Bump bonding options

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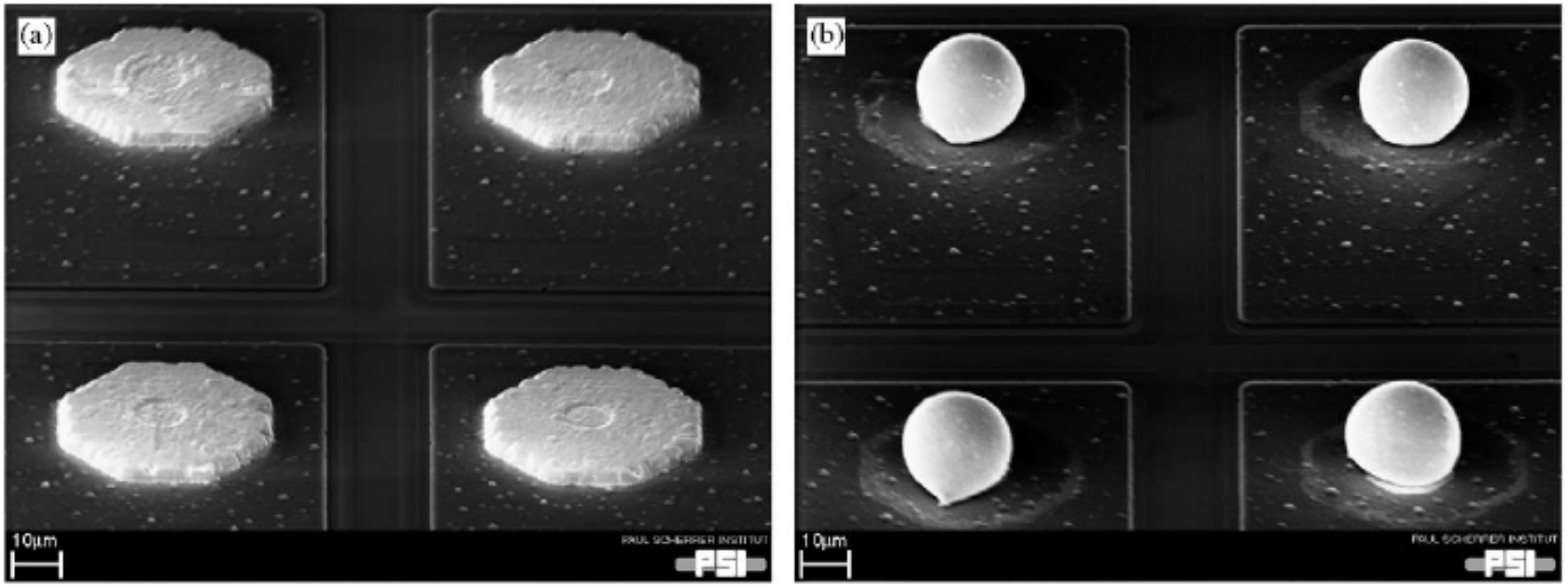
Karsten Hansen, DESY FEC
19.4.2011

- Bump bonding at IZM is the most expensive task in the pixel upgrade project.
  - IZM declined to offer just the bump deposition step.
- Search for alternatives:
  - Bump placement without wet chemistry or lithography: solder ball technique from PacTech!
  - Flip chip bonding at DESY: which bonder to buy?
- Test structures designed and ordered.

CMS Pixel bump bonding

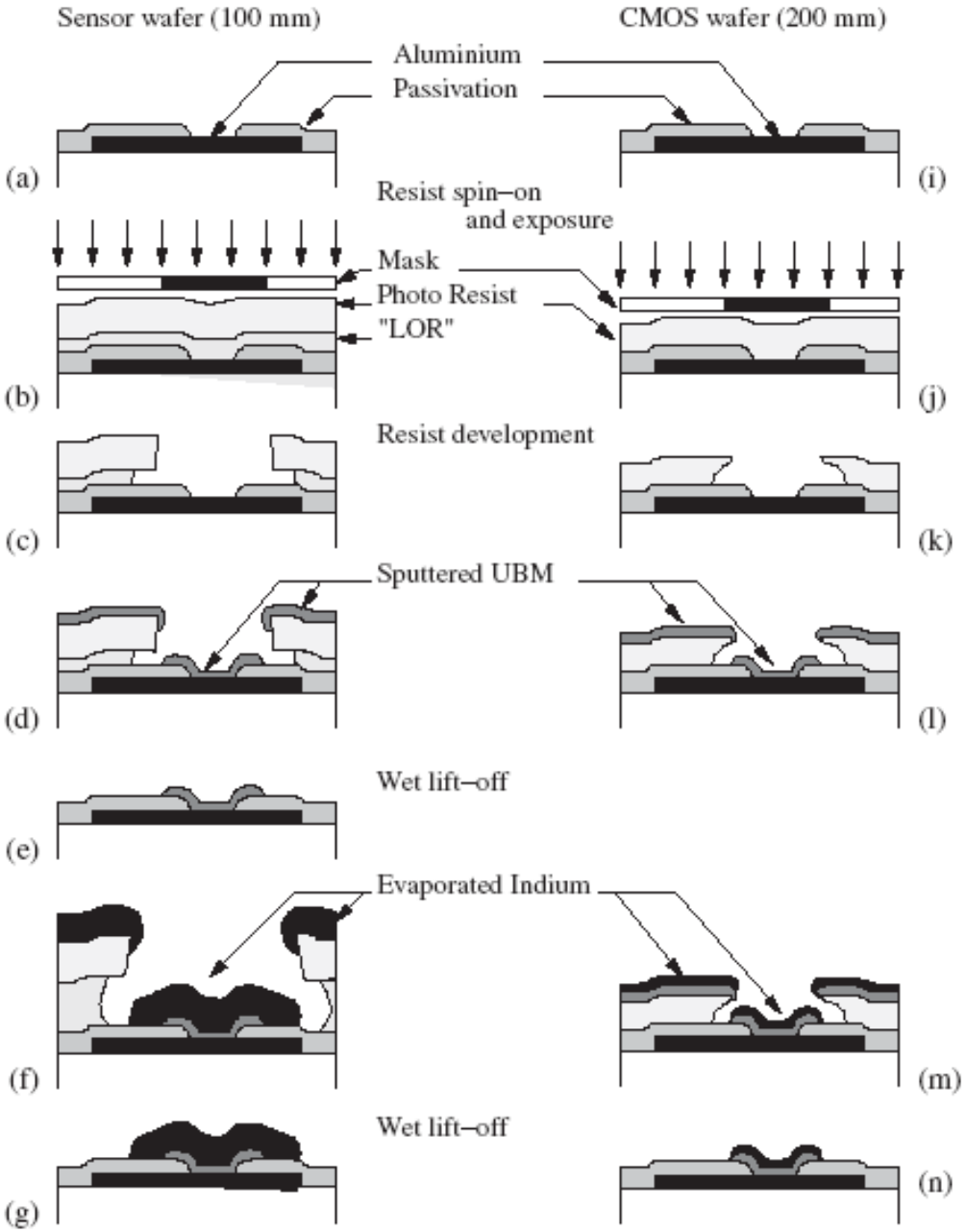
Deposit bump material
in a planar process:
sputtering,
photo lithography,
etching:

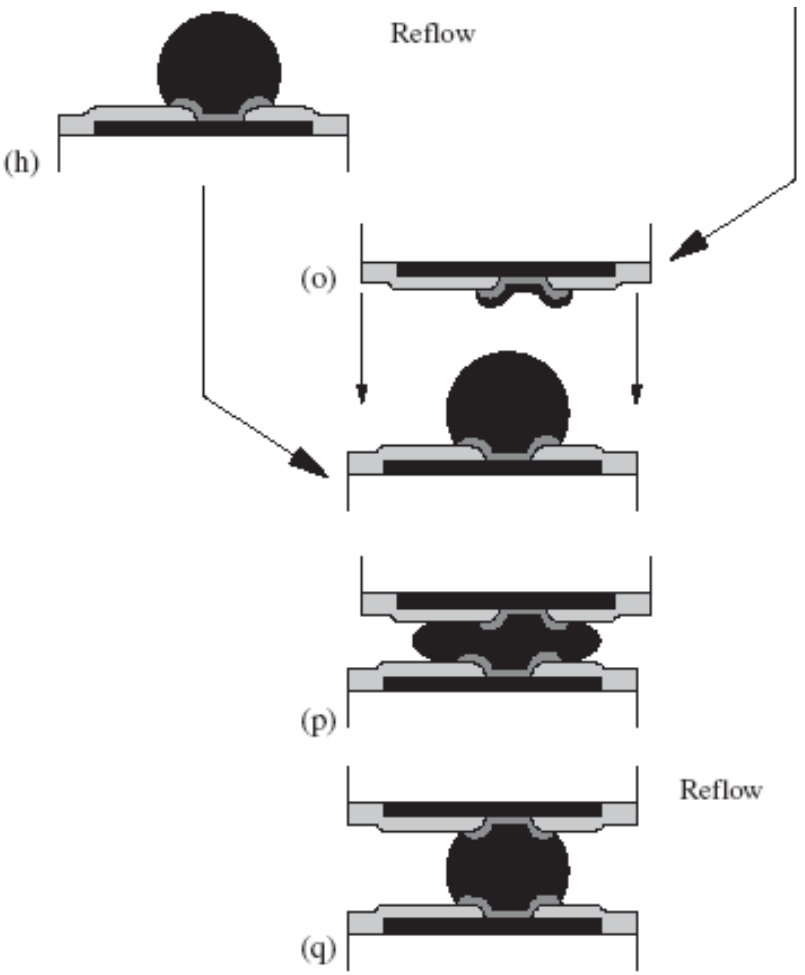
Form bumps by melting
in a re-flow oven:



PSI process uses Indium: low melting point at 156.6°C.
Not favored by industry: brittle, long term stability?

