3D Integration for SOI Pixel Detector

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(T-Micro)

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Device target

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SOI Pixel detector

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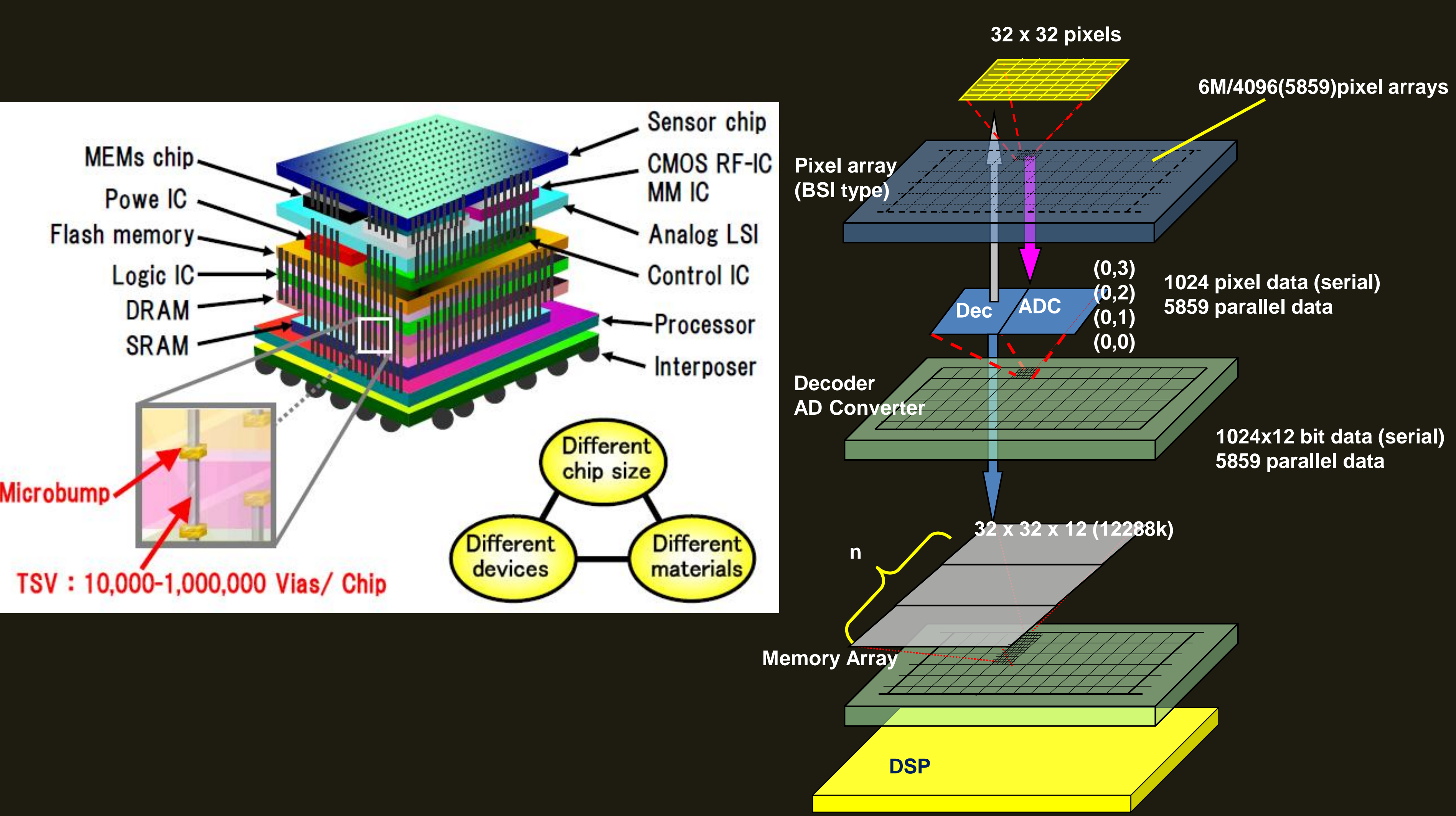
Target of our 3D technology



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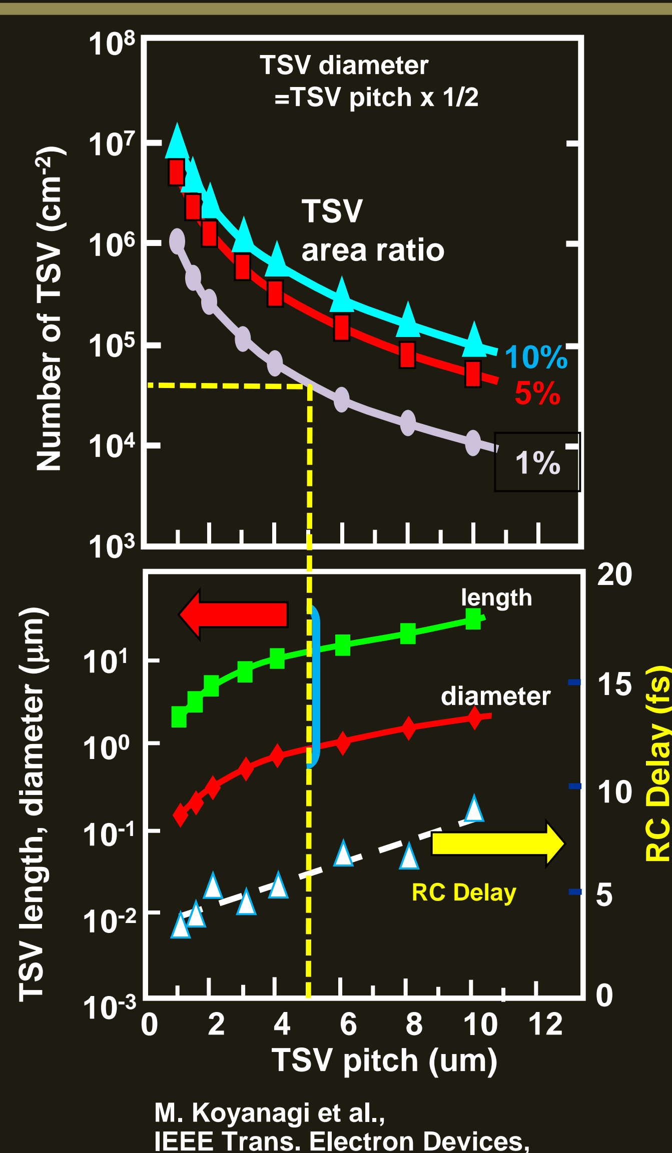
Target 3D Technology

- Via last process
- Interconnect density 10^4~10^5/cm^2
- Area penalty ≤1 %
- Good manufacturability (high yield, reliability)
- Low process temperature
- Low cost

TSV and µ-bump technology with the pitch less than 5µm



M. Koyanagi et al.,
IEEE Trans. Electron Devices,
VOL.53, NO.11, pp.2799-2808, 2006

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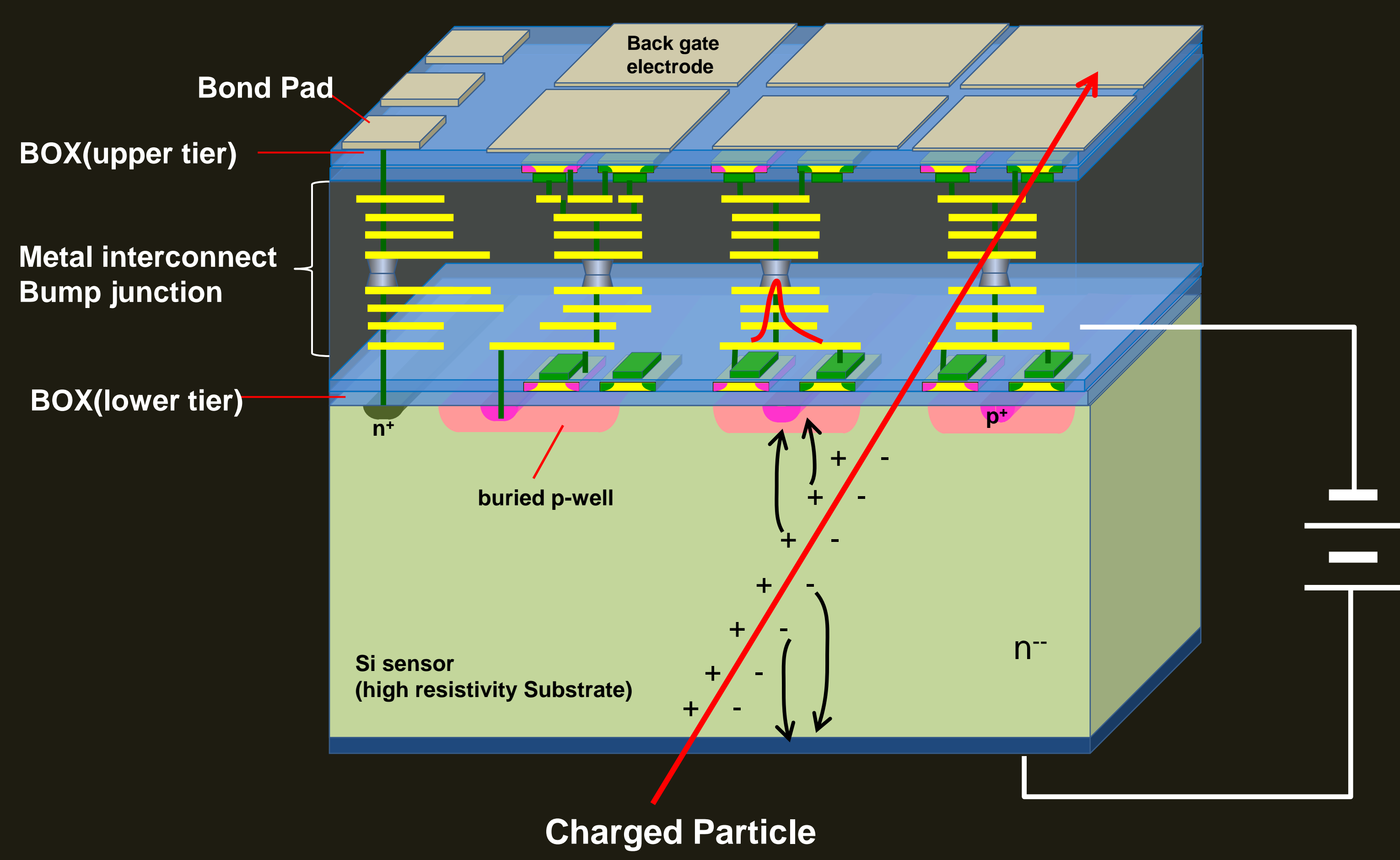
Stacked SOI Pixel detector



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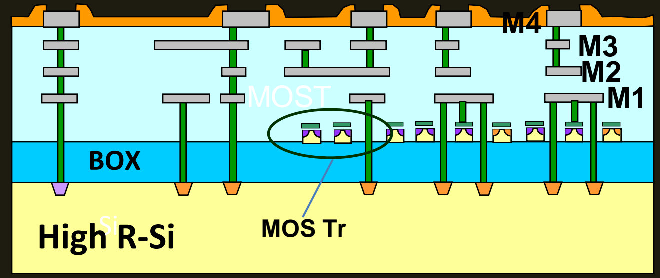
Process flow (1)

