Especial Bump Bonding Technique for Silicon Pixel Detectors

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Outline

- Motivation
- Summary of bump bonding techniques
- Sn/Ag bumping
- Technique evaluation
- Conclusion

Motivation

- Hybrid Pixel Detectors present serious difficulties at packaging level. They have arrays of connection pads which have to be routed to the ROIC.
- Bump bonding flipchip connection is a good approach when the detector chip can be placed upside down (X-rays)
- As the distance between pixels is very small and the number of bumps very high, only some of the bumping strategies are suitable. Among them, bump electroplating.

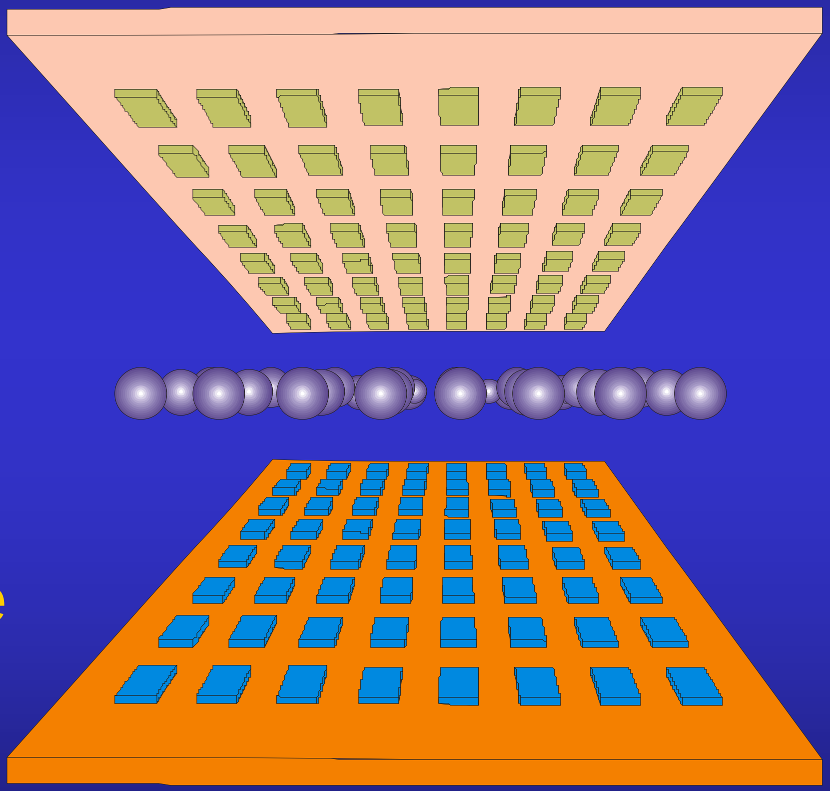
Motivation

Sn/Ag electroplating has been chosen because:

1. It is leadfree.
   - Ban directive for Pb
   - Pb is an alpha particle emitter, so a soft error inducer.
2. It has a moderate eutectic melting point (221ºC)
3. It is suitable for X-Ray detectors

Bump bonding flip chip technology

- Process steps:
  - Rerouting
  - Under Bump Metallisation (UBM)
  - Bumping
    - On substrate or on flip chip, depending on the application
  - Flip chip
  - Reflow, anneal or adhesive bonding
  - Underfilling

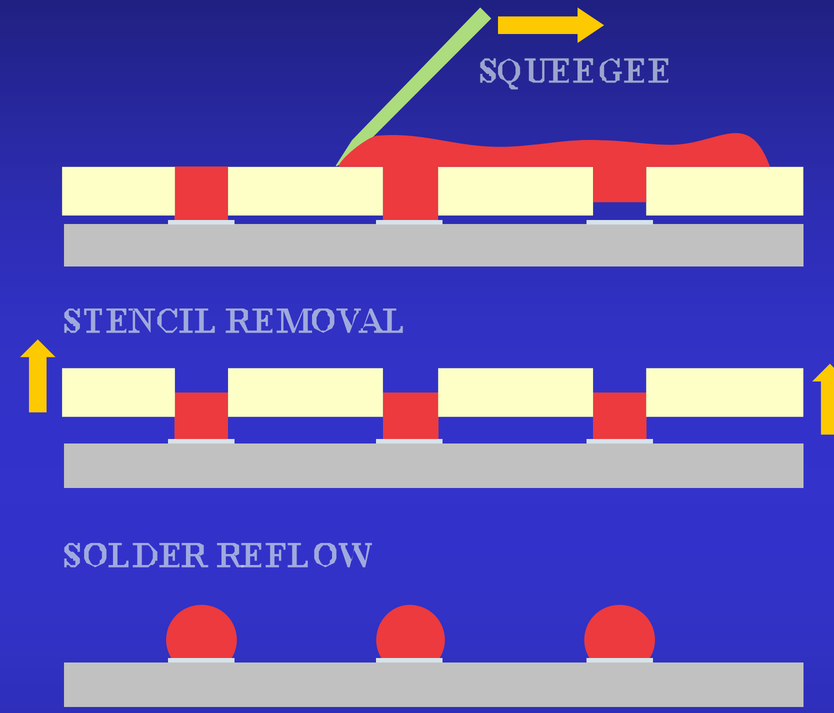


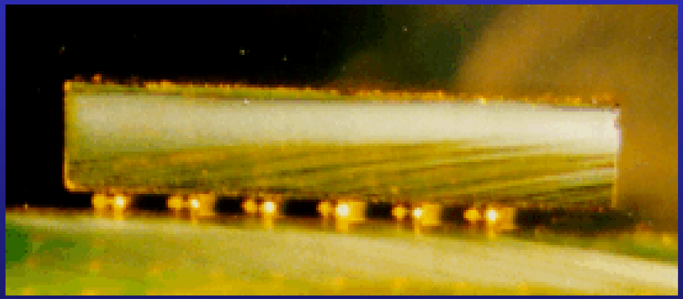
Bumping technologies

- Evaporation through metallic mask
- Evaporation with thick photoresist
- Screen printing
- Stud bumping (SBB)
- Electroplating
- Electroless plating
- Conductive Polymer Bumps

