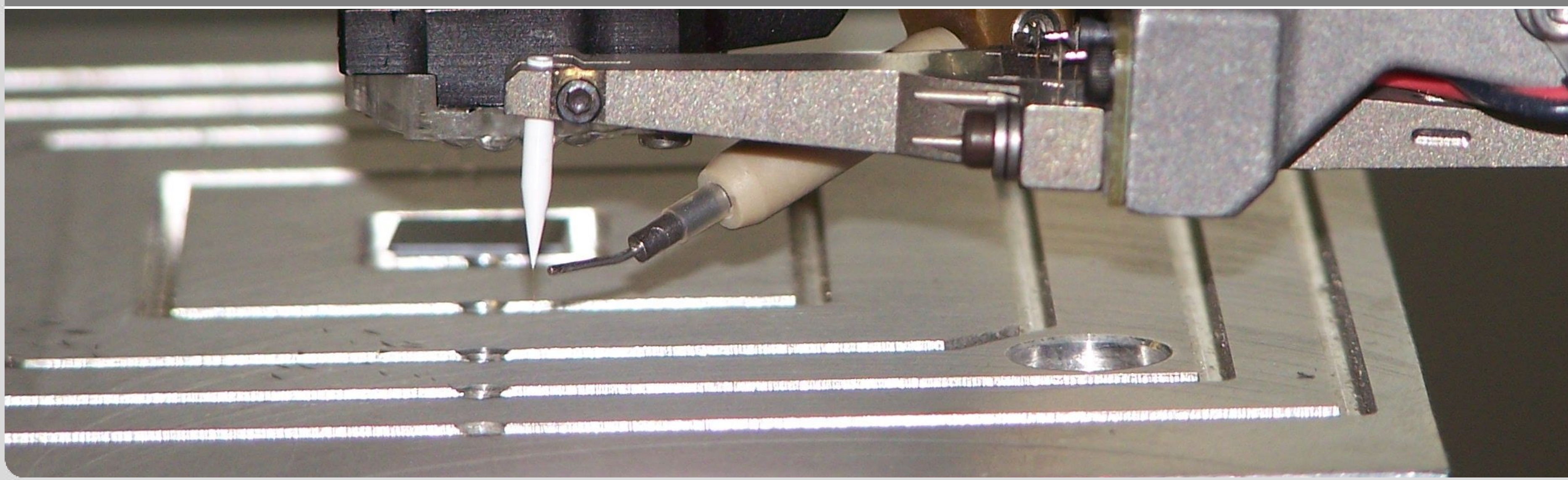
Gold-stud bumpbonding

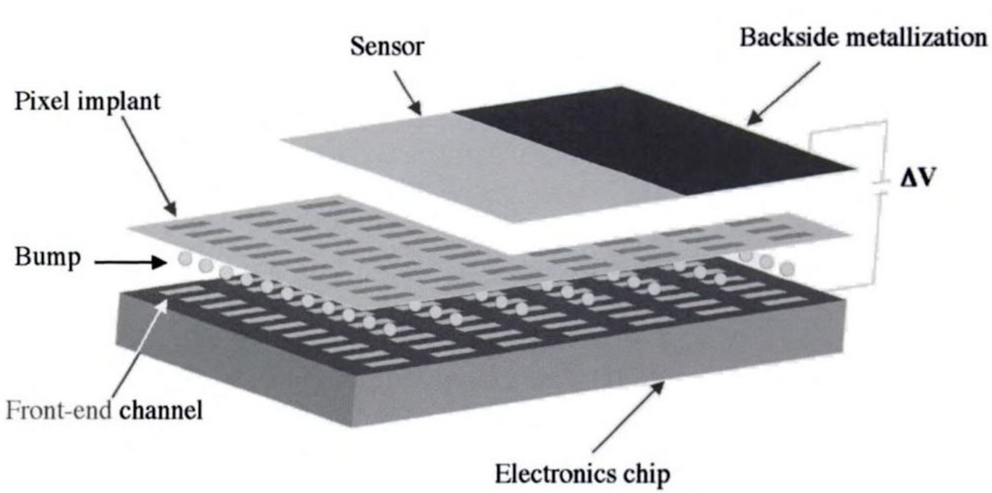
Interconnection technology for research and development of new detectors

Thomas Blank, Michele Caselle, Fabio Colombo, Ulrich Husemann, •Simon Kudella, Benjamin Leyrer und Marc Weber