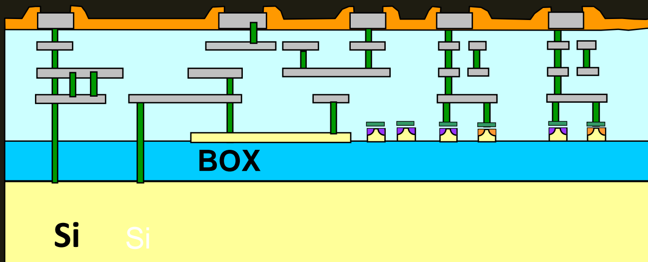
< Lower Tier >

(a) Start with FD-SOI device wafer

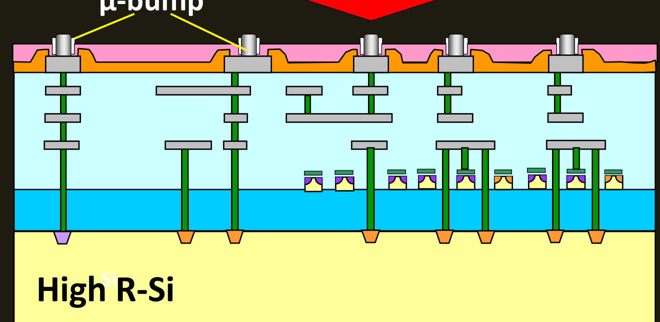
Active Si~50 nm
BOX:200 nm

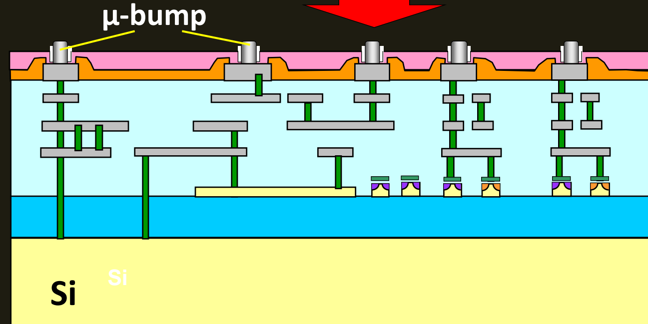
**FD: Fully Depleted*





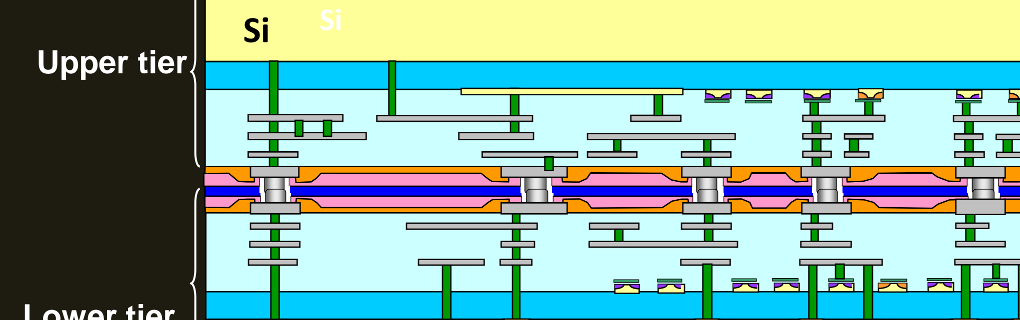
(b) μ-bump forming





(c) Chip bonding

- -face to face infrared alignment
- -temporary bonding
- -Adhesive injection
- -permanent bonding (<200℃)



adhesive

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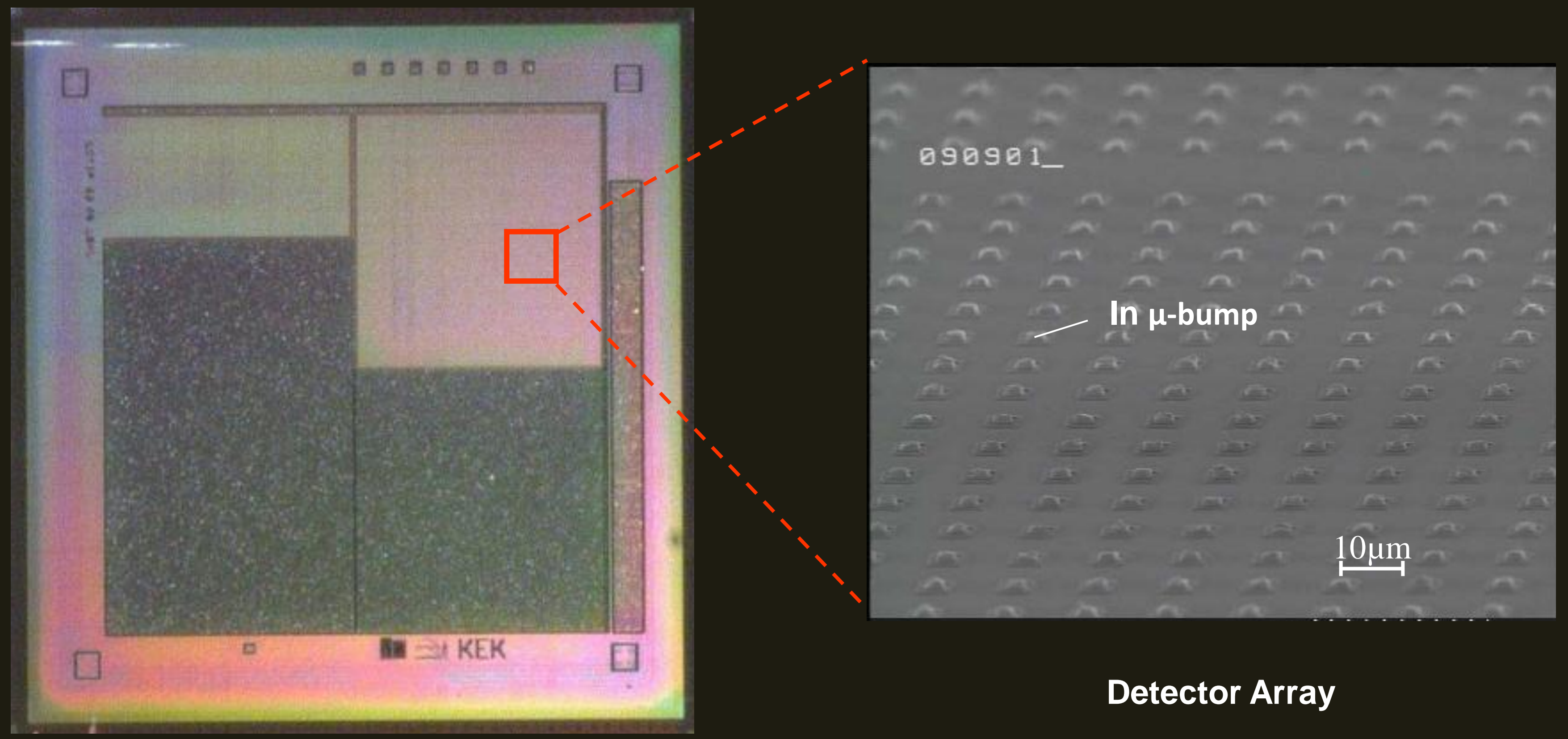
SOI pixel detector Chip

(After forming u-bump)



Upper tier

Detector Array

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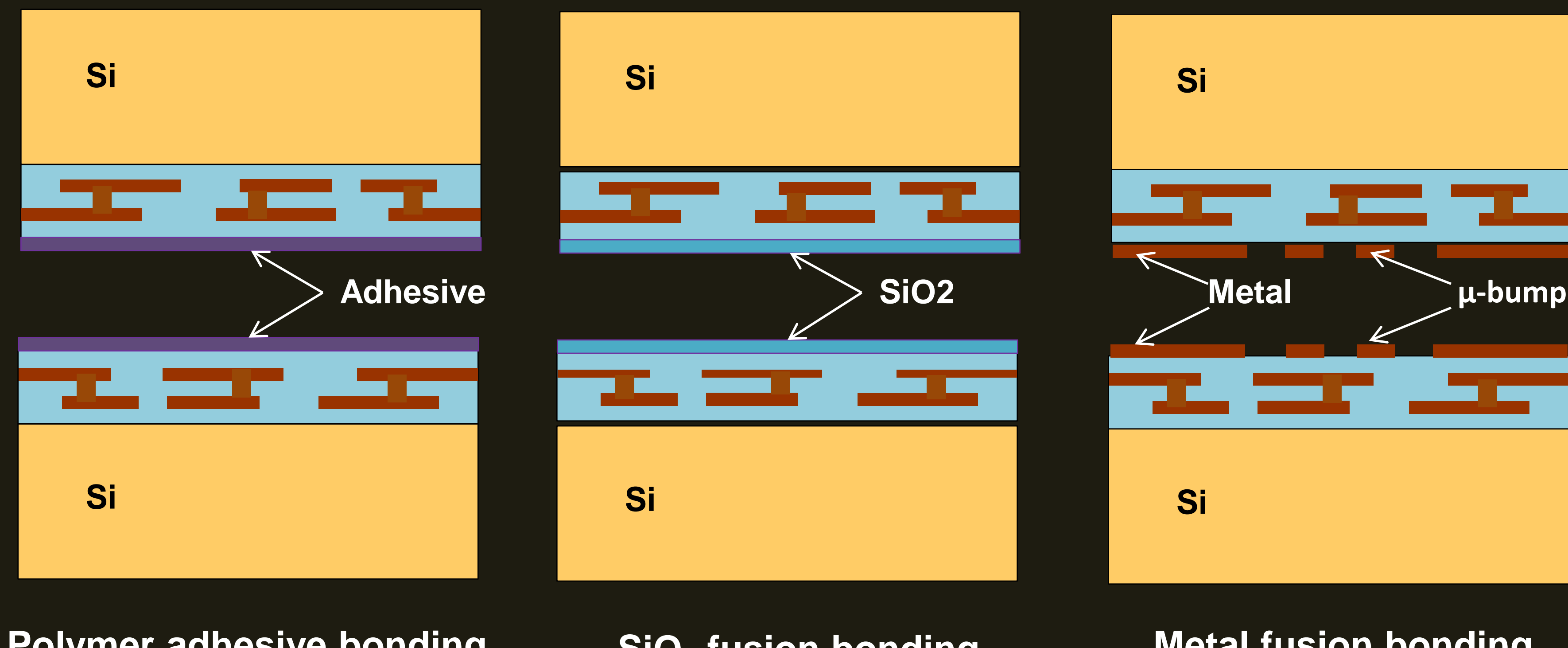
Selection of Wafer/Chip bonding technology



Polymer adhesive bonding

SiO_2 fusion bonding

Metal fusion bonding

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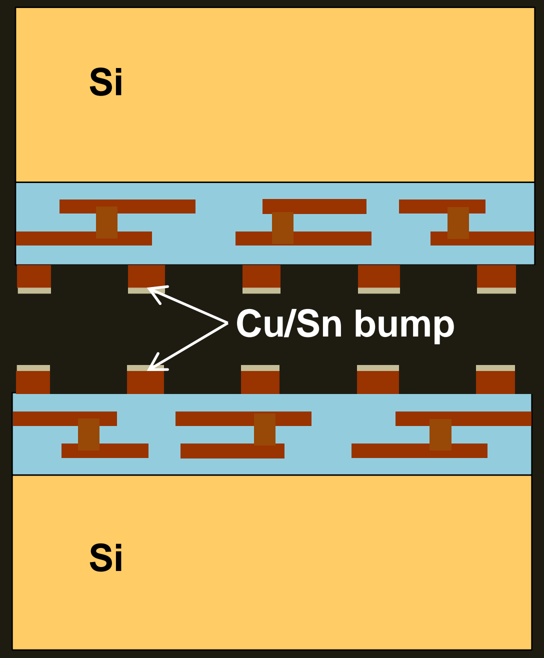
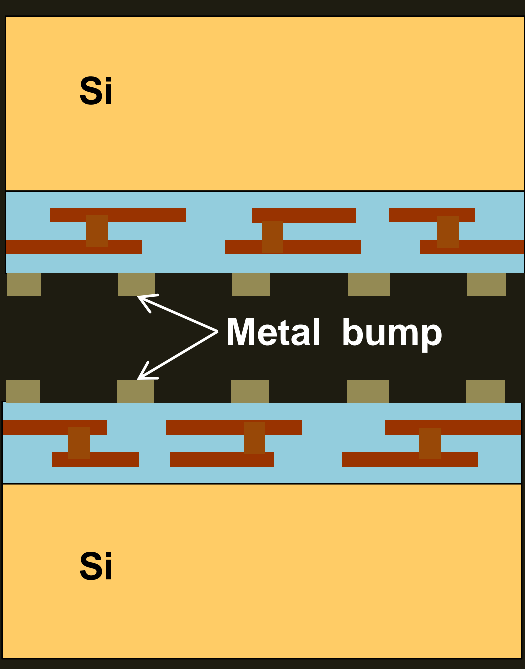
Selection of Wafer/Chip bonding technology (2)



Metal eutectic bonding



Bumping (Pb/Sn, Au, In)

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Yield model

Yield Model of LSI

$$Y = Y_0 \cdot Y_1(D_0, A, \alpha)$$

Y_0 : Systematic yield
Y_1 : The fraction of chip sites without process related effects and circuit sensibility
A : Chip Area
D_0 : Density of defects
α : Distribution parameter of defects

Defect source

- dusts or other particles in the environment, solution, process chamber in the production equipment
- pattern defects due to ununiformity of material
- oxide defects caused by process damage
- statistical factor

etc.