Screen printing

- Process steps
  - Stencil alignment
  - Solder paste deposition with a squeegee
- Characteristics
  - Minimum pitch: 150 µm
  - Stencil printing thickness: 100 - 50 µm
  - Same bump height
  - Solder pastes:
    - Sn/Pb, Sn/Pb/Ag, Sn/Ag, Sn/Sb
    - Pb free pastes: In, Pd, Sn/Ag
  - Most widespread
  - Very high yield



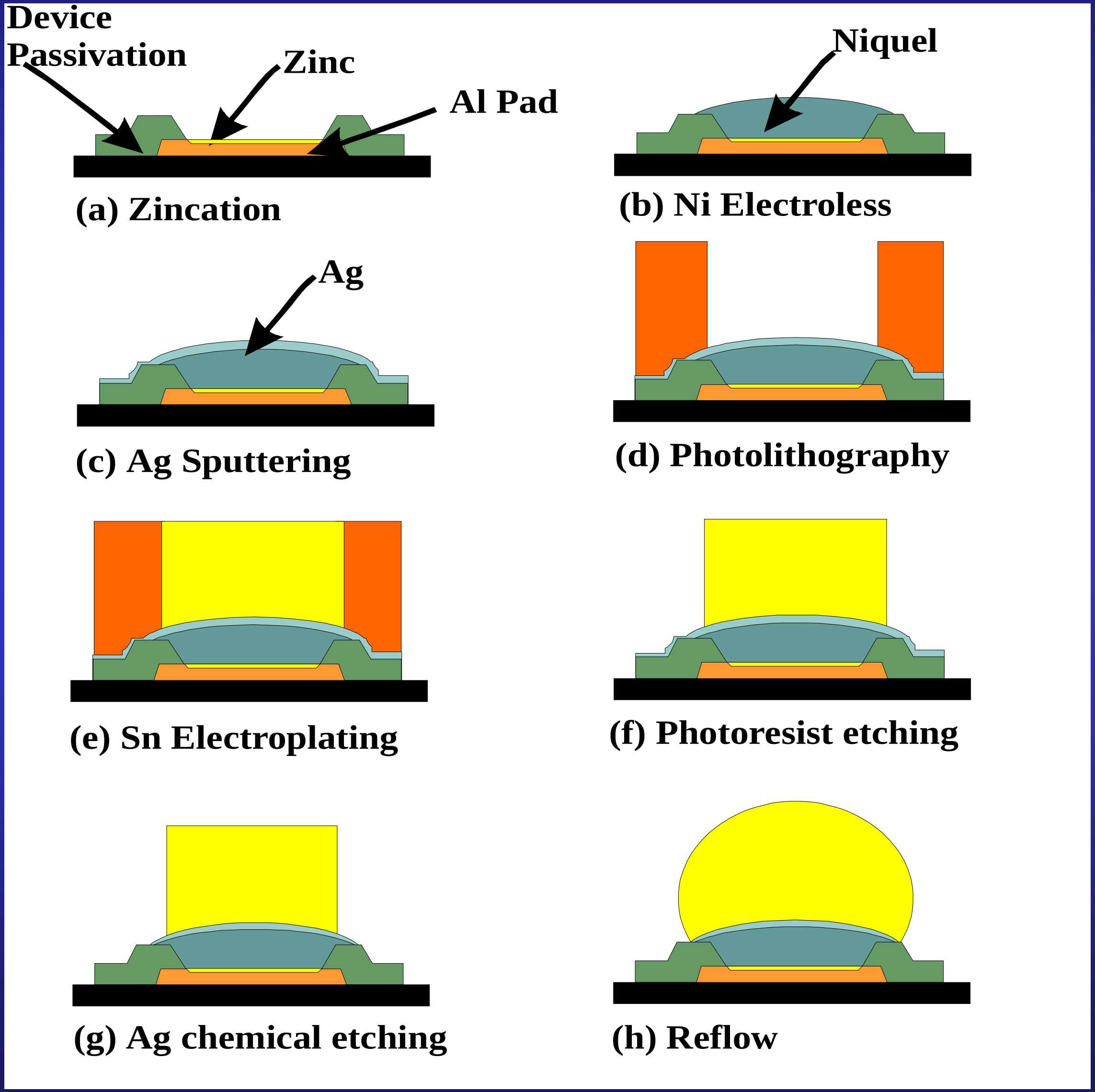


Screen printing => Rerouting

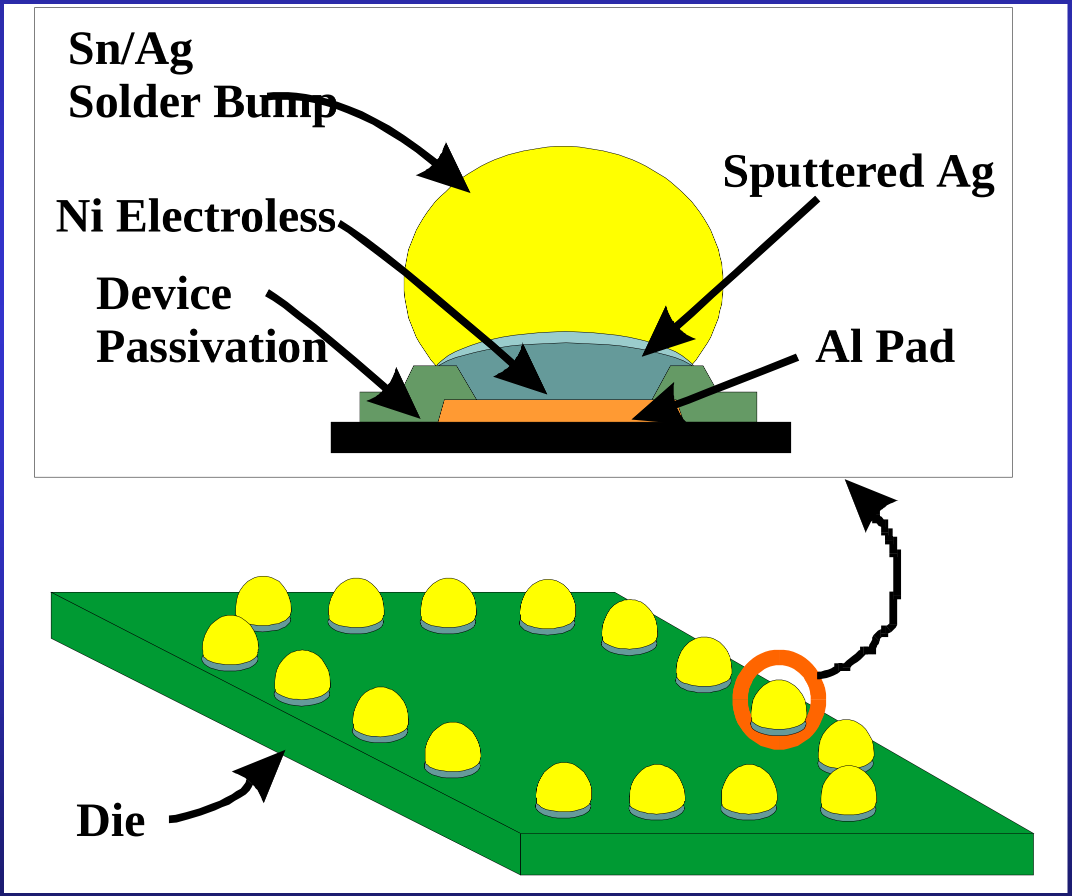
- 150-400µm pitch implies that peripheral pads have to be re-distributed into an array in order to have access to all of them.
- Three-step process + UBM