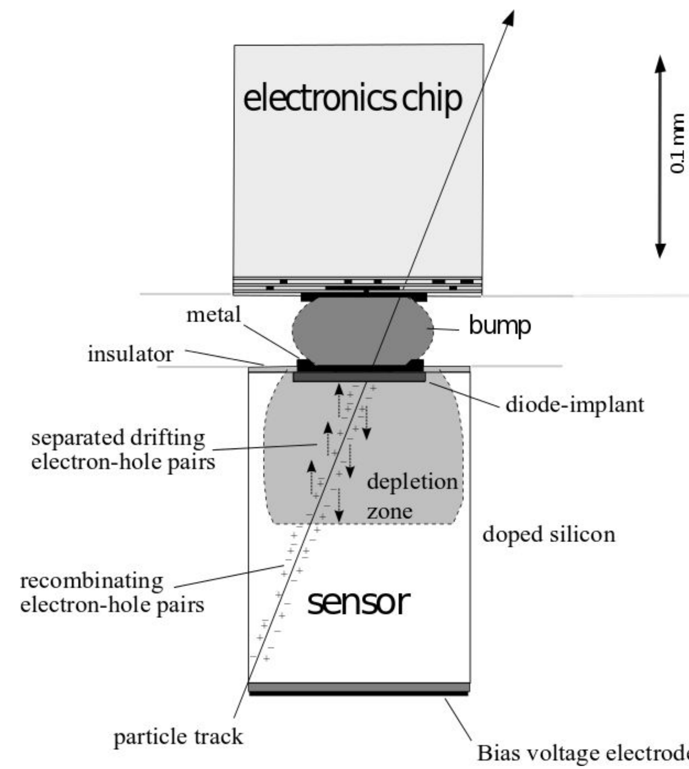
Institut für Experimentelle Kernphysik



Bumpbonding of pixel detectors



- Interconnection-density of pixel detectors to high for wire bonding
- Bumpbonding for vertical interconnection with high density

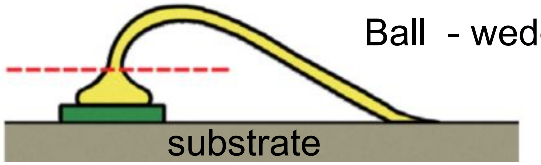


picture-source: L. Rossi – Pixel Detectors

- Standard technologies base on chemical bump deposition
- Chemical processes need Under-Bump-Metallization (UBM)
- Complex and expensive wafer-processing
- Search for cheap and flexible bumpbonding alternative technologies for single chip processing during R&D

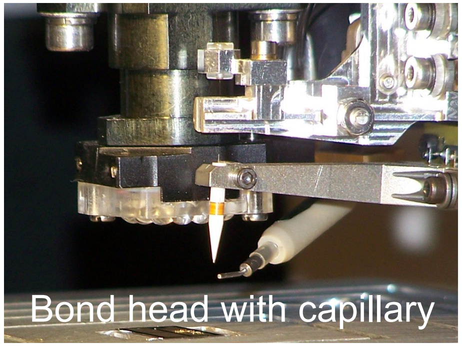
Alternative bumping method (KIT)

- Gold-stud bumping is an evolution of ~50 years of wirebonding
- Wire gets sheared after ball connection to substrate



- No UBM necessary
- Single-chip-bumping possible
- Cheap bumping process, @KIT
- 20 bumps/s

Ball-wedge-Bonder



Bond head with capillary

SEM-pictures of gold-stud bumps

Picture source: J.Jordan – Gold Stud Bumps in Flip-chip Applications

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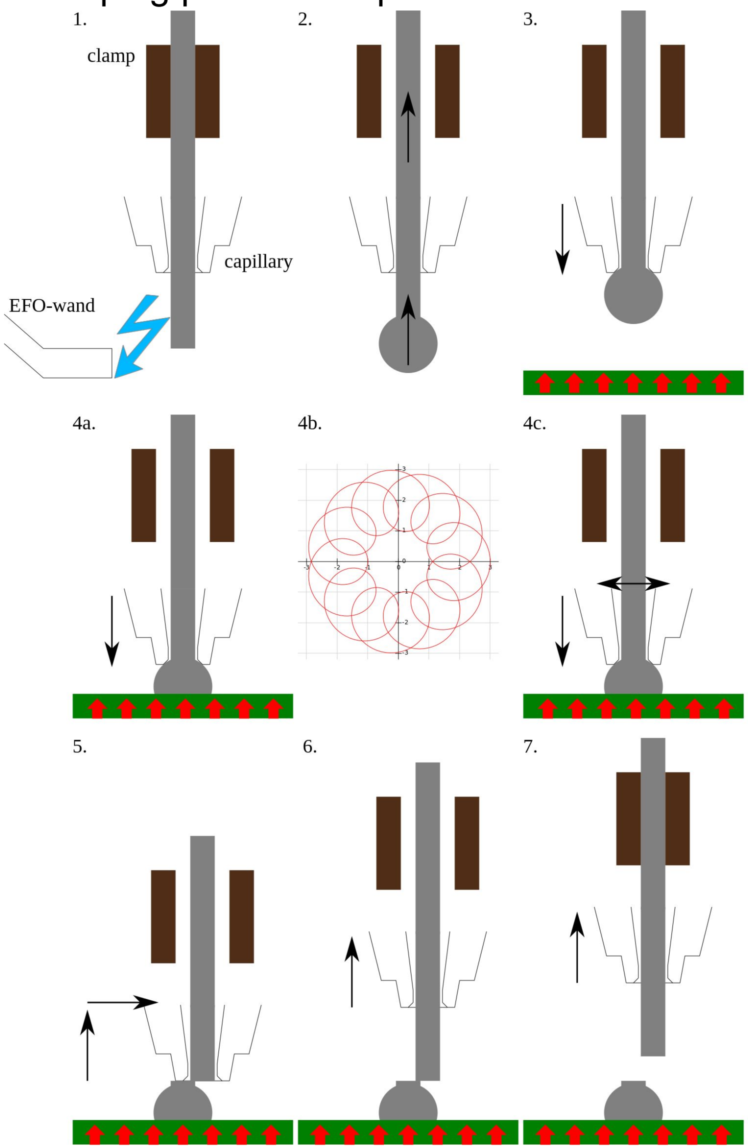
Bumping – process operation