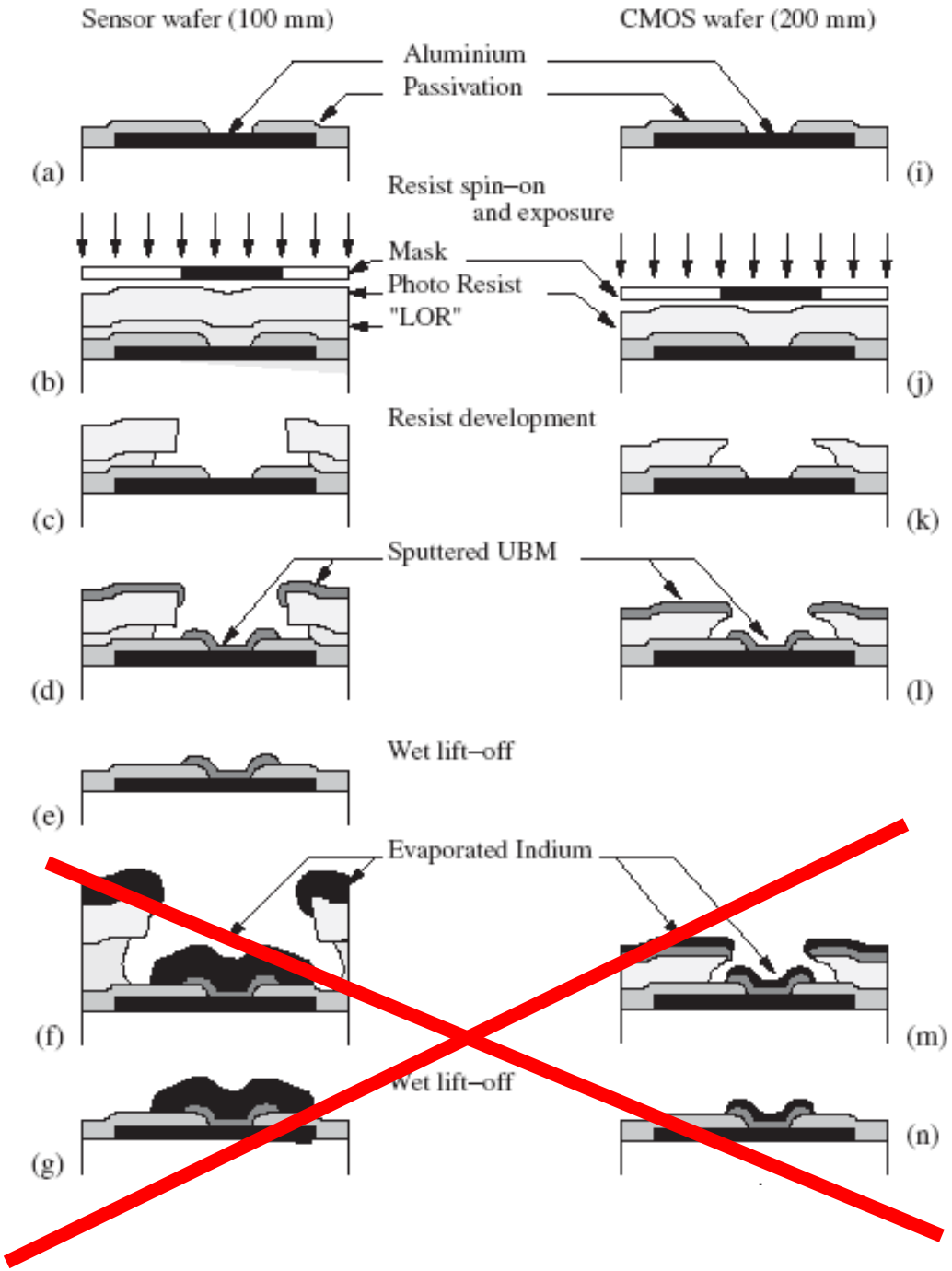
Bump deposition and flip chip bonding



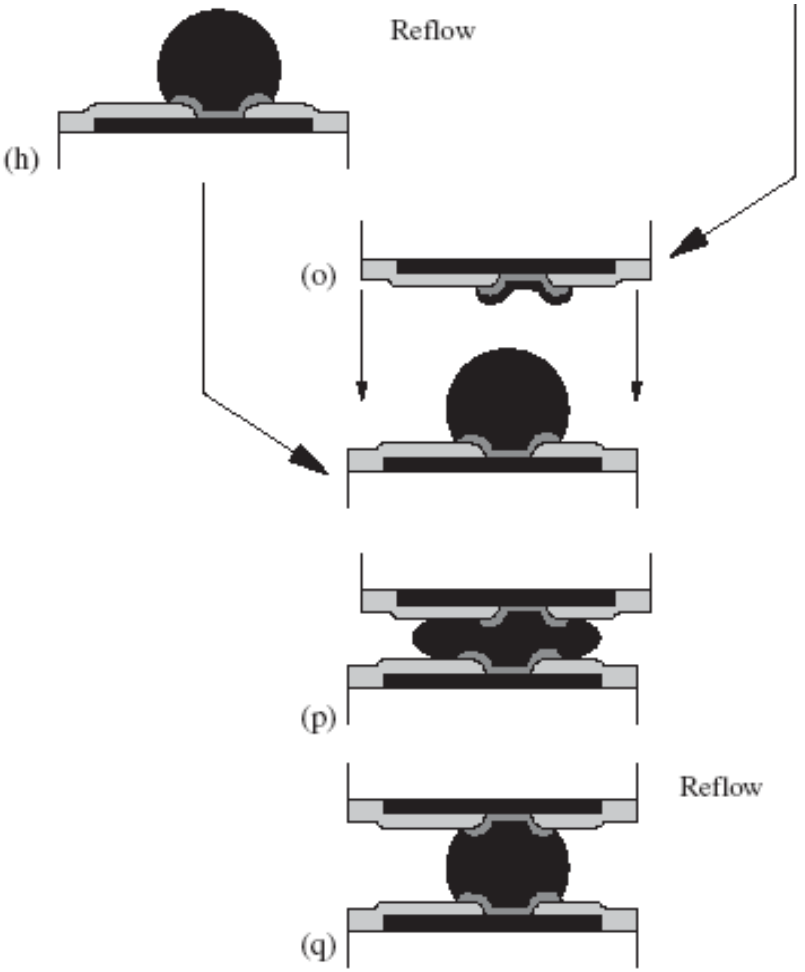


Ch. Broennimann et al.: Development of an Indium bump bond process for silicon pixel detectors at PSI
NIM A565(2006)303-8

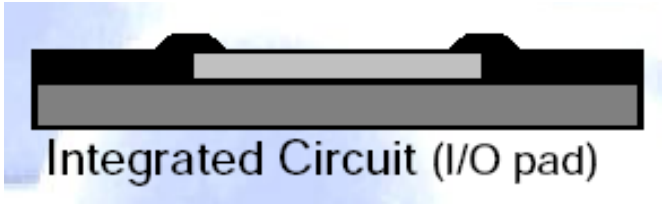
Alternative

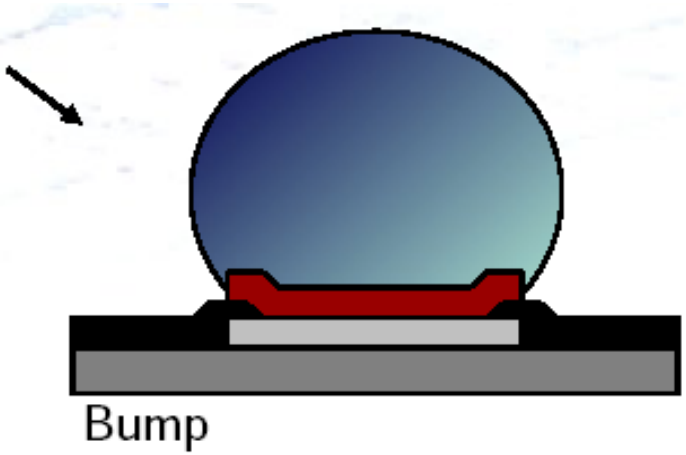


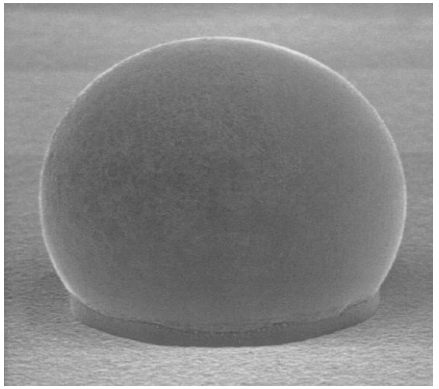
- Still need under-bump metal UBM
- Deposit bump ball directly
- Flip chip bond as before