  – 2 polyimides
  – 1 re-routing aluminum
- High cost: 4 masks + several Clean Room steps

Not suitable for Pixel Detectors

Sn/Ag Electroplating: Flow Chart



Sn Electroplating: Final Bump

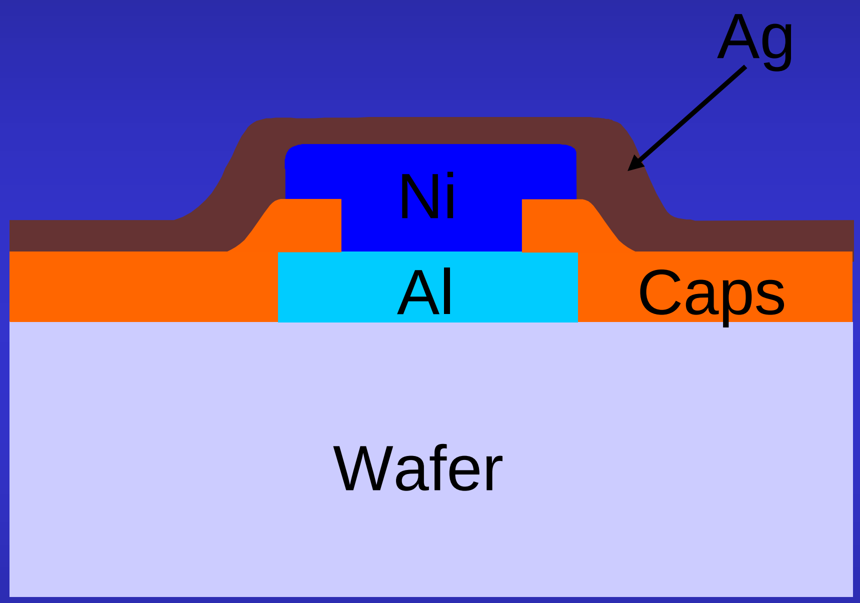


Sn electroplating: Process Flow Chart

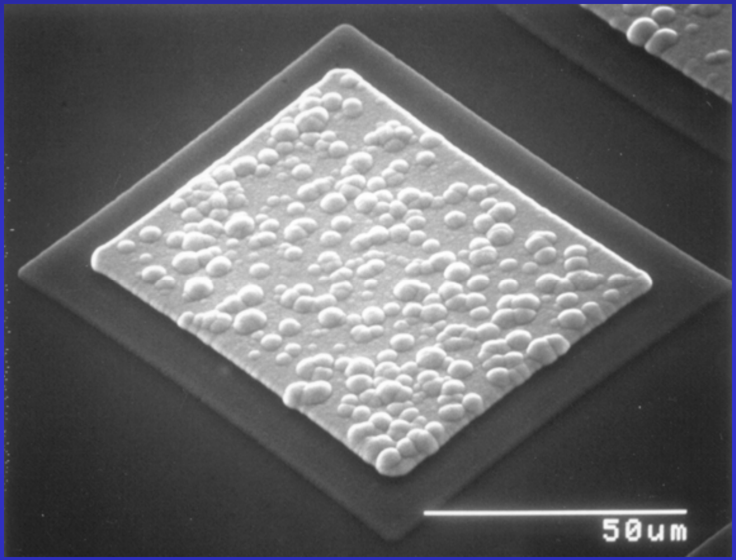
- UBM deposition: Ni Electroless
- Seed layer deposition: Ag sputtering → 700nm
- Photoresist processing AZ-4362 → 20µm
- Solder electroplating: Tin bath + wafer holder setup
- Photoresist removal: Organic solvent
- Seed layer removal: Especial bath
- Solder reflow: Glycerol bath