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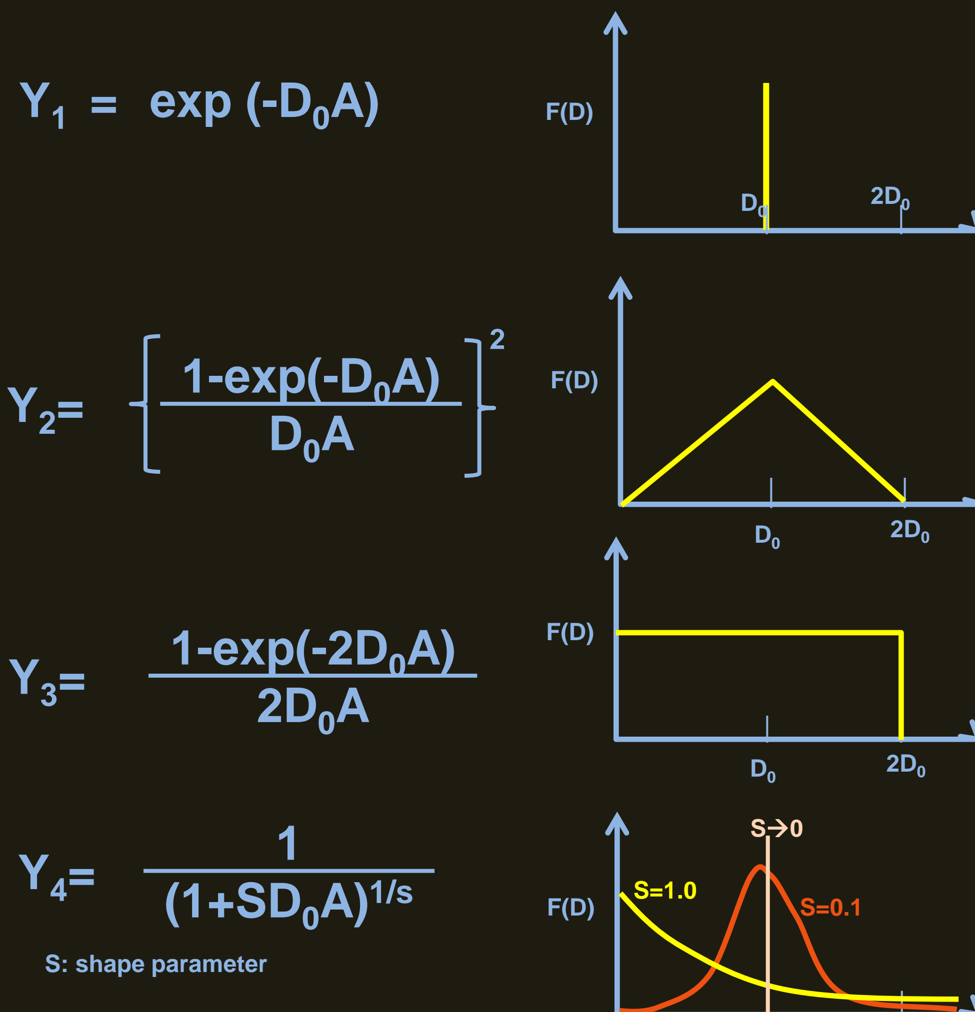
Yield model



Y_n : The fraction of chip sites without process related effects and circuit sensibility

A : Chip area

D_0 : Density of defects

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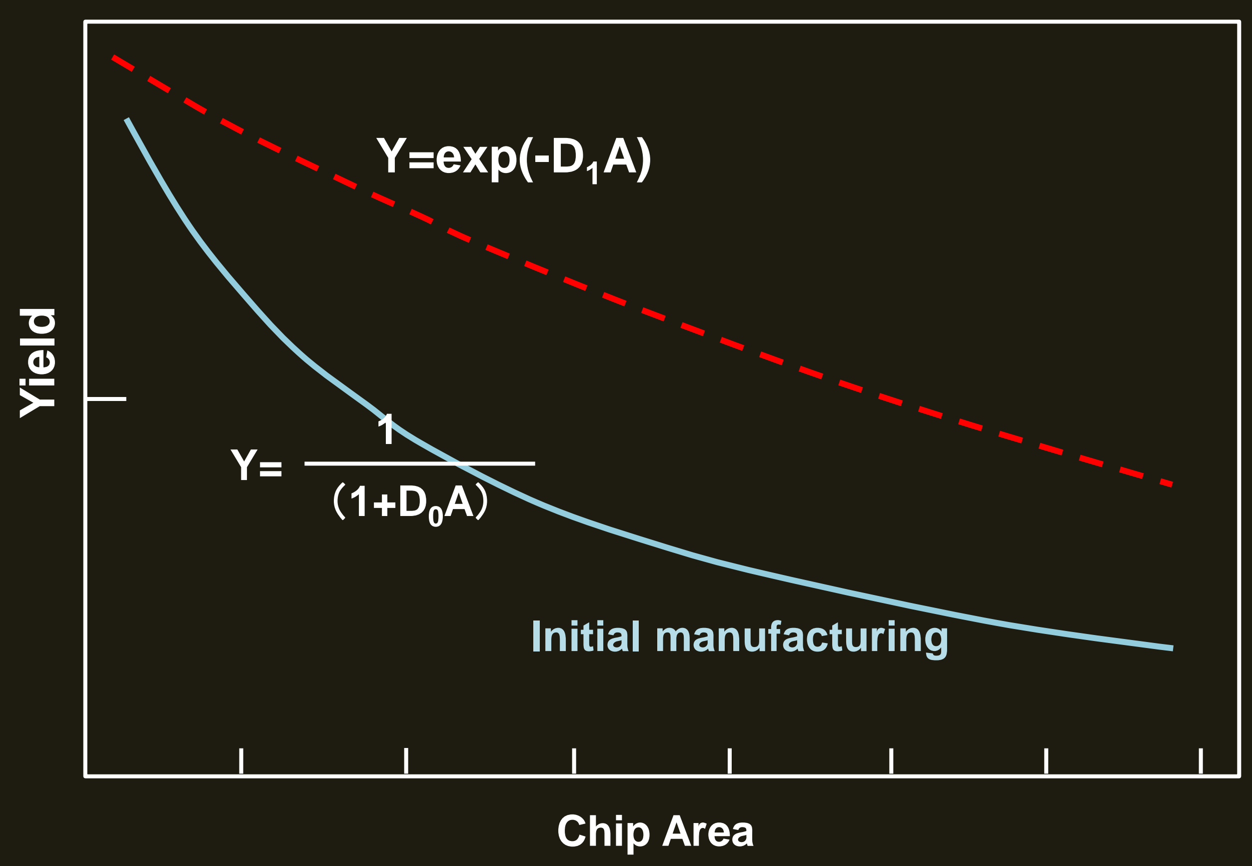
Yield Prediction



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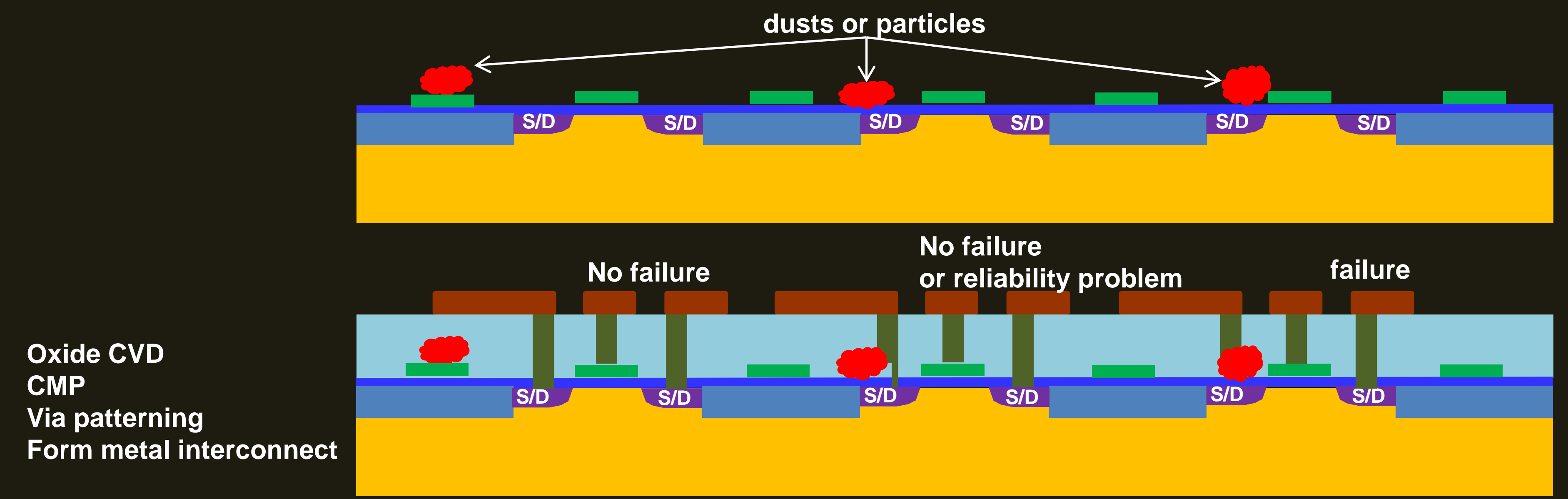
Yield and reliability



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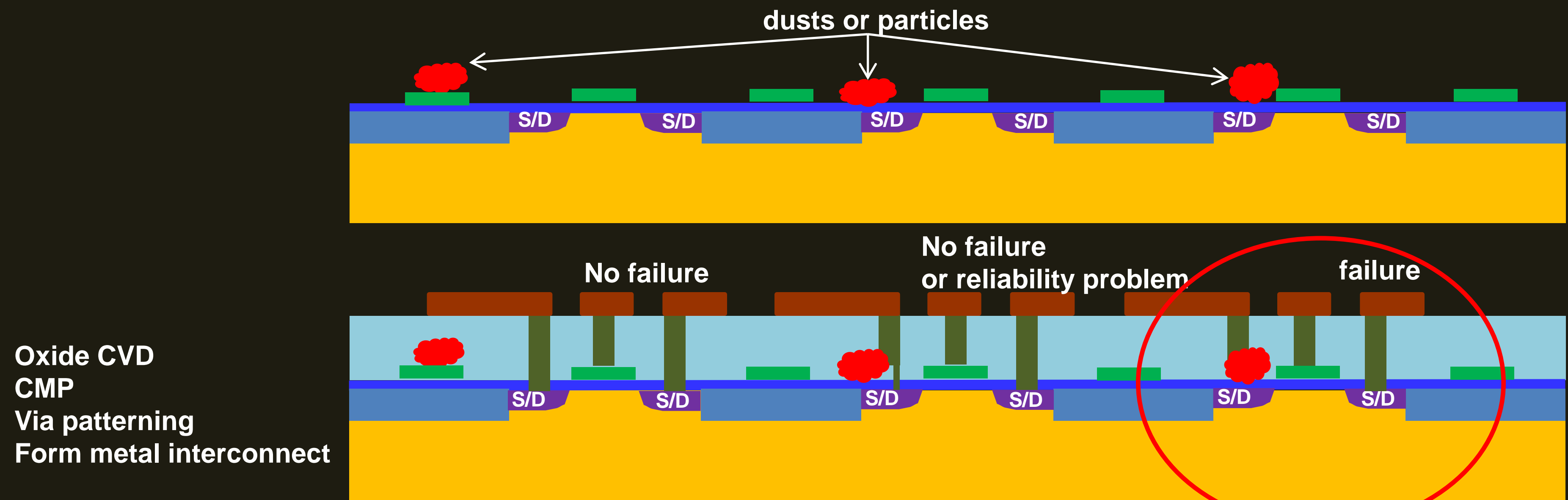
Yield and reliability



Oxide CVD
CMP
Via patterning
Form metal interconnect

We can only detect this failure from electrical testing.