- Process of upto 10 single steps
  - "Free Air Ball" formation
  - Touchdown onto surface
  - Bonding via ultrasonic bonding by ultrasonic generator (USG)
  - Shearing of wire
  - Re-feeding and ripping of wire

- Process with large number of paramters → optimization regarding:
  - Mechanical strength
  - Bumpsize and -shape
  - Long-term stability

Bumping process-sequence



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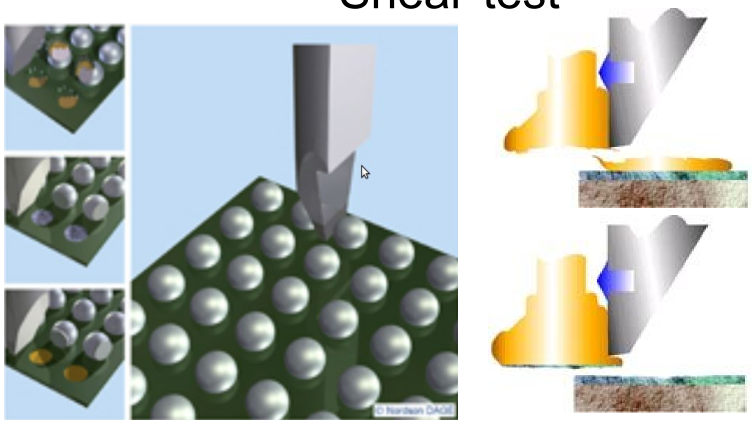
Bumping – mechanical strength

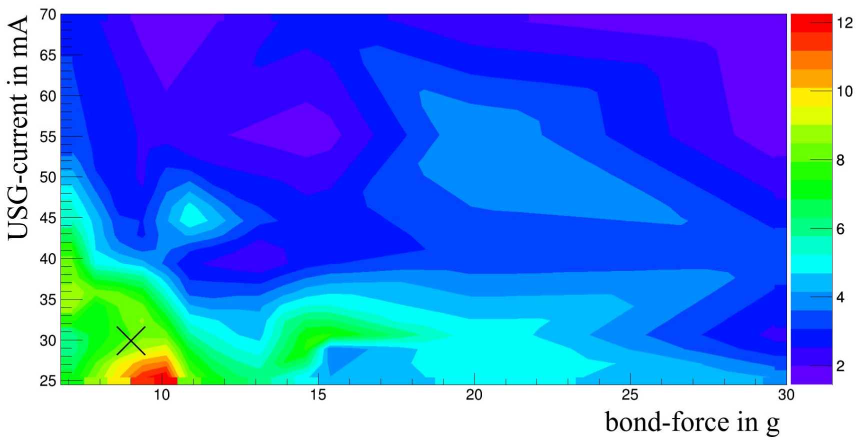
- Investigation by shearing of the bumps
- Looking for:
  - High shearforce per connection area
  - Separation process: bond-shear, aluminium-shear

Shear-test



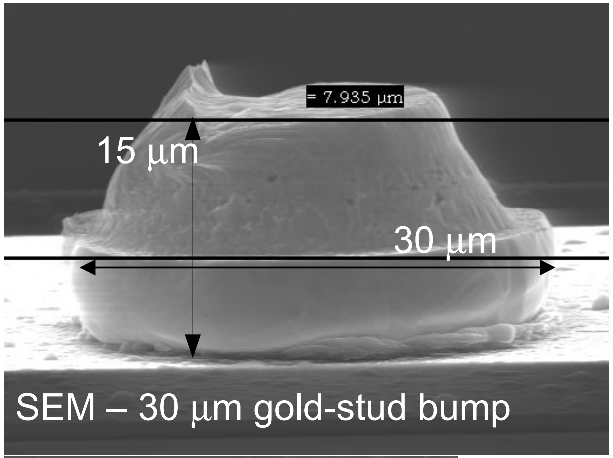
Picture sources: SPT & Nordson

$$\gamma = \frac{\overline{F}_{shear}}{A_{connection} \cdot \sigma(F_{shear})}$$

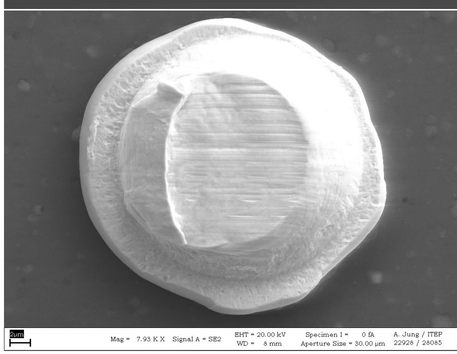


- Systematical investigation of mechanical strength
- No connection for I_{USG}<25 mA or F_{bond}<7 g
- Dimension for mechanical strength $\gamma=\overline{F}/(A\sigma)$, σ=standard deviation
- Parameters in area of high stability chosen
- Shearforce: 8 g per bump