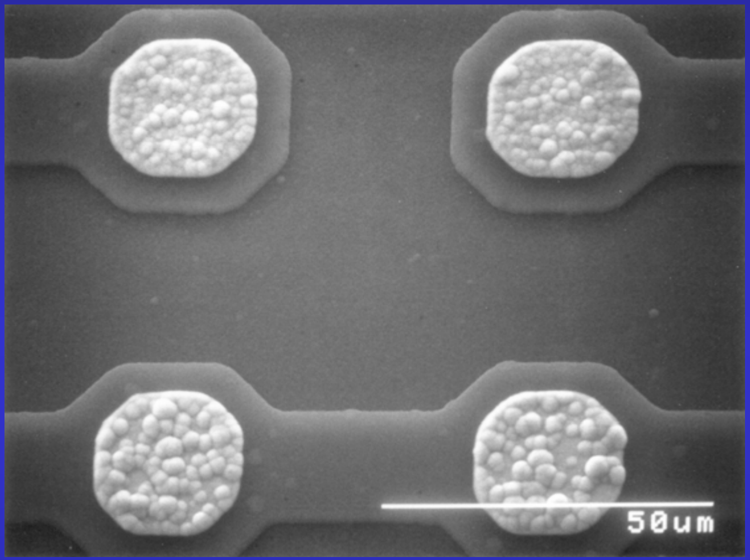
UBM + Seed layer definition

- Process steps
  - Pad conditioning
  - Ni electroless deposition
  - Ag sputtering (700nm)
- Characteristics
  - No need for electrodes
  - Photolithography not required
  - Bump material: Ni
  - Minimum pitch 50 µm
  - Bump diameter 20 µm
  - Bump height 2 µm