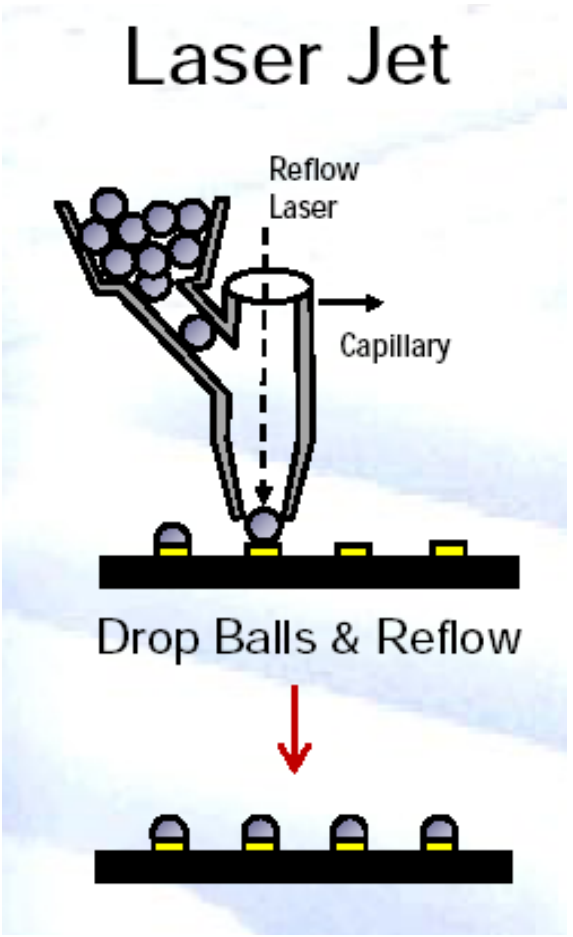


PacTech solder ball laser jet









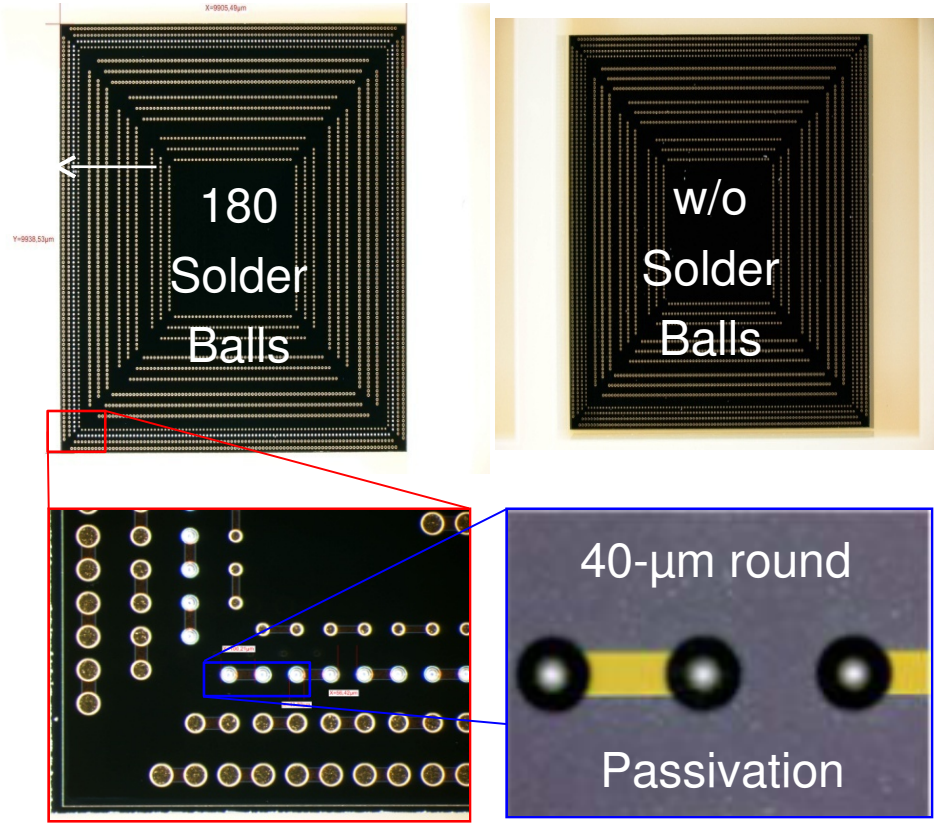
- Start with high-precision balls.
- 40 µm balls at 80 µm pitch possible now.
- 30 µm balls being certified.
- Drop through capillary towards pad.
- Melt by laser pulse during fall.
- Solidify on pad.
- Step-motor controlled.
- 5 balls / second.

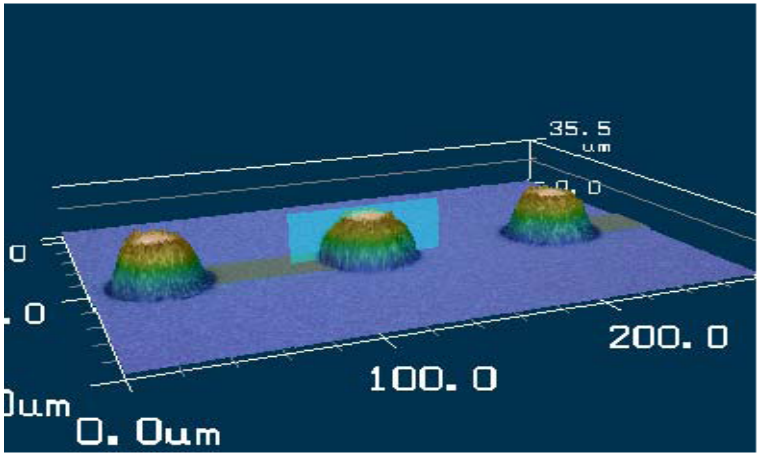
http://www.pactech.de/index.php?option=com_content&view=article&id=154&Itemid=21 pub 68

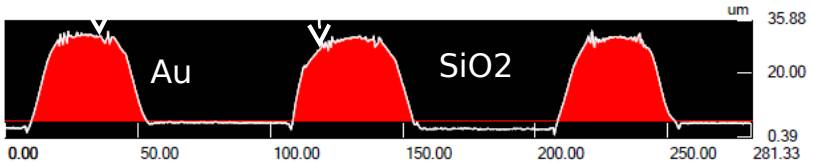
PacTech test structures

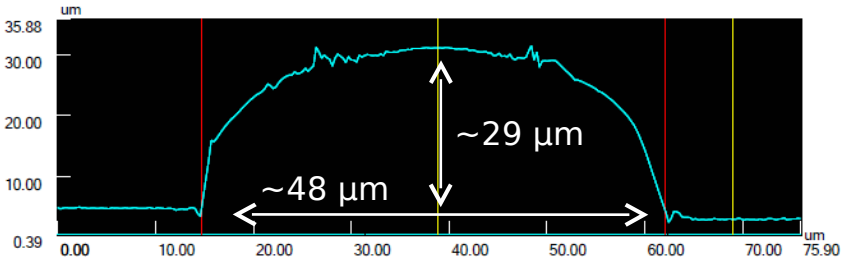
Pac 2.7 Wafer from Pac Tech GmbH

- Two 200-mm Wafers with 275 Chips each
- 5-µm electroless Ni/Au UBM on both
- 40-µm SAC305 Solder Jetting with SB2 on one
- Wafer Sawing & Chip Singulation