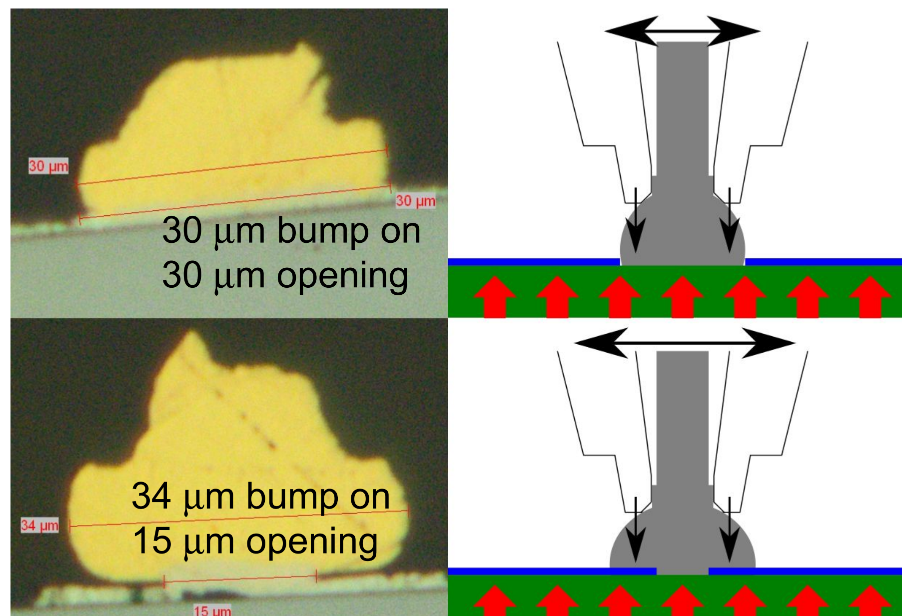
Bumping – Bumpgröße & -form



SEM – 30 µm gold-stud bump



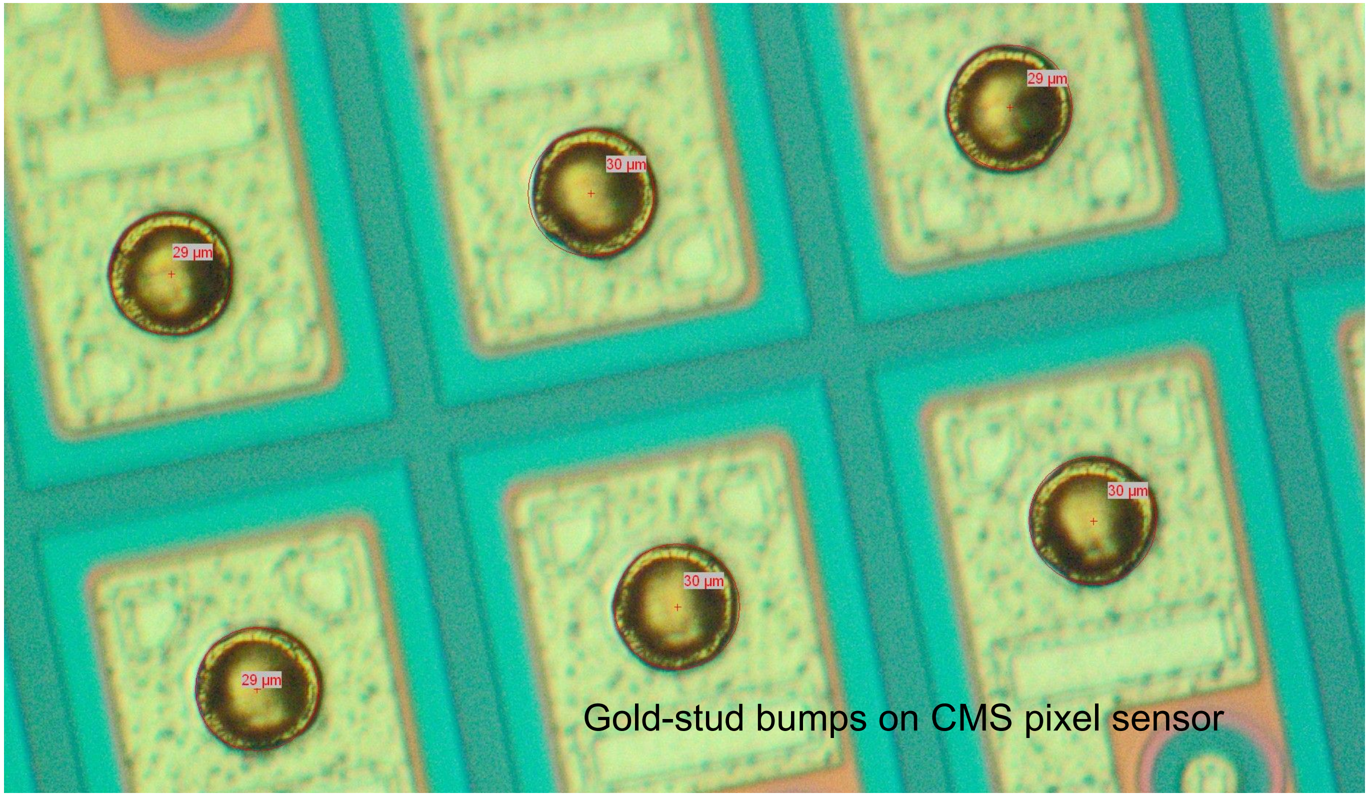
- Bump-shaping via wire-shearing parameters
- Current status: 30 µm diameter, 15 µm height
- Bump-diameter comparable to lithographic process