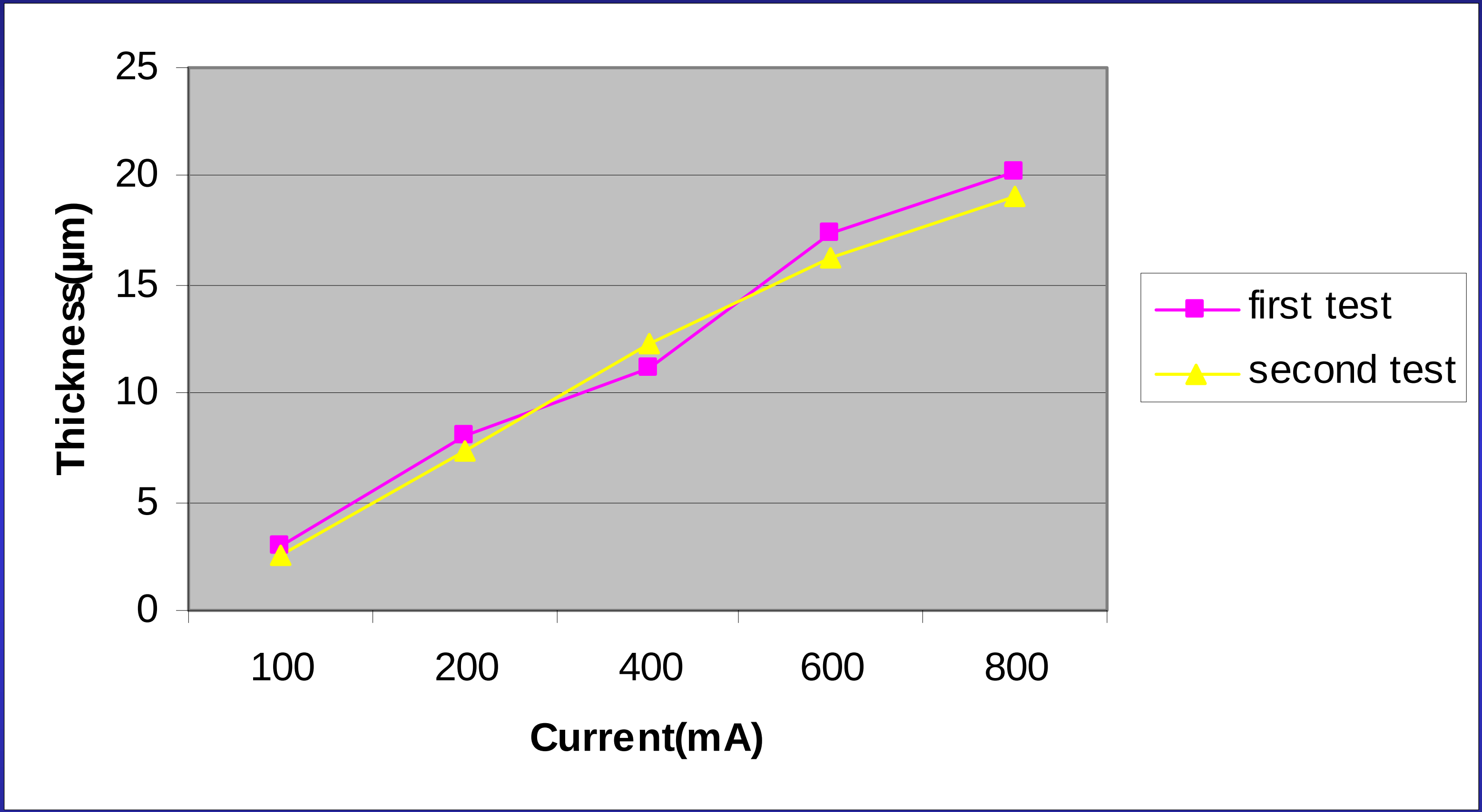
UBM: Ni Electroless





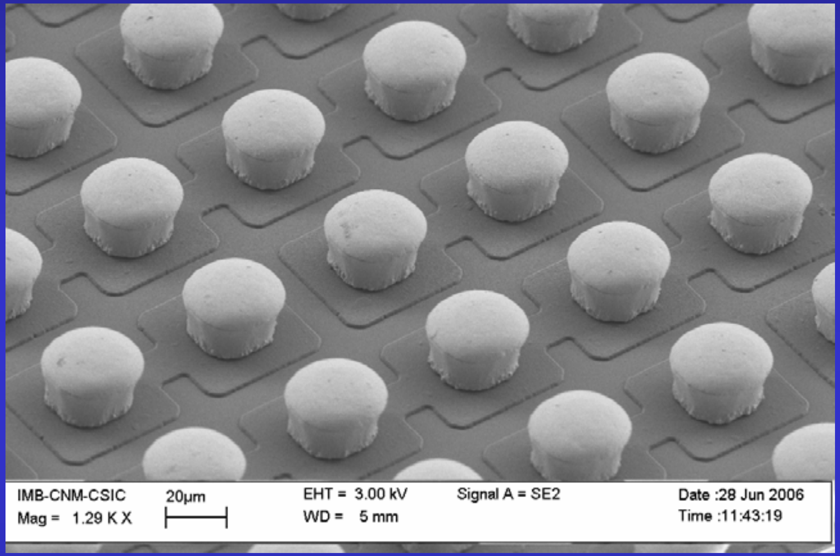
- SEM pictures taken after final Ni Electroless process.
- 2.5μm are deposited onto Al pads.

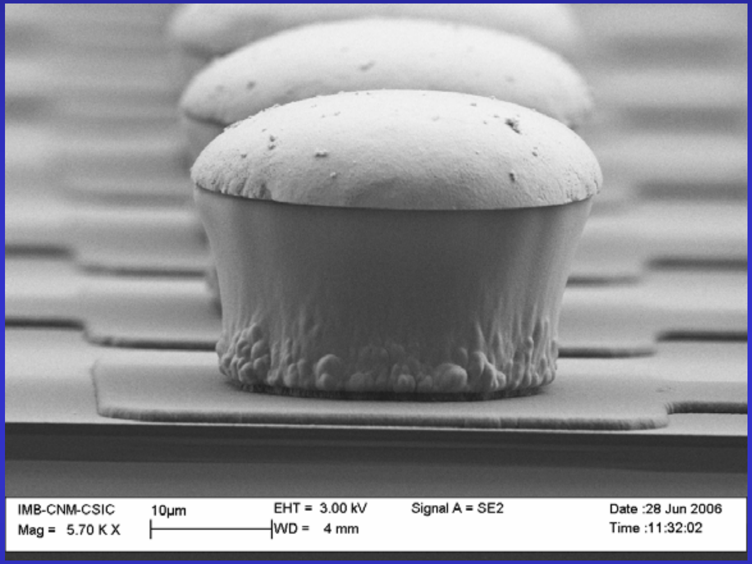
Sn Electroplating: Deposition rate



The deposition rate is proportional to the applied current, but too much current is responsible for a higher Sn roughness and also for a bad adhesion between Sn and Ag

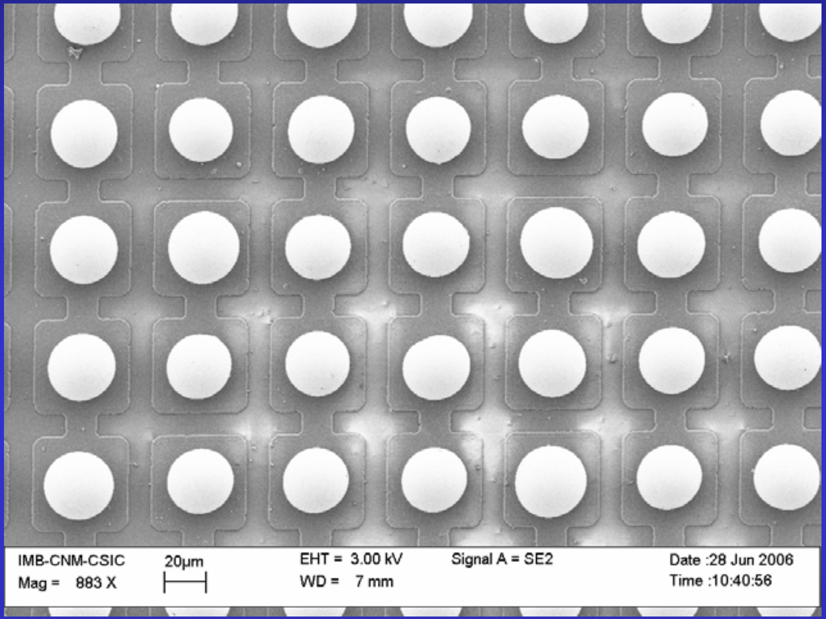
After Photoresist removal

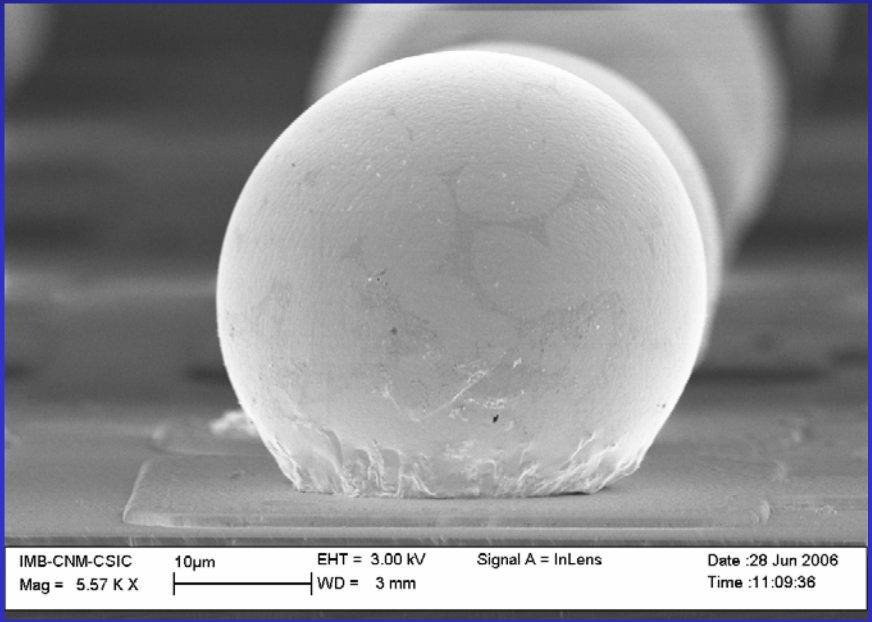




- Photoresist is removed using an organic solvent
- Sn ‘muffins’ act as etch mask during Ag removal