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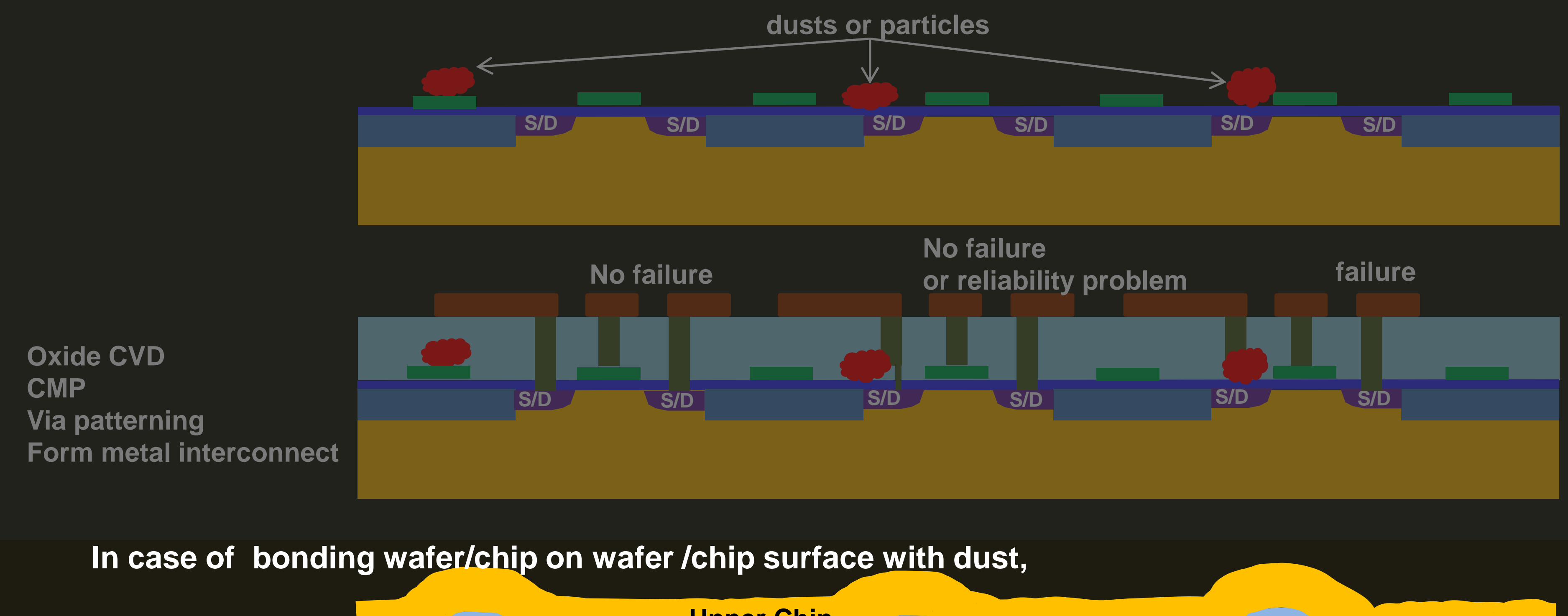
Yield and reliability



If the bonding method which needs microscopic smoothness and cleanliness, bonding yield will be affected by defect density of dusts and particles.
So we have chosen the bump bonding with adhesive injection.

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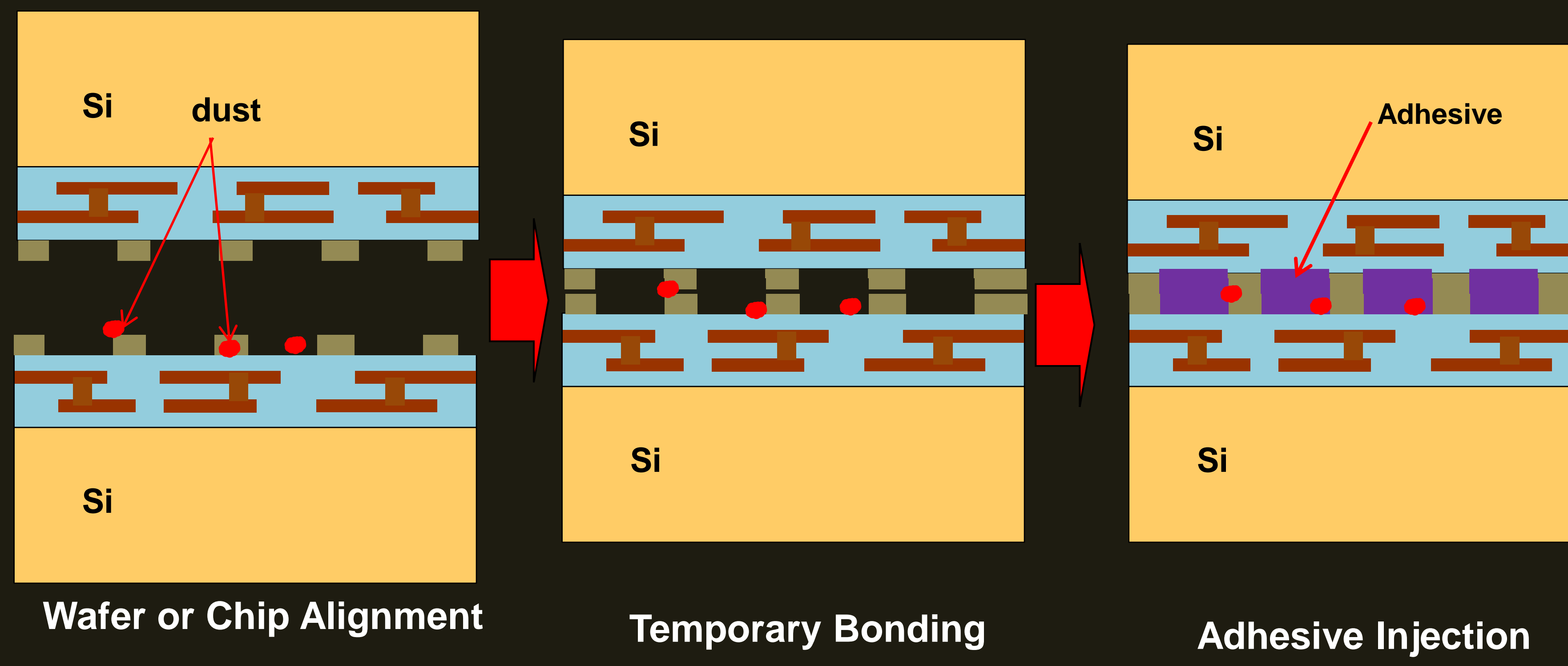
Wafer Bonding Method (Tohoku University/T-micro)

Bump size (~μm) >>dust or particle size (≤0.2μm)



In μ-bumps do not have enough mechanical strength, so the combination use of adhesive is indispensable.

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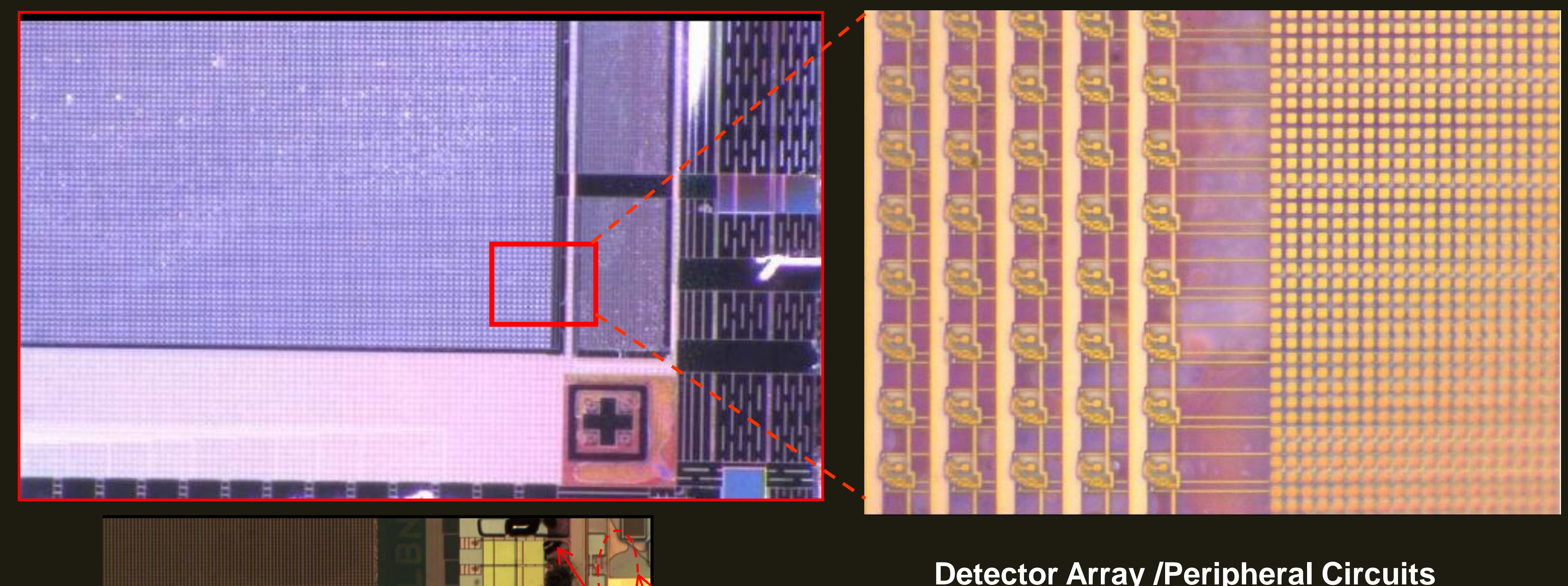
SOI pixel detector Chip

After Si removal



Detector Array /Peripheral Circuits

Voids

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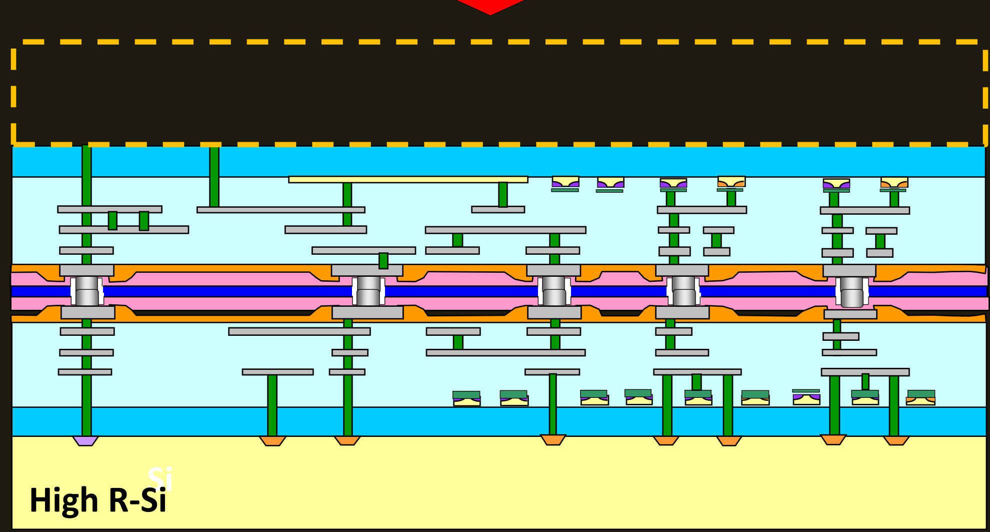
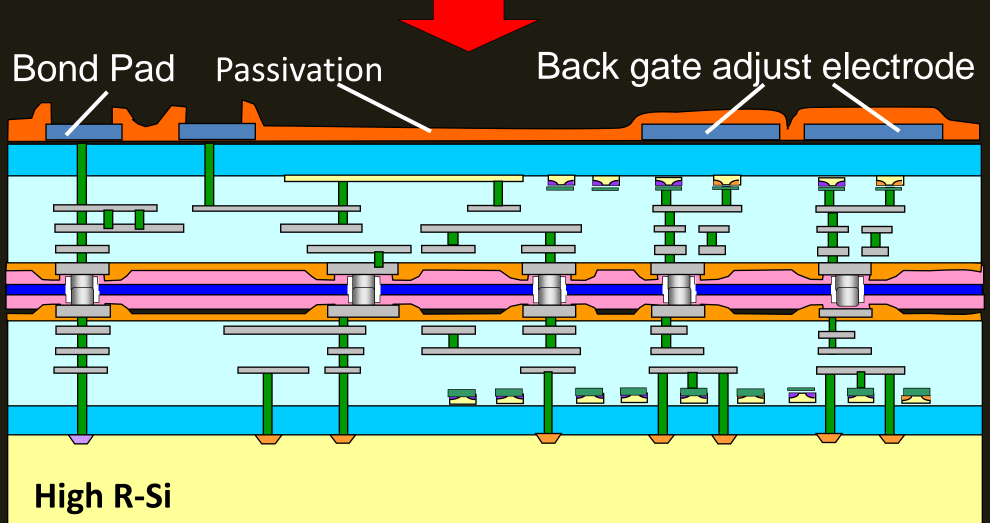
Process flow (2)