- Minimal bump-diameter depending on opening diameter of passivation → small passivation openings cause bigger bumps

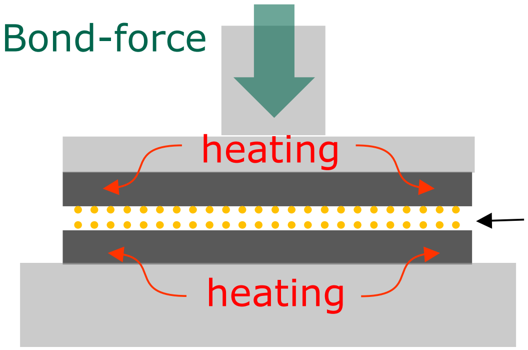
Bumping – long-term stability

- Long-term stability depending on hardware parameters (condition of wire , cleaniness of wire-feed system) and bumping parameters
- Current long-term stability >4000 bumps without interruption → bumping of a CMS pixel single sensor (4160 bumps) process in <5 min



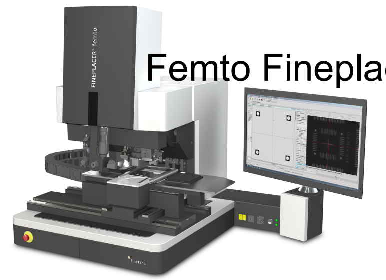
Gold-stud bumps on CMS pixel sensor

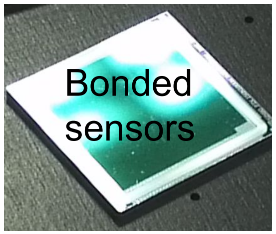
Bonding – process operation



Bond-temperature

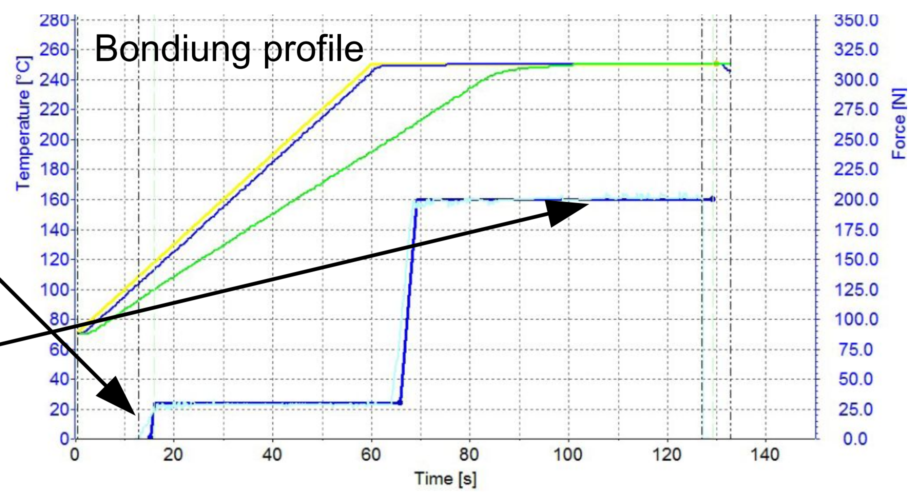
- Flip-chip bonding by thermo-compression
- Bonding with Femto Fineplacer® @KIT





Picture source: Finetech GmbH & Co. KG

- Two-step process
  1) Establishing planarity by gamber tool
  2) Bonding by thermo compression
- Process parameters
  1) Bond-force: 200 N (4,9 g/bump) for 60 s (necessary for bumpdeformation)
  2) Bond-temperature 250 °C for 60 s (no elektromigration in ROC/Sensor)