Reflow in Glycerol

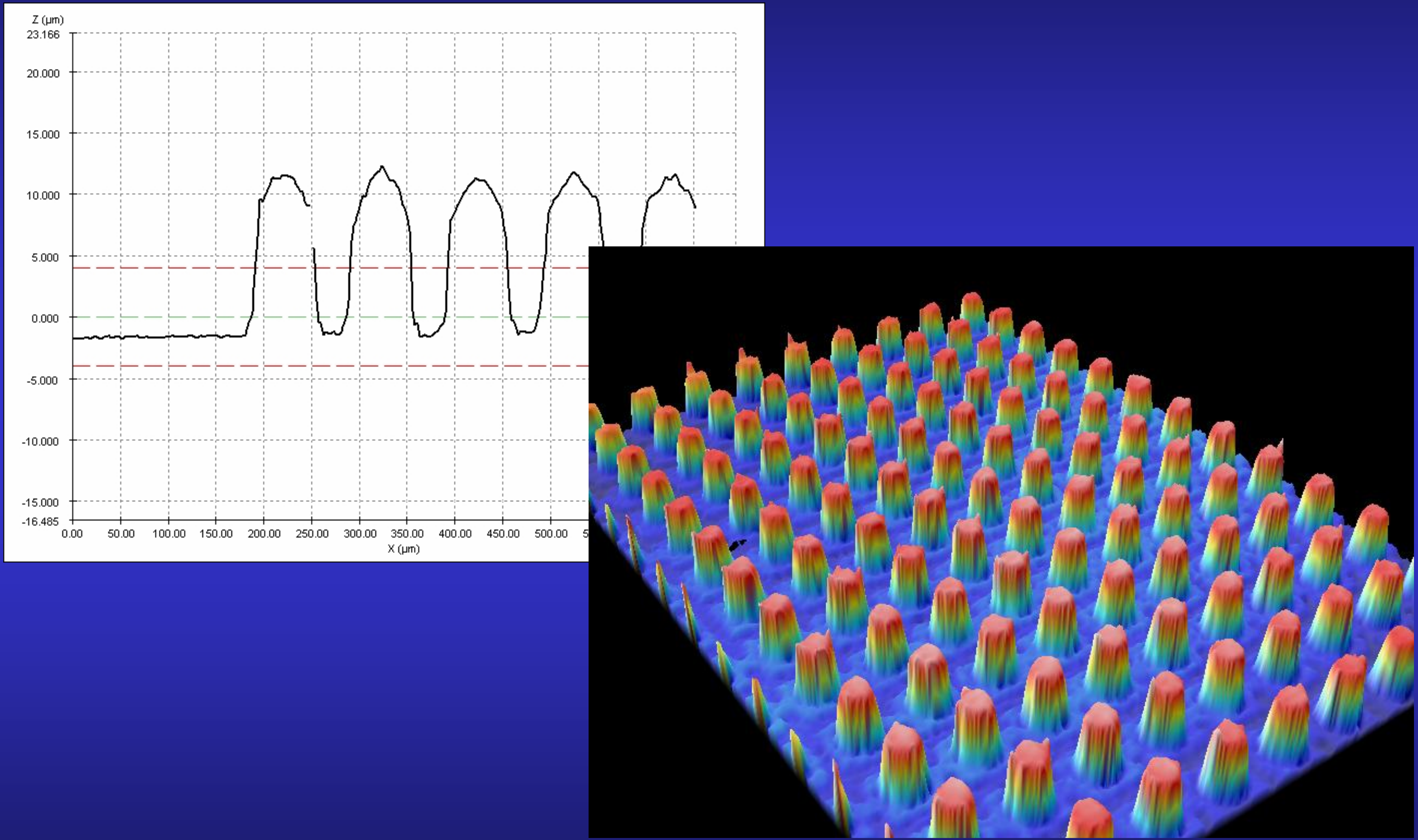




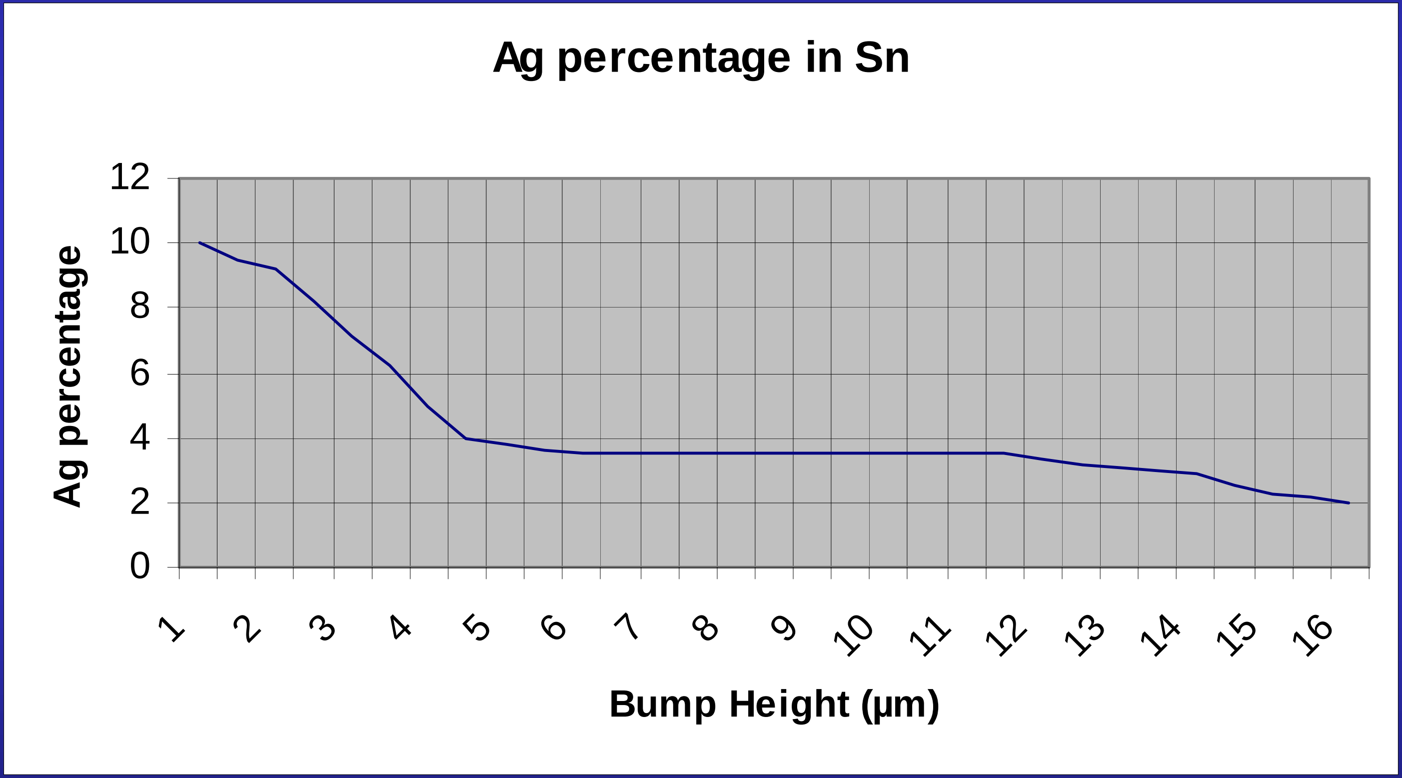
After reflow in a glycerol bath:

- The bumps become spherical
- Ag disolves into Sn and forms the eutectic alloy Sn/Ag(3.5%)

Confocal Microscope: Sn Profile

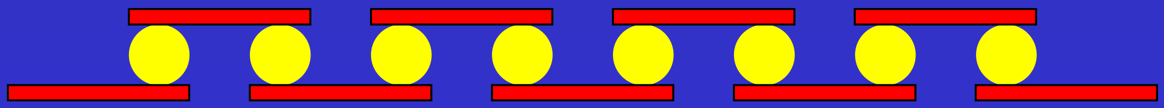


Auger Spectroscopy Analysis



Test Structure Design (I)

- Test structure made of two sides for flip chip: chip side (c-side) and detector side (d-side)
- Daisy chain structure kind such as if one bond fails ('bad bond') the whole chain fails.