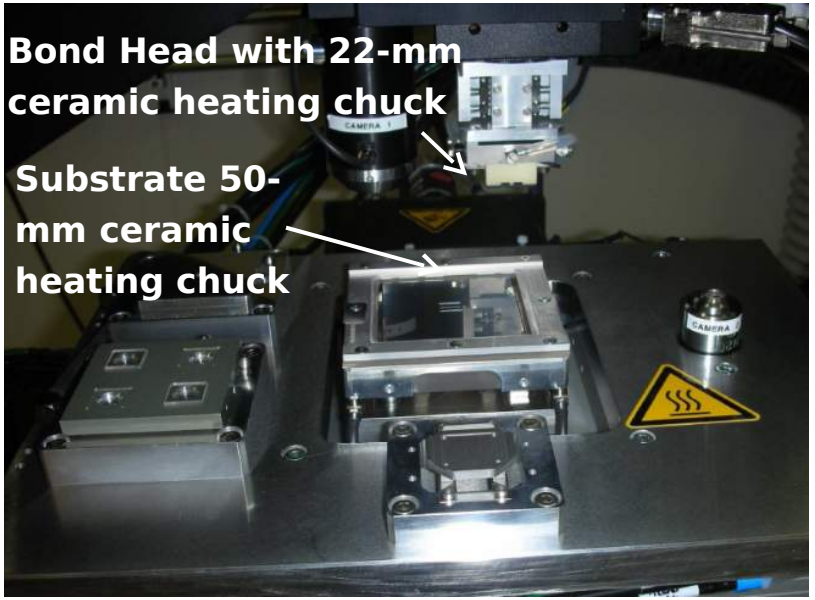


Available since Dec 2010.
Used with 4 machines/vendors.
Only 180 bumps / chip.
Diagnostics difficult.

Bump bonding tests with Kadett at SET

Flip-Chip Bonder *Kadett* from S.E.T.

High-Accuracy
Placement
&
Semi-Automatic
Device Bonder



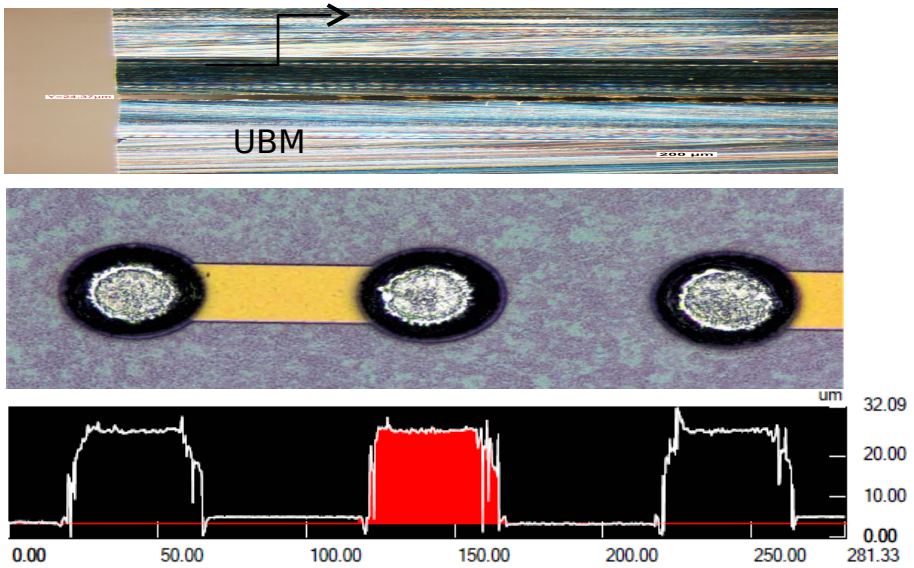
Tacking-Cycle Parameters:

automatic Alignment: diagonal B2B

Chip & Substrate Heating: 25 ... 200°C, 0 ... 20 s

Force Adjustment: 1 ... 6 kg, 5 ... 20 s

example: 1 kg in 5 s @ 163°C in 10 s
sheering test:



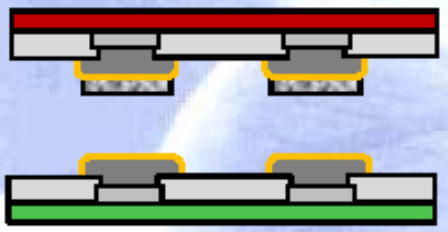
Compression: appr. 8 µm

Shear Force: 1.8 kgf → 55 mN / Bump

Karsten Hansen, DESY FEC

Laser flip-chip bonding

1) Pickup Die & Align
(±5 µm)

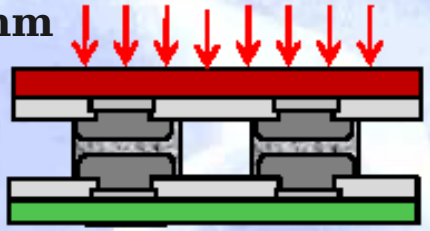


2) Contact
(10kgf)

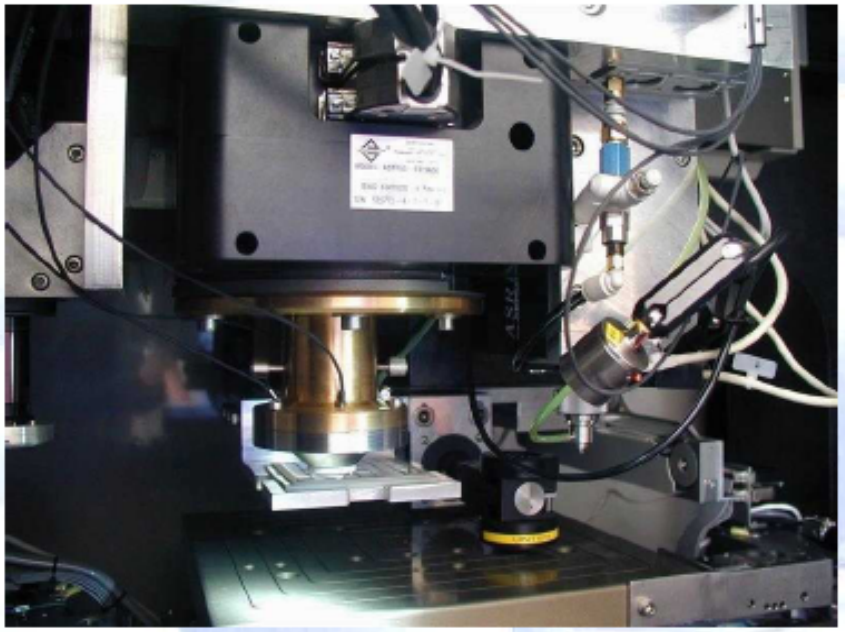
Neodym-dotierter Yttrium-Aluminium-Granat-Laser 1064 nm