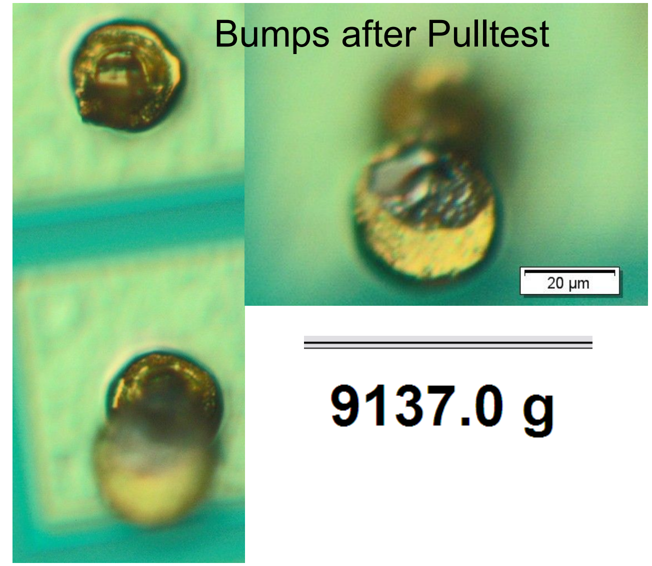


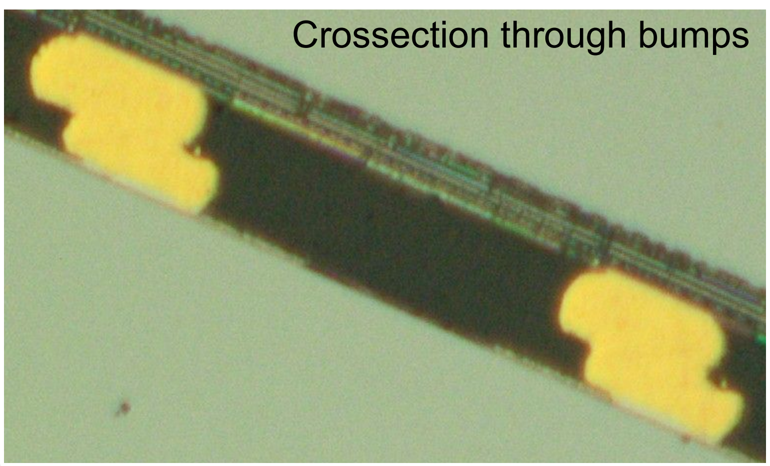
Simon Kudella

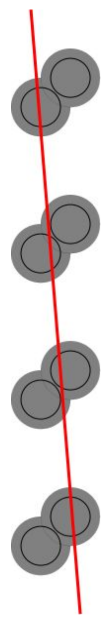
Institut für Experimentelle Kernphysik

Bonding – test results

- Pulltest:
  - High pull force of >2,2 g per bump
  - Separation process: 95% bump-to-bump, 5% aluminium-liftoff
    → bumping optimized
    → bonding not optimized yet
  - Chip shift due to weak vacuum







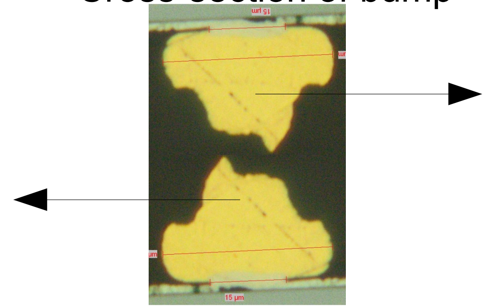
- Cross-section:
  - Very good connection of the gold bumps at 250 °C
  - Chip shift due to weak vacuum

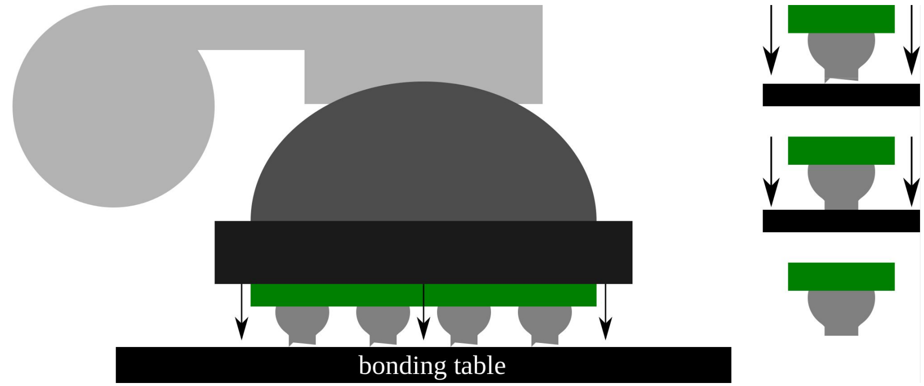
Bonding – flattening of bumps

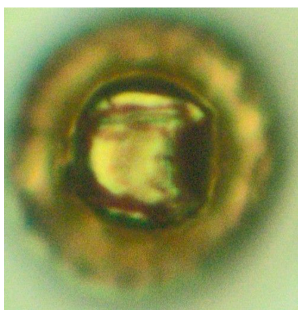
- Shift due to high shear-forces during the bonding