(d) Bulk-Si removal



(e) Pad patterning and passivation



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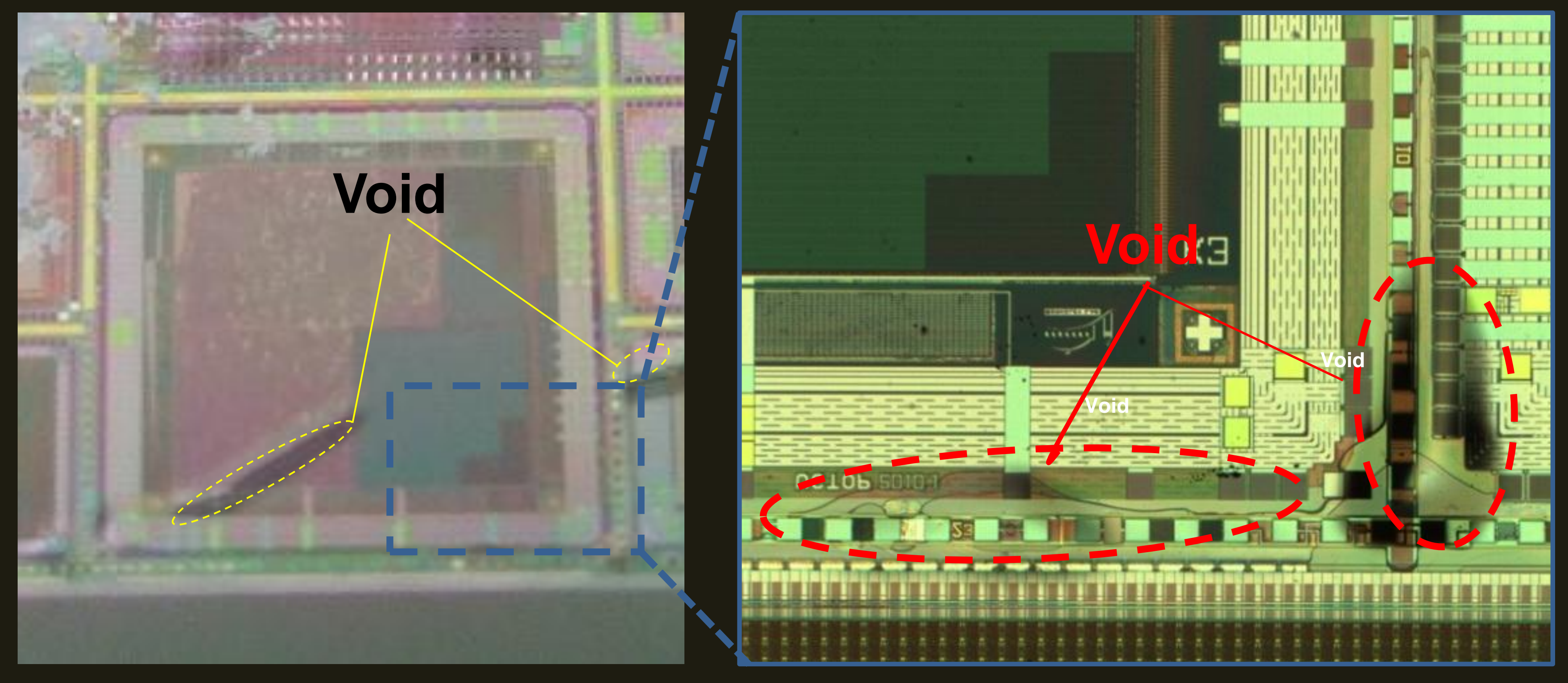
Void problem



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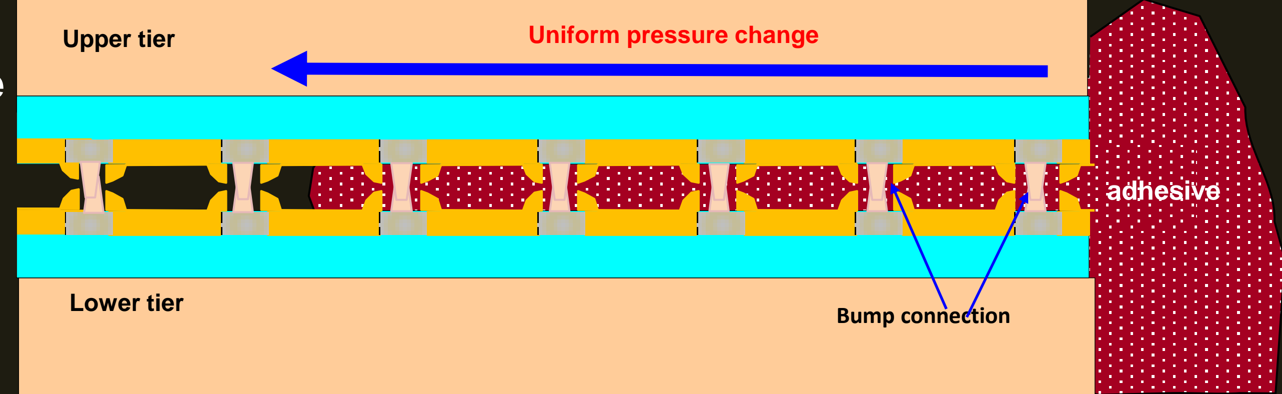
Mechanism of void formation (1)

(a) Simple test device



voids

No void in pixel array

(b) Circuit test device

Peripheral circuit

Detector array

non-uniform pressure change

Uniform pressure change

Top metal

void

Top metal

Passivation layer

Top metal

interlayer

adhesive

Si-sub

Bump connection

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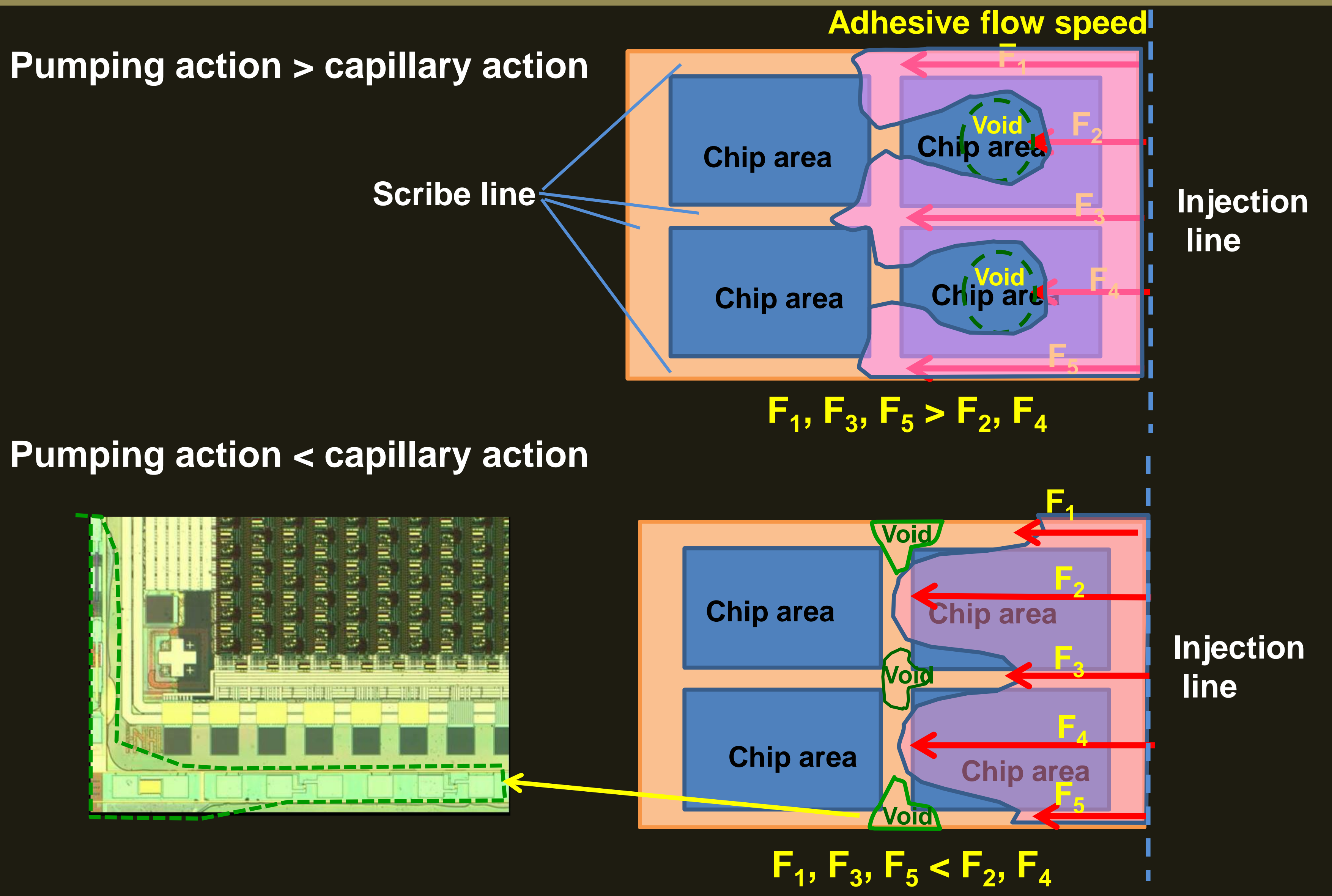
Mechanism of void formation (2)



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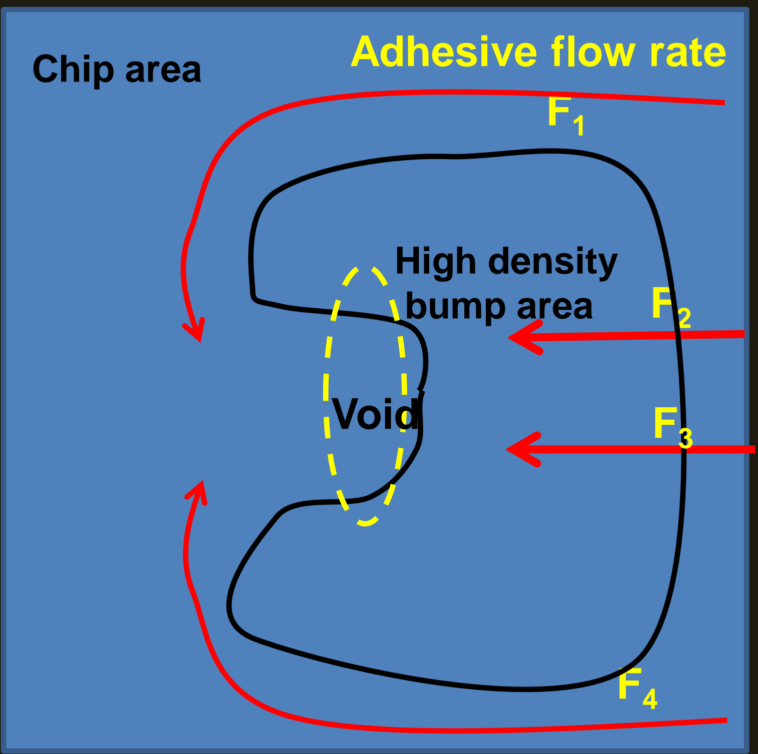
Mechanism of void formation (3)