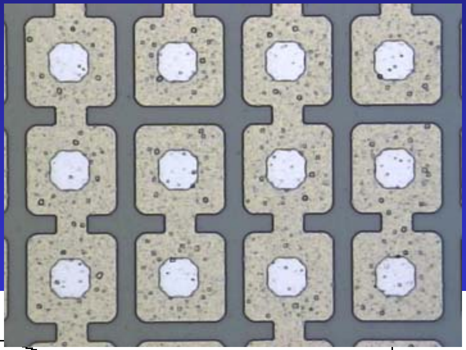


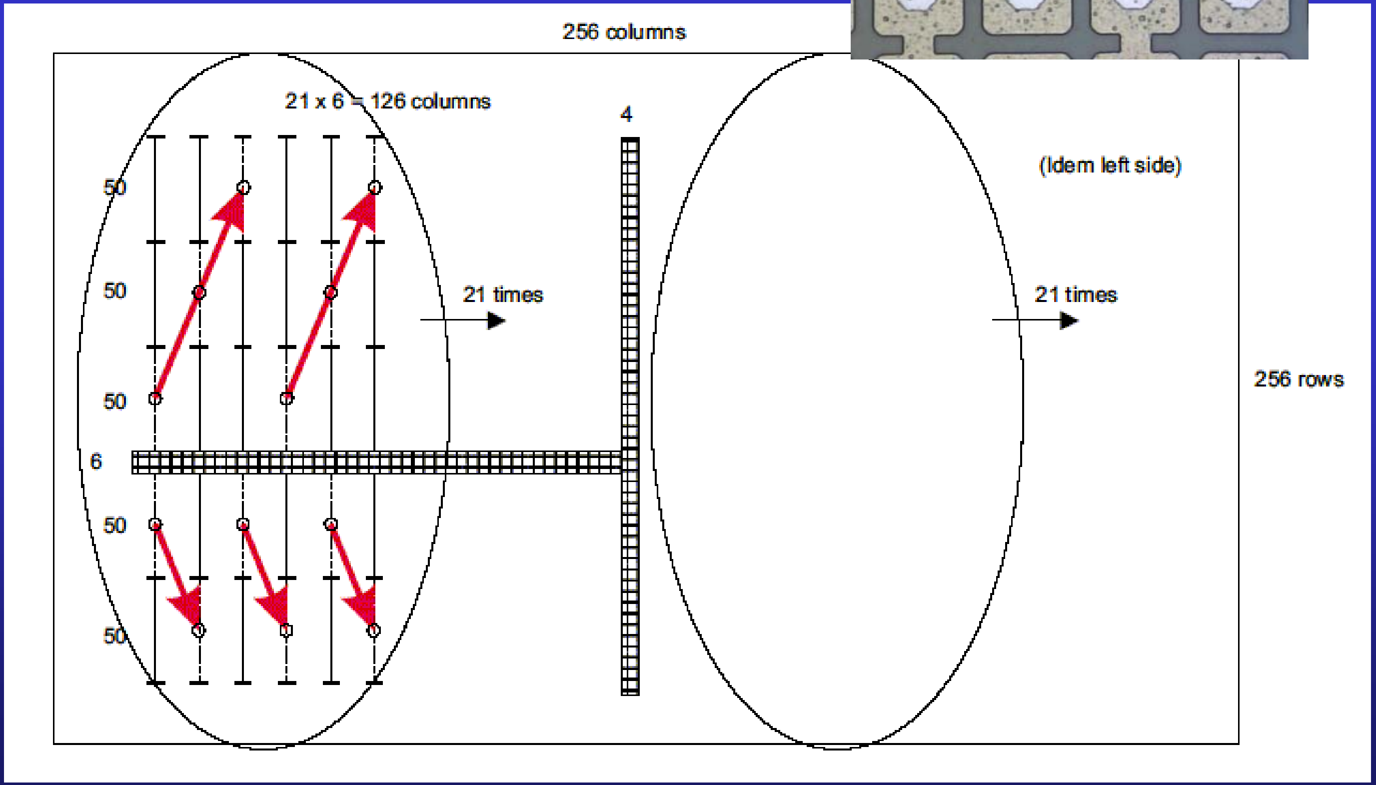
- *N* chains made of *L* bump bonds evenly distributed across the assembly for statistical calculation.
- *N, L* have to be properly chosen for the yield range of interest of the particular application.
- Case: 256 x 256 assembly (55 μm pitch)
  504 chains of 50 bonds
- Chains connected to a central ground bus and to an array of probe card test pads (1x16) for fast easy test
- Automatic conductivity measurement of each chain