  → Reduction of the shear-forces by flattening all bumps
- Pressing bumps onto bonding table

Cross-section of bump

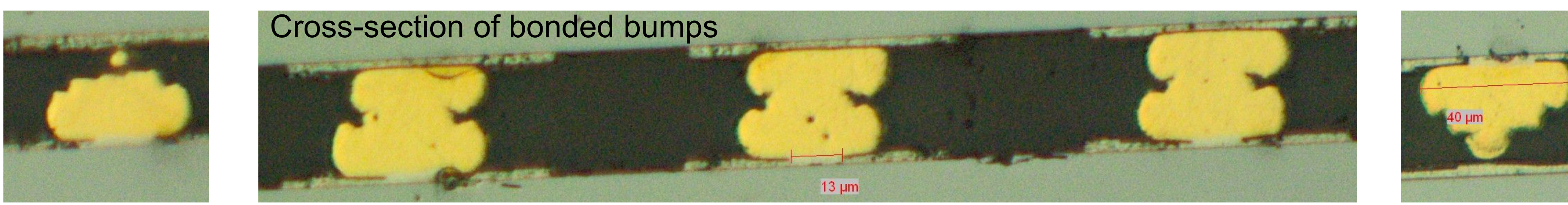




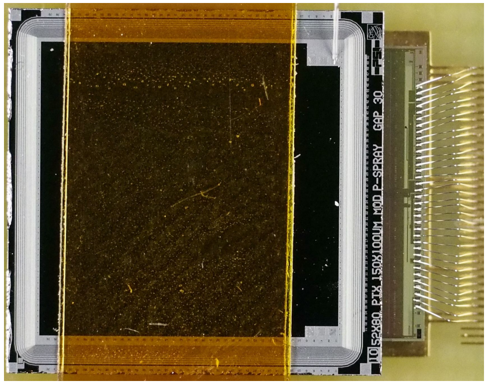


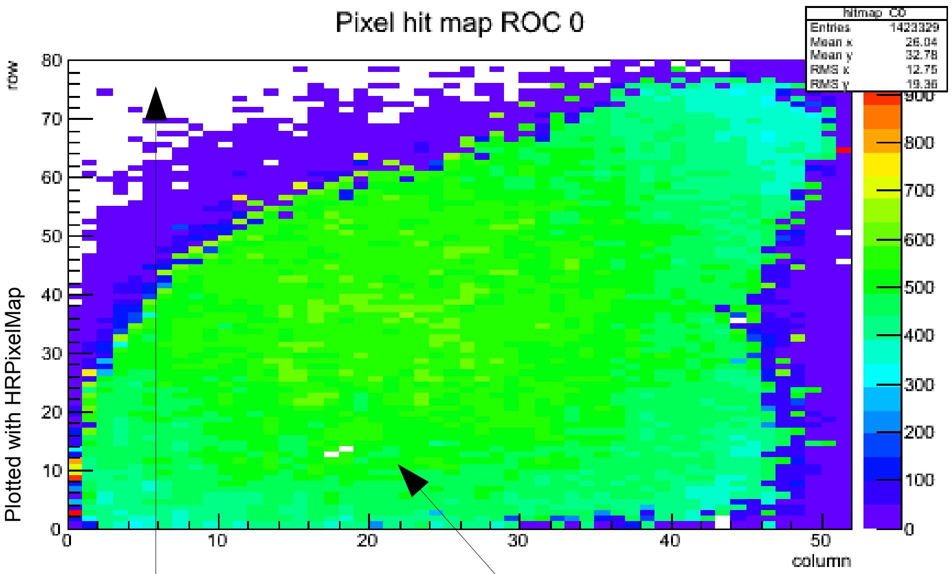
Gold-stud surface

- Shift reduced
- All bumps seem to be connected → electrical test



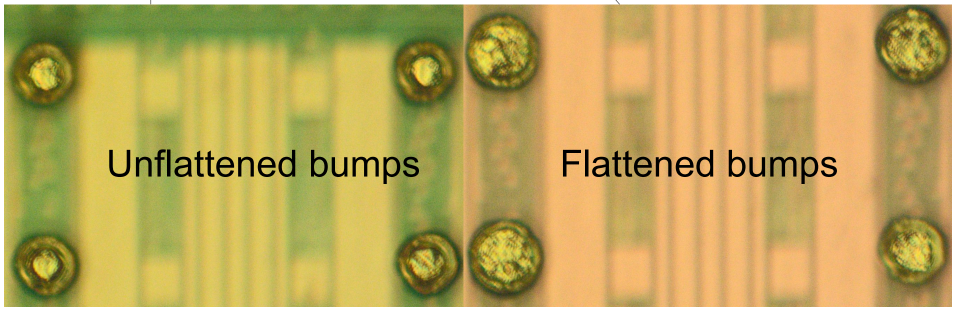
Bonding – electrical test

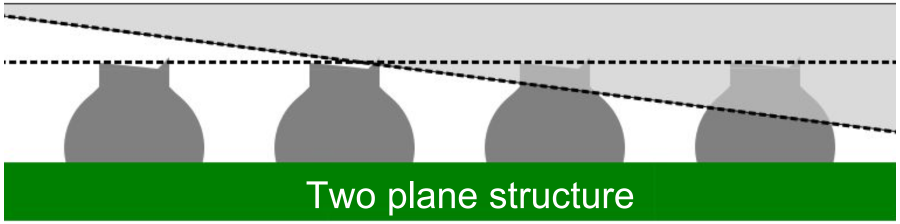




- First prototype assembled
- Chip alive after processing and 80% of connections established
- Source test shows planarity problem

  → correlated to flattening problem causing two plane structure
- Improving flattening process to assemble class A singles soon