3) Laser Reflow

(20msec, $Nd^{+3}YAG$)



LaPlace Assembly System™ PacTech

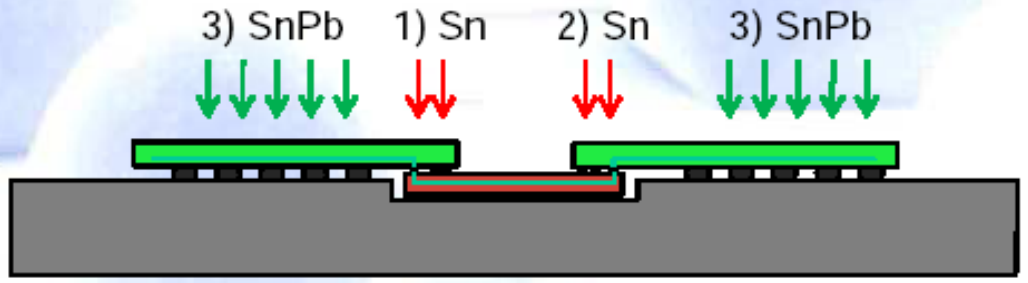


Placement accuracy: +/- 15um: 3000 - 5000 UPH
Placement accuracy: +/- 10um: ~2000 UPH
Placement accuracy: +/- 5um: ~1000 UPH
Placement accuracy: +/- 2.5um: ~500 UPH

units per hour

Laser based assembly allows localized heating:

- Selective to individual die
- Energy localized to bumped areas
- Ability to differentiate between solder alloys
- Low stress
- Minimizes IMC (time/temp)



Mp SnPb = 183°C Mp Sn = 232°C

PacTech
publication 66
Nov 2009

Pac Tech: SB2 Jet

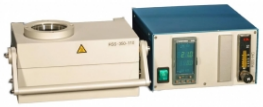
Solder Ball Placer:
pre-formed balls are placed sequentially at 6-7 Hz
fused by laser heating
30 µm balls being certified, 40 µm ordered for test.

SET: FC 150 Flip-chip bonder

Industry standard, expensive, slow.
For placing and re-flow heating. Used at IZM.

SET: Kadett K1

Unitemp: RS-350-110



PSI design: cheapest, slow.
no > 50 mm heating chuck available.
Tacking Tests completed on small samples:
> 0.6 g/ball @ 155°C for chip & substrate.
Re-flow tests completed: OK.

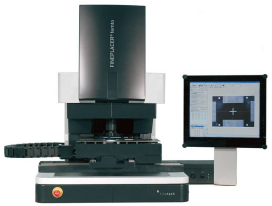
Pac Tech: Laplace

RFA 300M

Reflow Oven RFA 300M

Novel Industry Standard: medium price
laser-assisted, fast.
Tacking Tests completed:
low force with chip at 195°C for 1s.
Reflow Tests completed: OK.