$F_1, F_4 > F_2, F_3$

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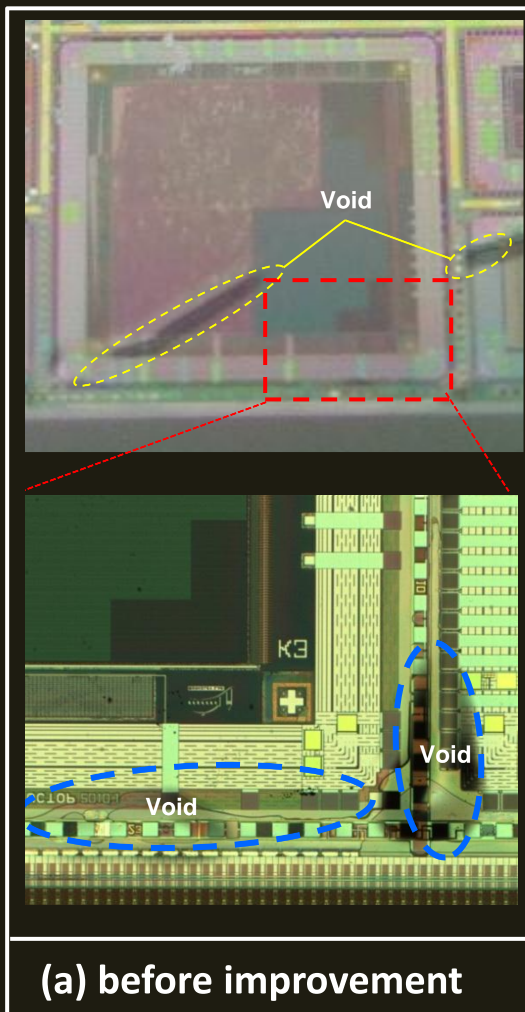
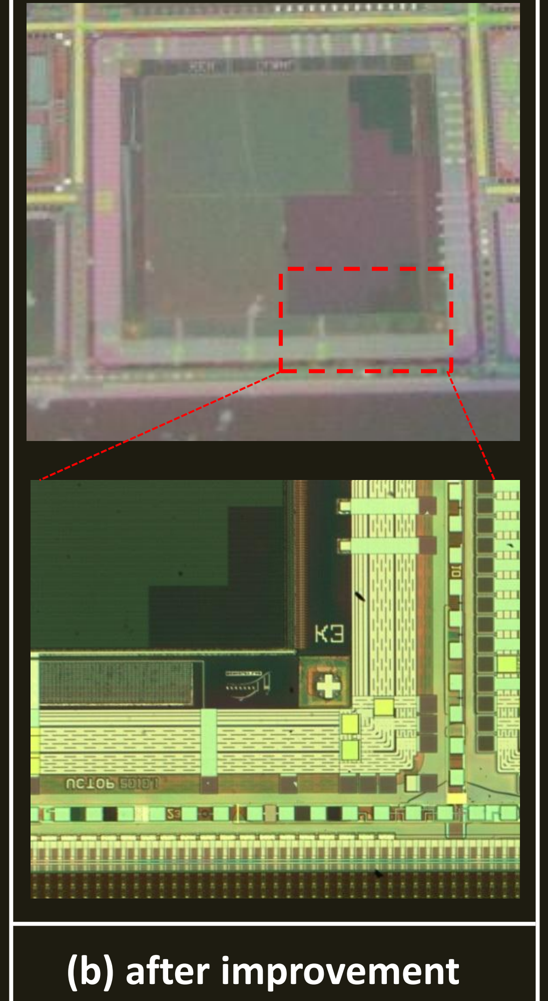
Pixel detector chip after Si removal



(a) before improvement

Optimize
- bump layout
- differential pressure of adhesive injection
- process temperature (control the viscosity of adhesive)
- wettability of adhesive



(b) after improvement

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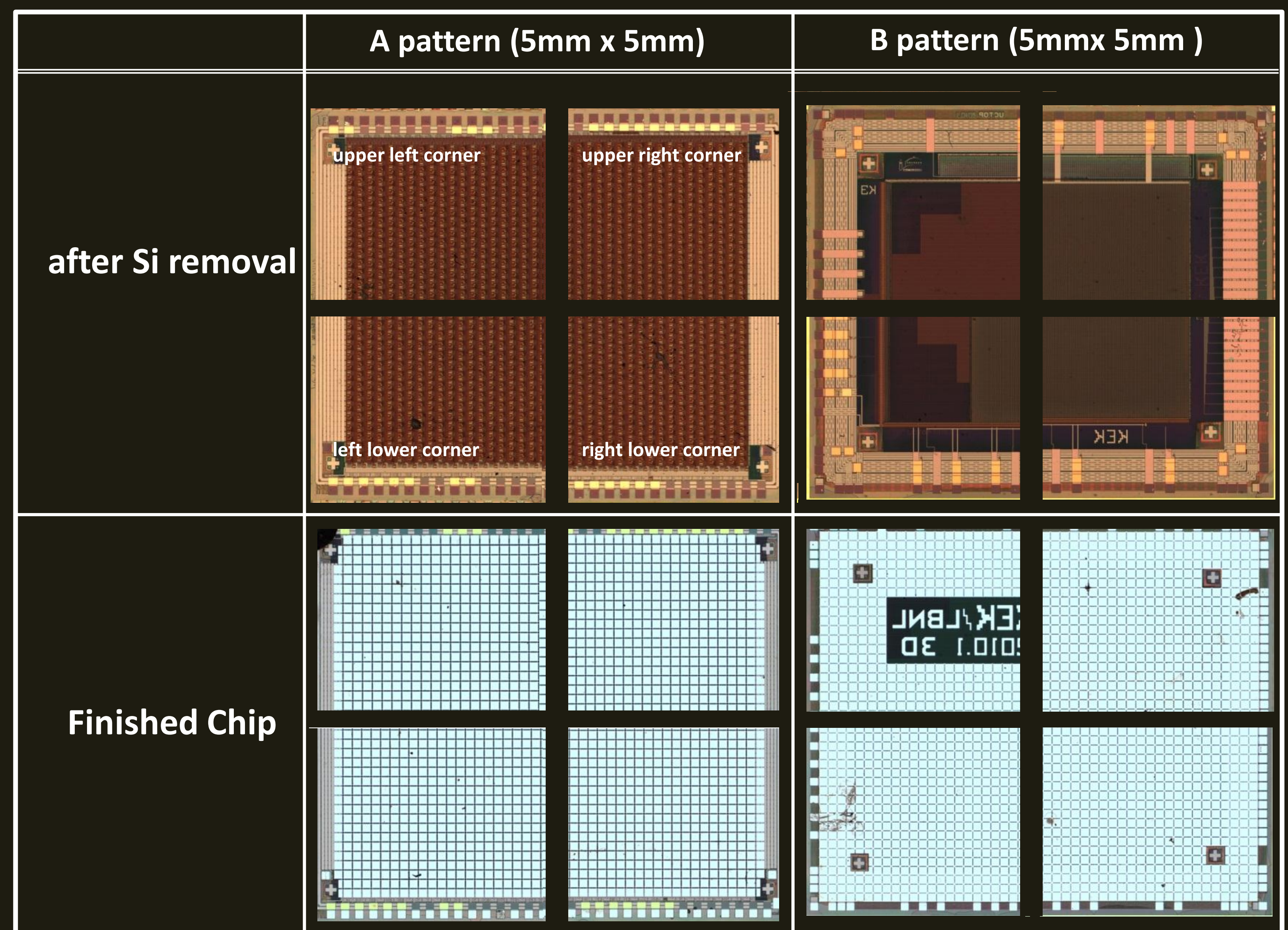
Two types of pixel detector chip



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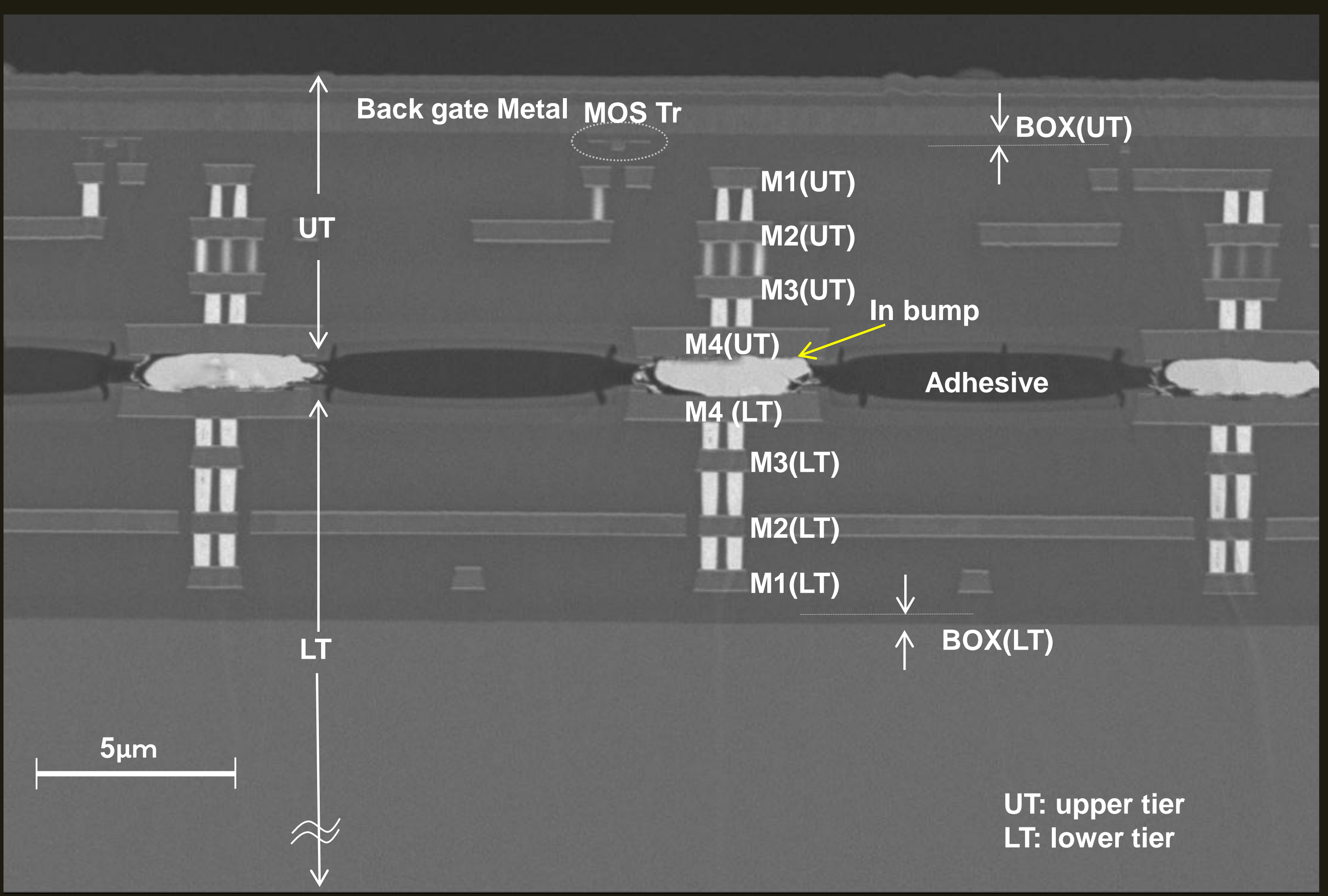
Cross sectional SEM image of pixel array



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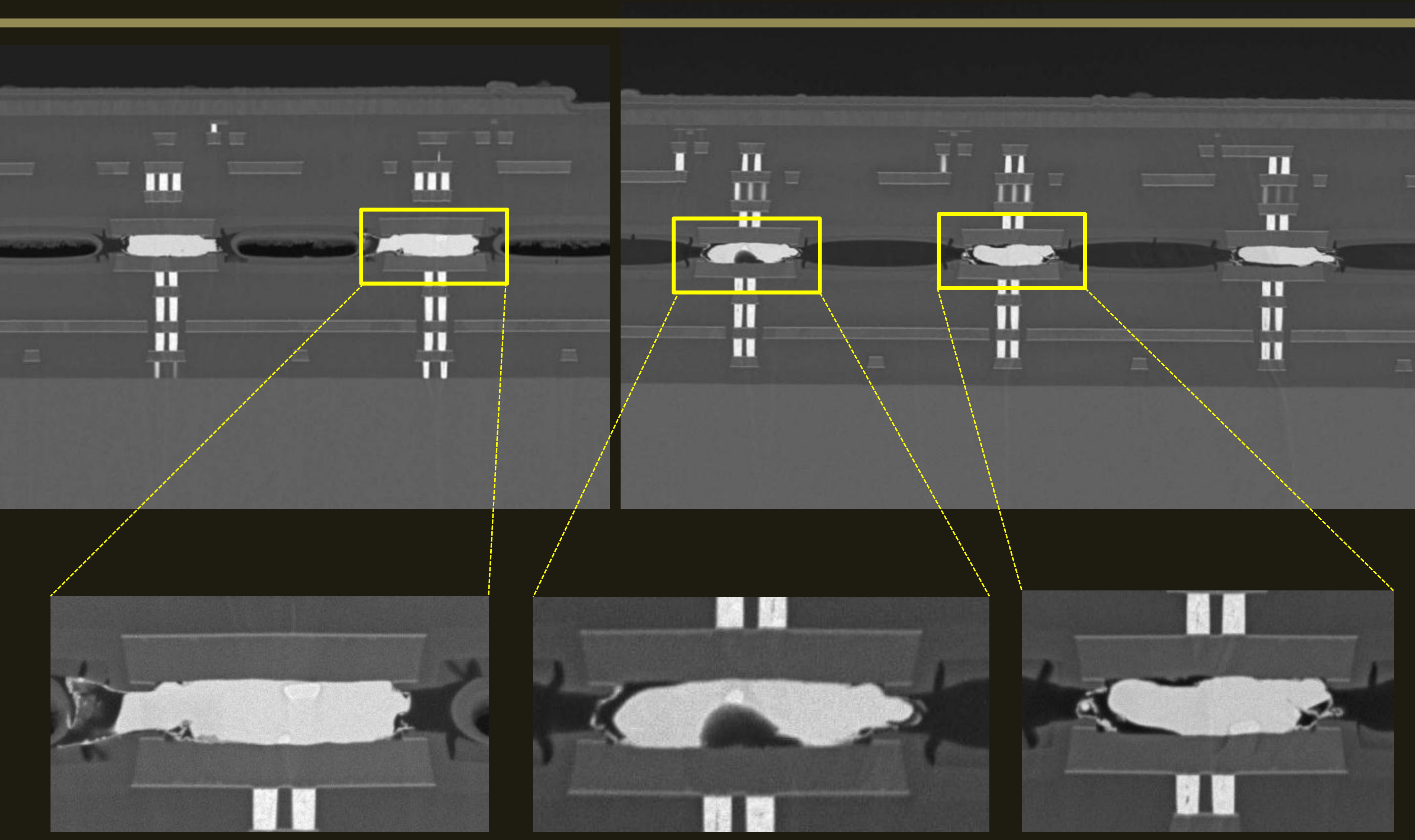