Summary

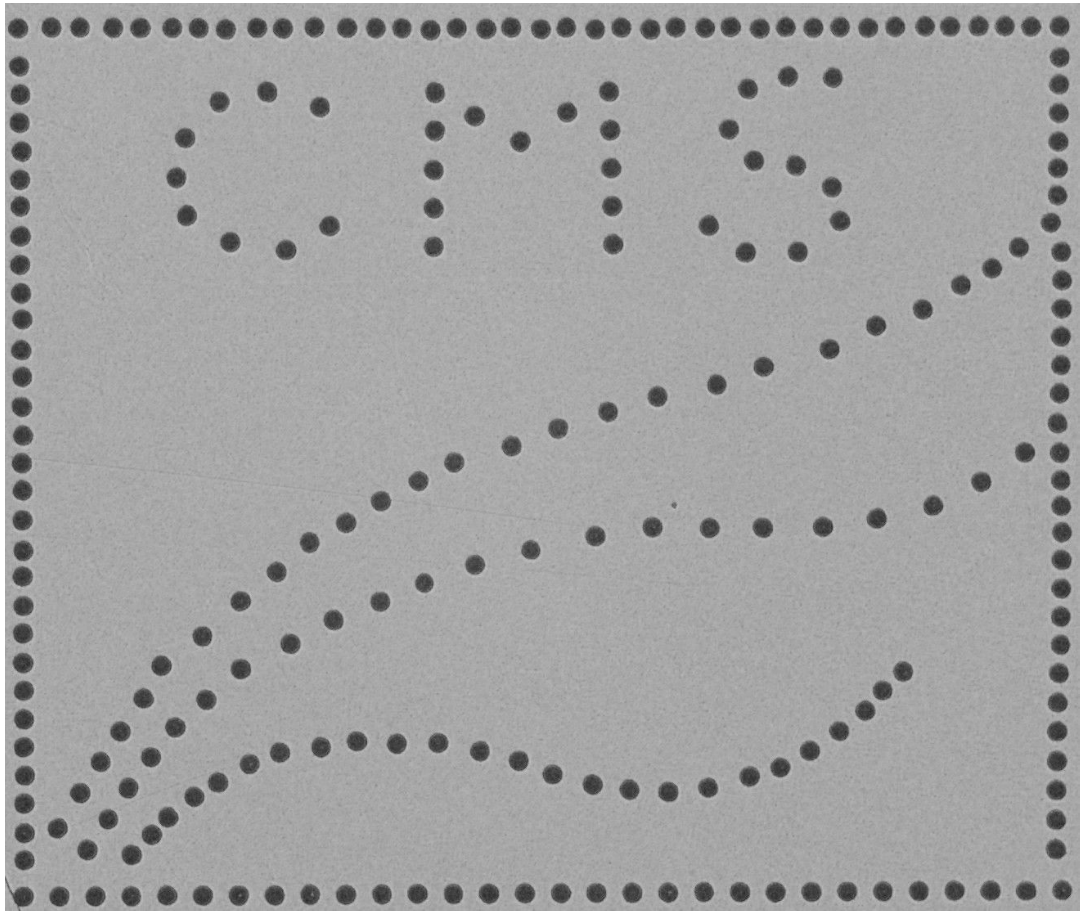
- Bumpbonding necessary for hybrid pixel detectors but complex and expensive
- Gold-stud bumpbonding as cheap flexible alternative that enables single-chip processing in the R&D phase

- Setting at KIT:
  - Bumping with Ball-wedge bonder (@KIT)
  - Bonding with Flip-chip bonder (@KIT)

  } Bumpbonding process @KIT

- Status:
  - Stable process producing 30-µm-bumps
  - Very good and strong interconnection using 250 °C bond-temperature
  - Chip shift due to weak vacuum → flattening of bumps to avoid shear forces

- Upcoming:
  - Improvement of flattening process and produce class A singles



Thanks for your attention!