Finetech: FINEPLACER femto

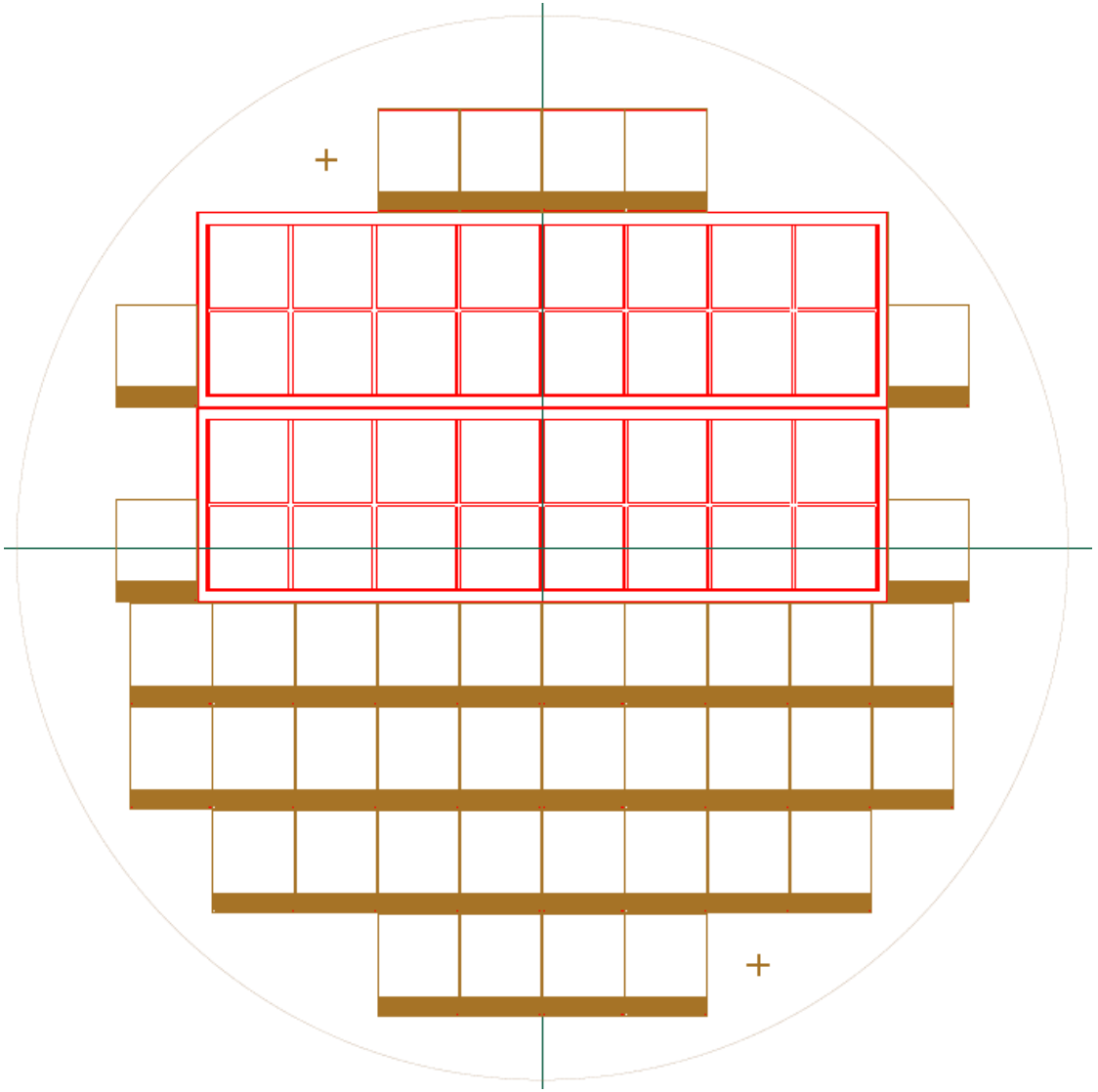


Novel FC 150 competitor: medium price.
Placing and re-flow heating, low-force, fast.
Tacking / re-flow tests under way.

New test structures for bump bonding

- Designed by I. Diehl, DESY FEC:
  - Contact chains with 160 bumps, sensor and ROC geometries.
- Idea:
  - Measure electrical continuity on external pads,
  - Get statistics in the ‰ range.
- Ordered at CIS Erfurt:
  - 100 mm silicon substrate, 400 µm thick, 20 wafers.
  - 2 masks: one metal layer, one passivation layer
  - pad metalization AlSiCu, under bump metal Ti-Ni-Au.
  - delivery now promised for end of May.
- At PacTech:
  - Thin some wafers to 175 µm or less.
  - Deposit 40 µm bumps on the sensors, dice wafers.
  - Flip chip bonding.