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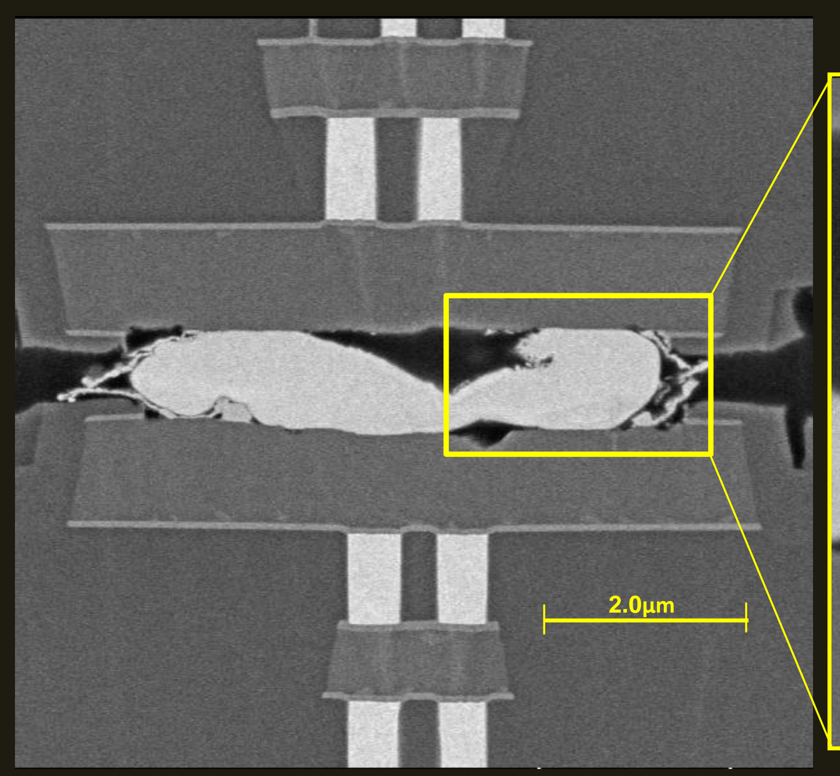

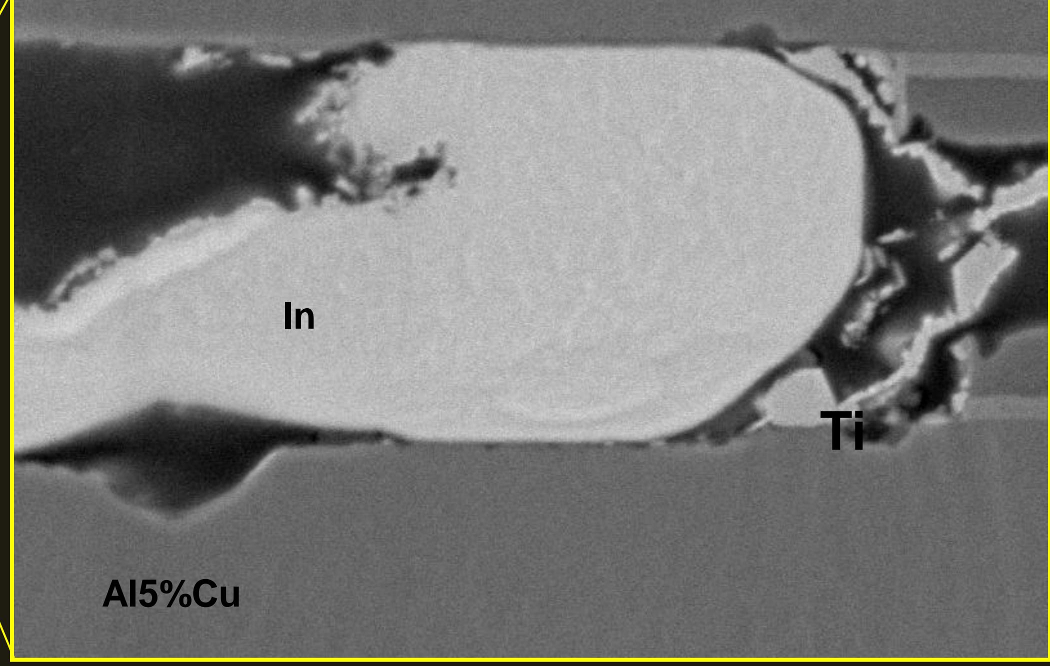

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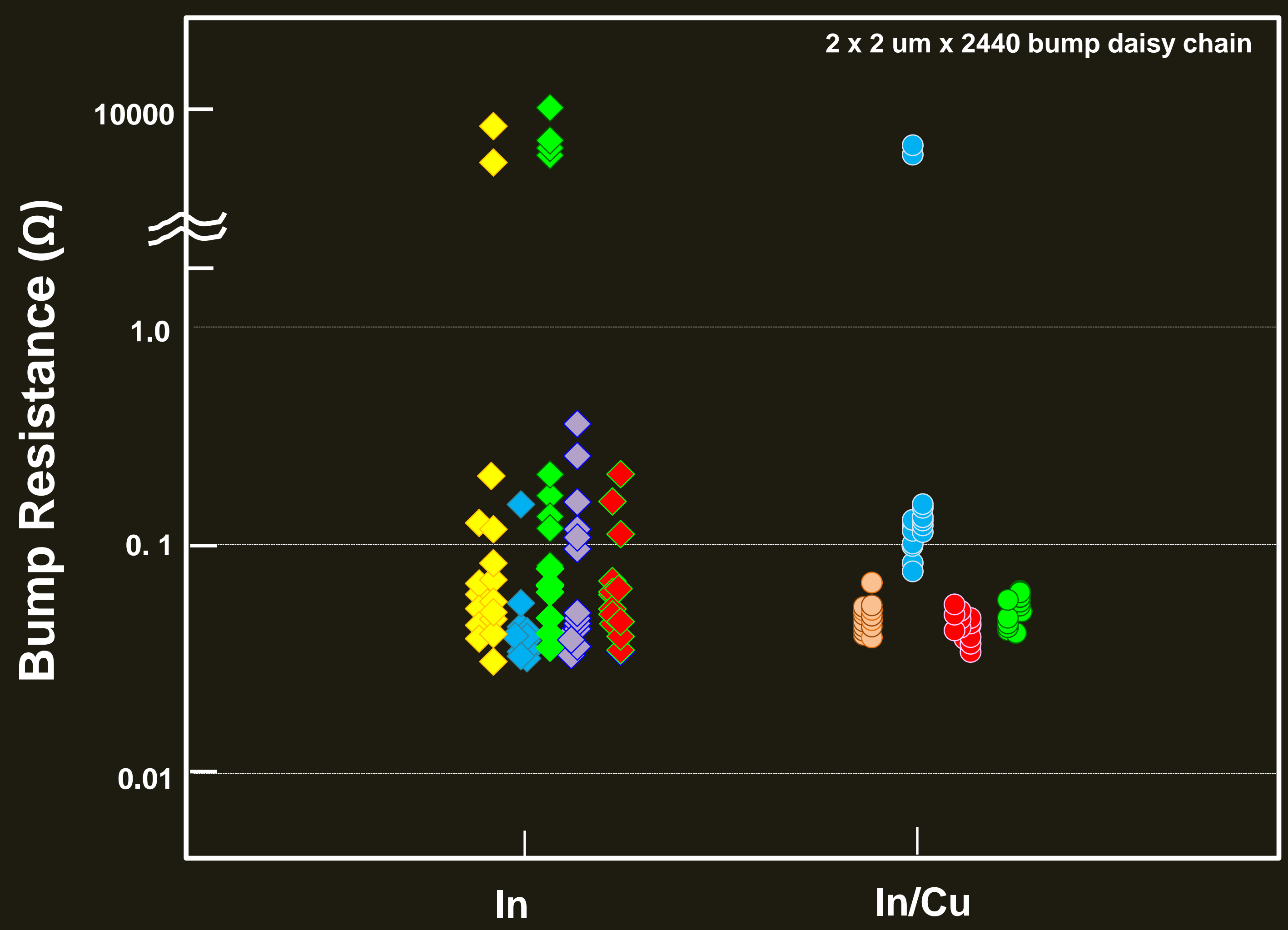
In bump vs In/Cu bump



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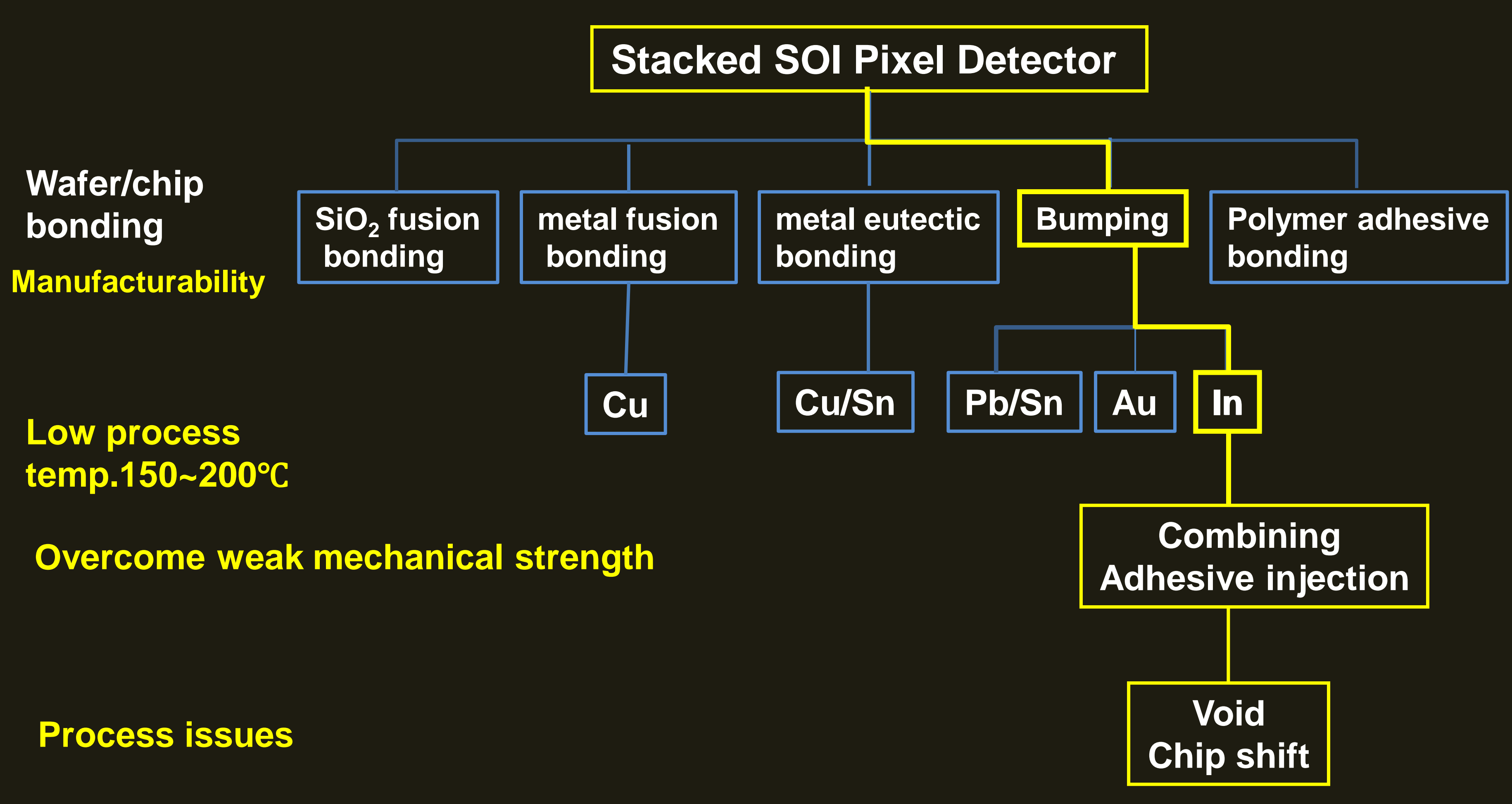
Summary-Technology selection chart



