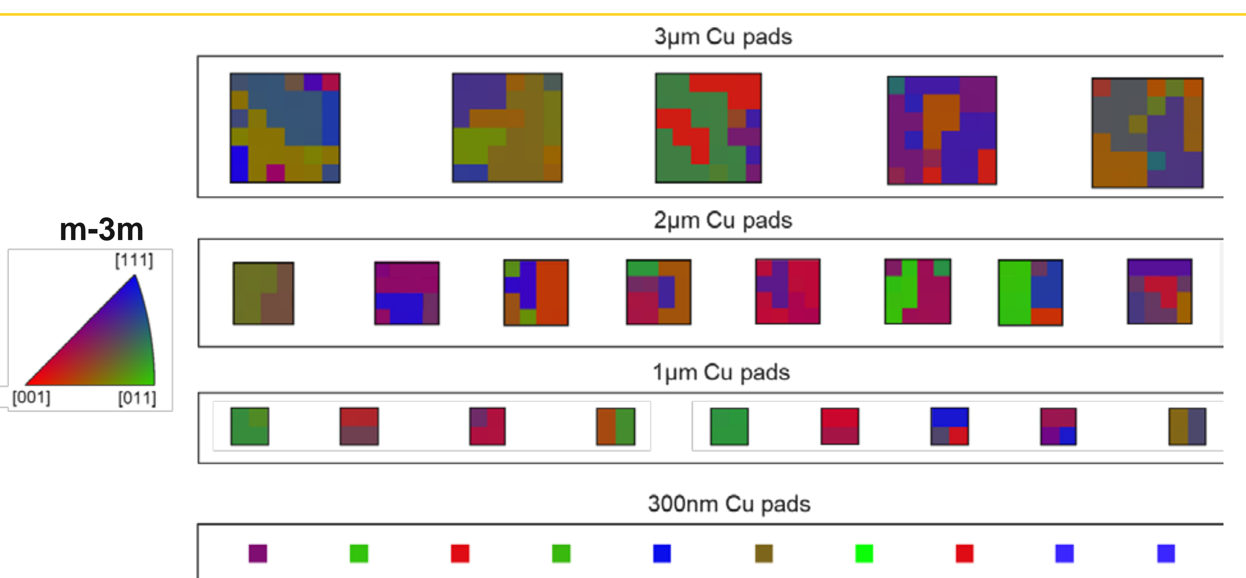
EXPERIMENTAL SET UP

Output: Cu Laue patterns



Laue patterns give access to copper microstructure and deviatoric deformation.