New test structures for bump bonding



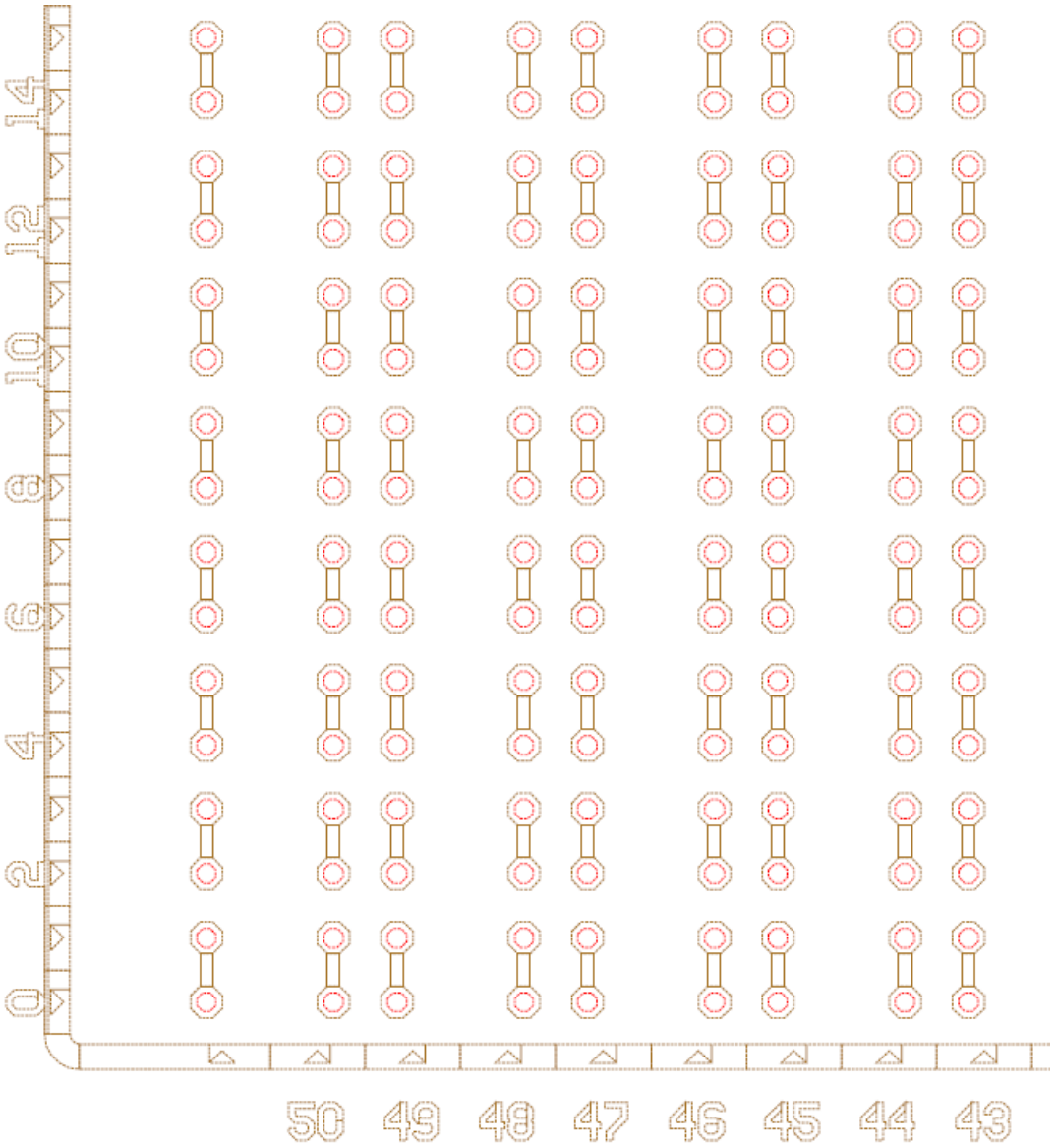
100 mm wafer

2 CMS pixel sensor structures

40 ROC structures

Inge Diehl, DESY FEC

New test structures for bump bonding

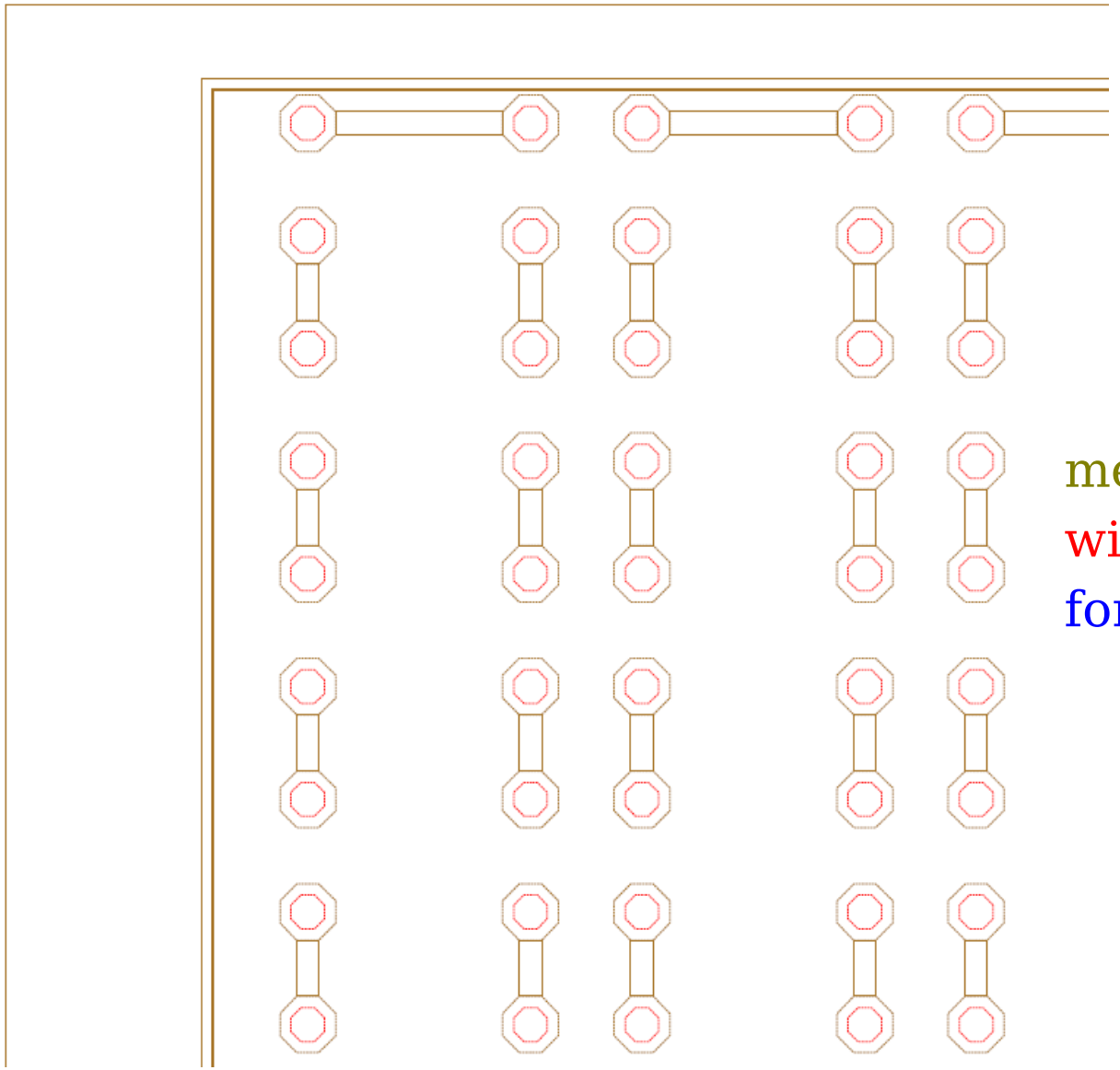


pixel sensor structures

these will receive the bumps

Inge Diehl, DESY FEC

New test structures for bump bonding

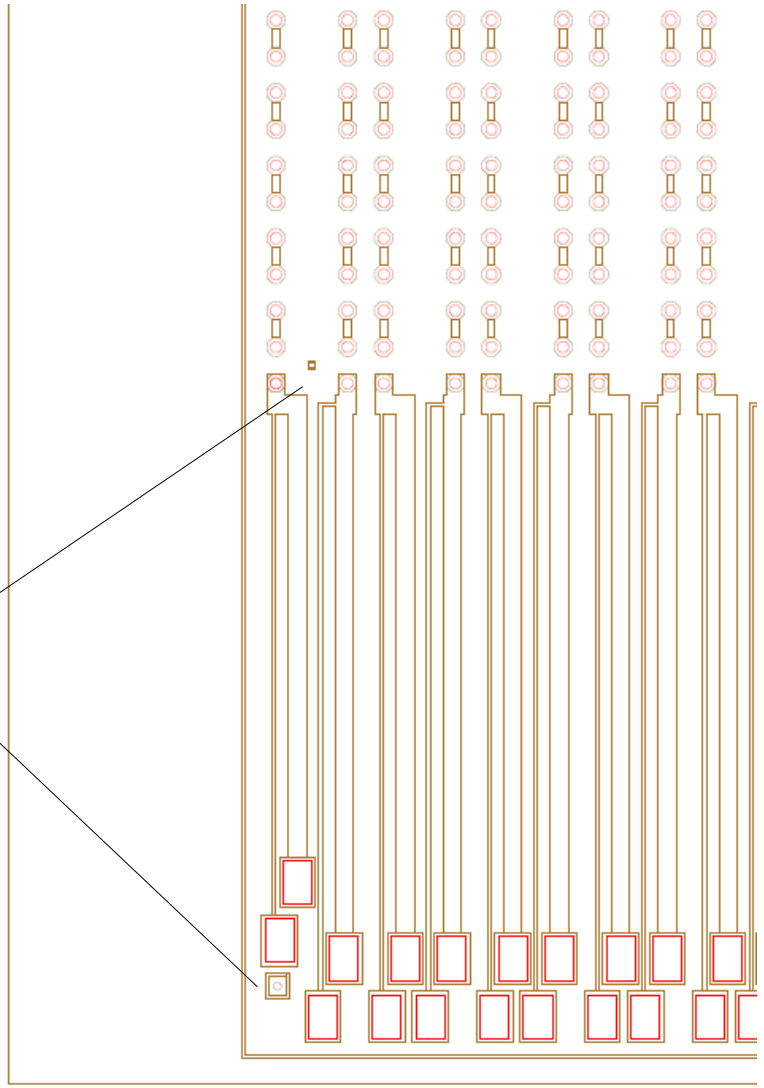


double-column chain
pixel chip structures

metal pad 50 µm Ø
window in passivation 30 µm
for 40 µm Ø bumps

Inge Diehl, DESY FEC

New test structures for bump bonding



pixel chip structures

alignment marks

test pads for 4-point I-V measurement

Inge Diehl, DESY FEC