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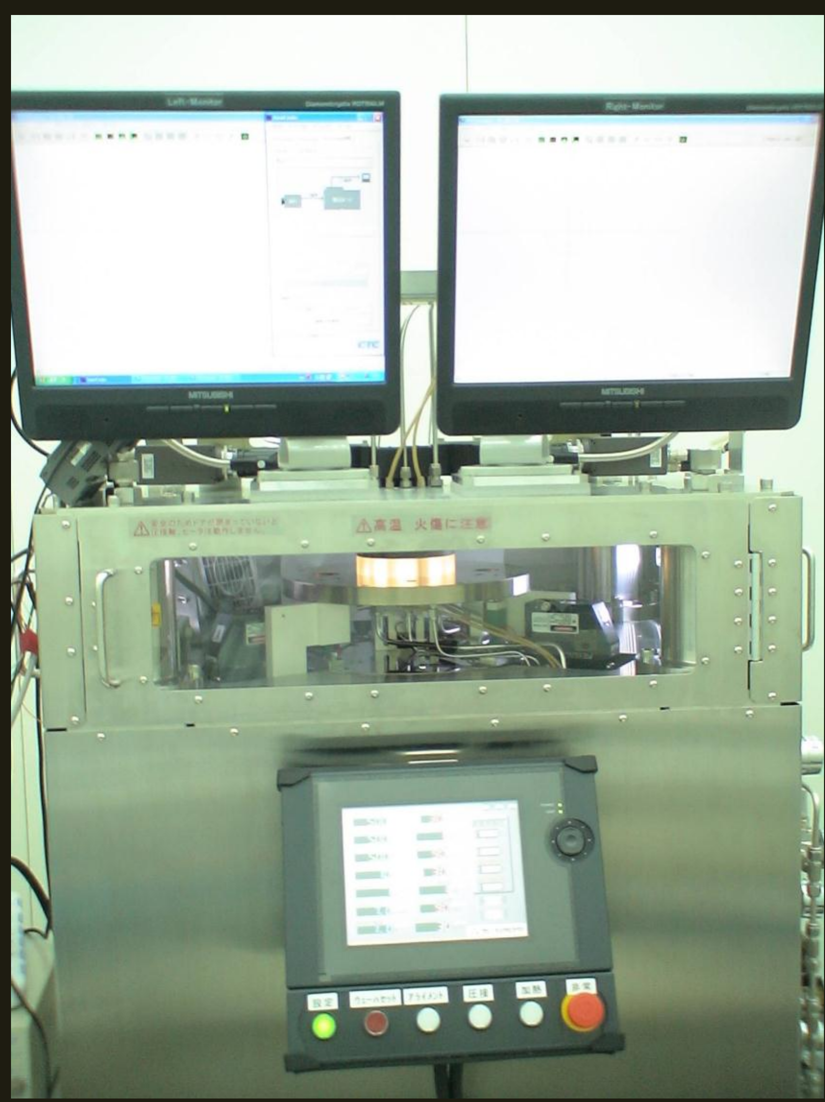
Prototype of 8” Self-Assembled Chip Bonder



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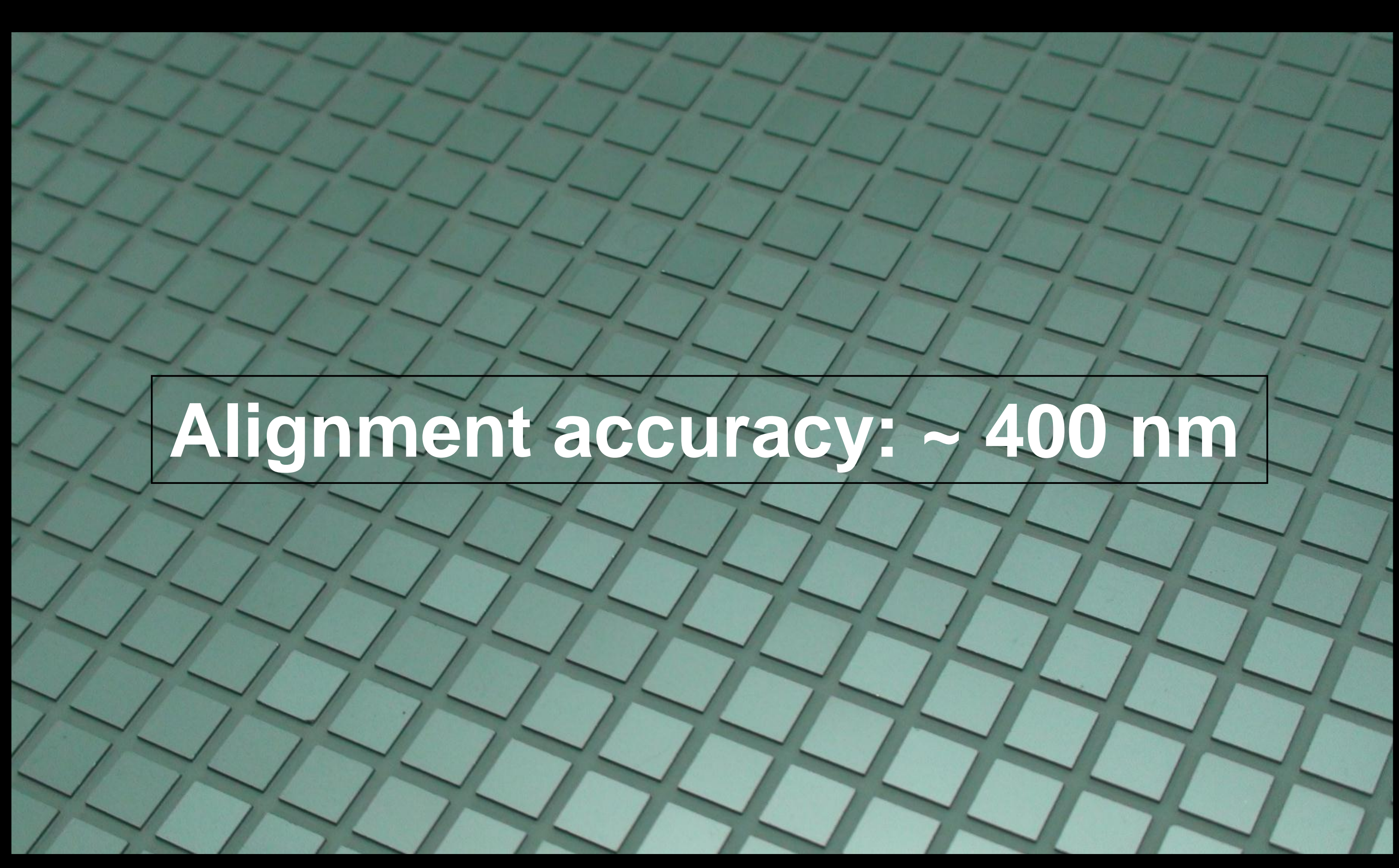
Self-Assembly Process with 8-inch Wafer



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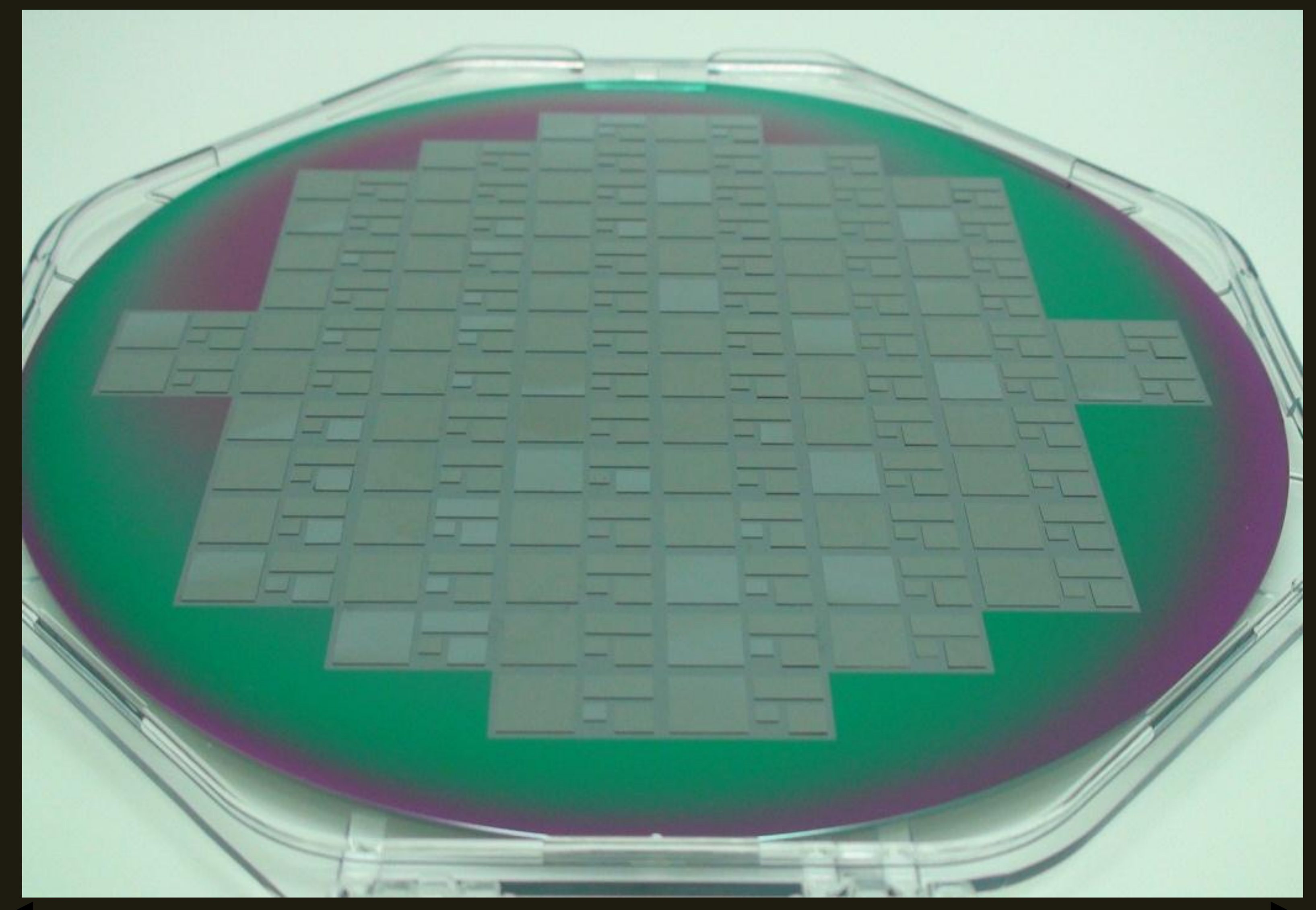

200 mm

図4 試作製造装置で多数のチップを仮接着したウェーハの全体写真

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Conclusion

- 3D LSI Integration technology using minimum 5μm pitch bump is verified using SOI stacked pixel detector as circuit level test device.

- In this technology, adhesive injection is found the key technology. Optimizing layout, process parameter and adhesive injection method, this process have completed without void.

- The dispersion of bump resistance is still high, the following optimization are still ongoing.
  Improvement of wettability between bump and pad
  Introducing the new Cu/In IMC bonding

- In further development of wafer /chip bonding with few μm pitch bump , it might be necessary to optimize the gap between tiers and volume of bump metal.

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