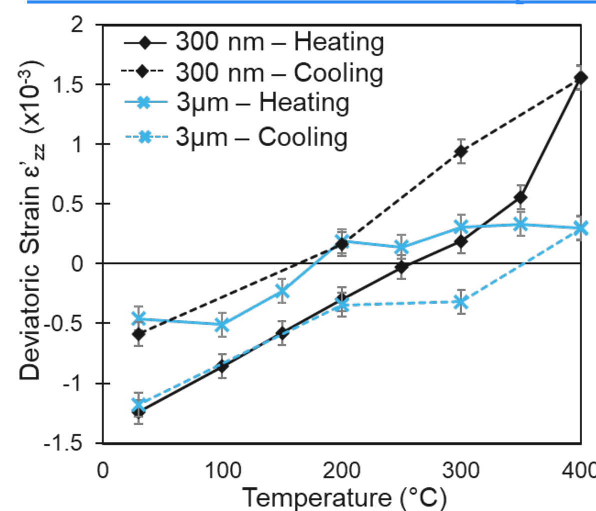
COPPER MICROSTRUCTURE MAP



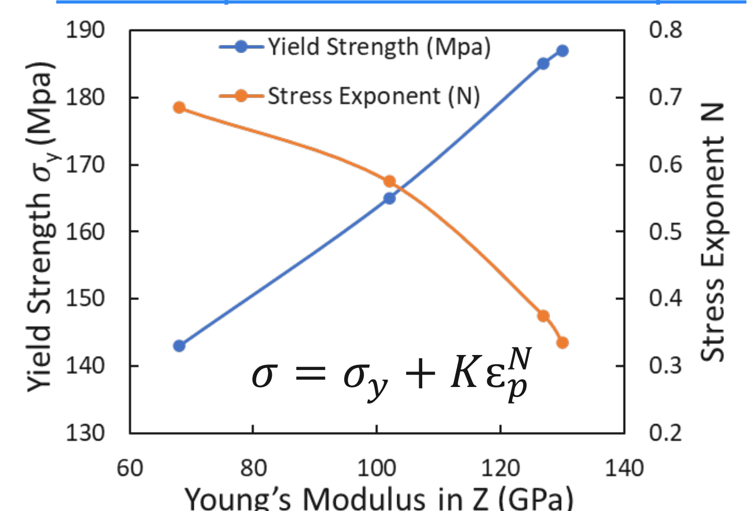
The grain size and number decrease with width reduction down to a single crystal for the 300nm Cu pad. There is no orientation evolution with temperature.

THERMOMECHANICAL BEHAVIOUR

Grain orientation close to [001]



Ludwick parameters for 300nm pads

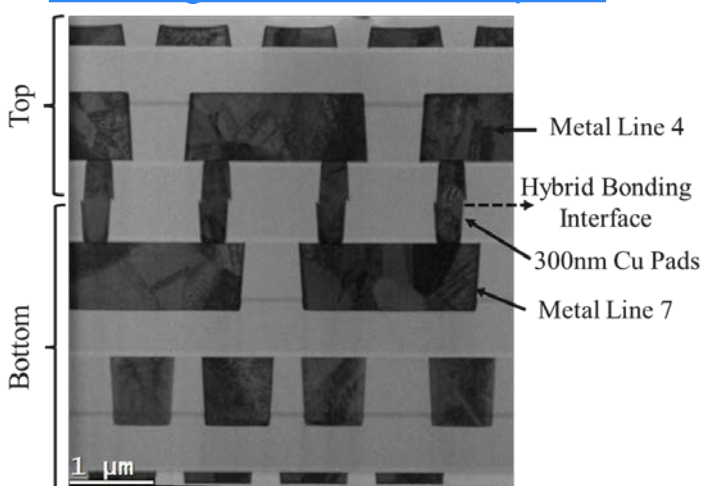


The deviatoric deformation is dependent on grain size with single crystals having higher deformation at T>350°C.

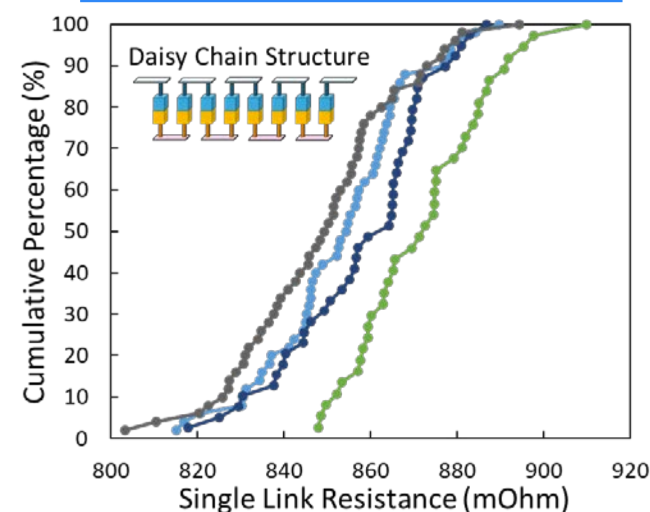
By FEM, plastic behaviour of 300nm grains driven by orientation.

METHODOLOGY VALIDATION

Bonding with 300nm Cu pads



Cu-Cu electrical connections



Based on Micro Laue results and FEM, successful bonding of 300nm Cu pad width was achieved by hybrid bonding with 100% yield in electrical connection within a given overlay range.

CONCLUSION

Thermomechanical behaviour of copper with pad size reduction studied by Laue microdiffraction at ESRF (Grenoble)

- From mono (300nm pads) to polycrystalline microstructure (>1µm pads)
- Orientation is not temperature-dependent

Deviatoric deformation evolution with temperature for the 3µm and 300nm pads

- Distinct behaviour dependency on grain size and orientation
- Monocrystalline grains have higher deformation at T>350°C

Combined FEM simulations and experimental data for 300nm grains

- Total deformation extracted ➔ used to achieve hybrid bonding with 300nm Cu pads

ACKNOWLEDGMENTS

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