Test Structure Design (II)

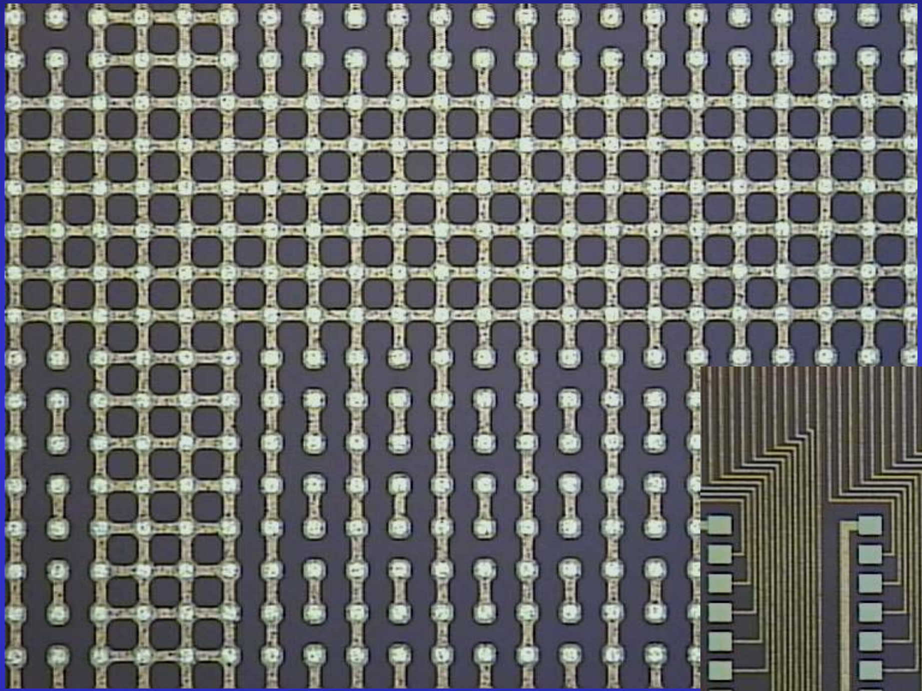
D-side:

- Central ground bus
- Chains in columns
- Even distribution of chains



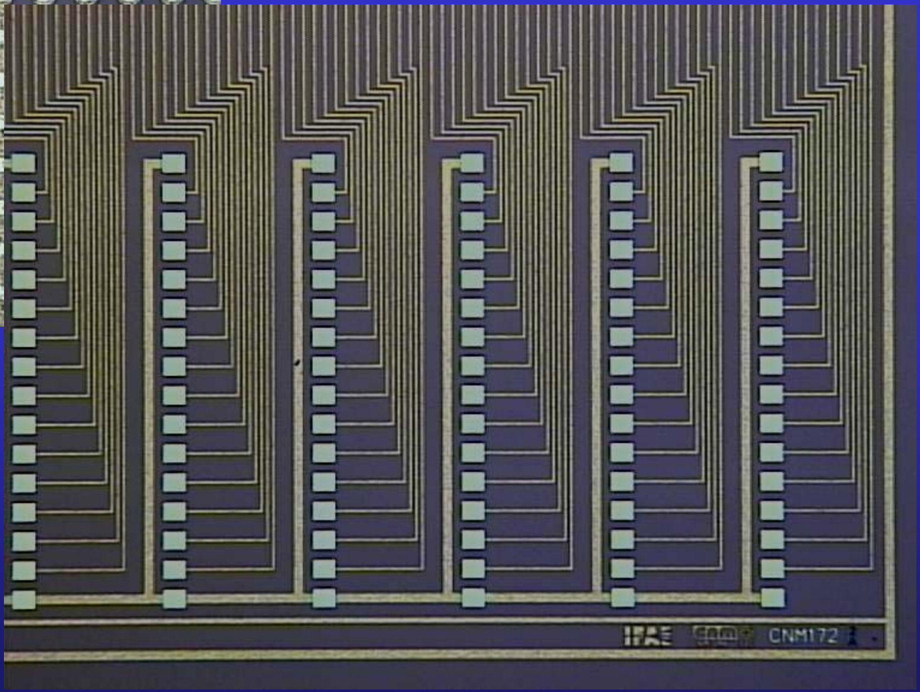


Assembly



Central ground bus d-side

Probe card test pads c-side



Conclusion

- A bumping technique allowing very fine pitch has been developed
- Yield tests are being carried out
- Other alternatives such as including Cu into the bumps are being taken into consideration