IEEE SW Test Workshop
Semiconductor Wafer Test Workshop

Luca Cecchetto
STMicroelectronics

Mechanical Simulation of Probing on SMART POWER POA devices

June 8 to 11, 2008

San Diego, CA USA

Authors

- **L. Cecchetto, L. Zullino, R. Vallauri, L. Cerati, A. Andreini**
  - STMicroelectronics
- **S. Lazzari, R. Vettori, C. Albini**
  - Technoprobe S.p.A.

Table of contents

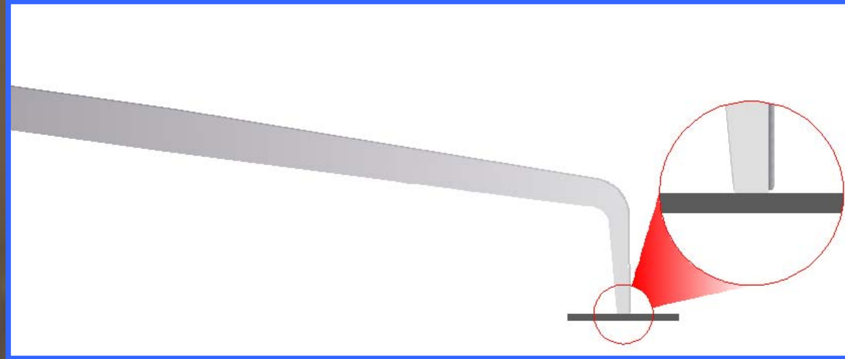
- Purpose and introduction
- Mechanical Simulation approach and results
  - 2-D: stress induced by EWS process
  - 3-D: Pad Over Active (POA) behavior under EWS stress
- Simulation-driven needles development
- Future improvements and conclusions

Table of contents

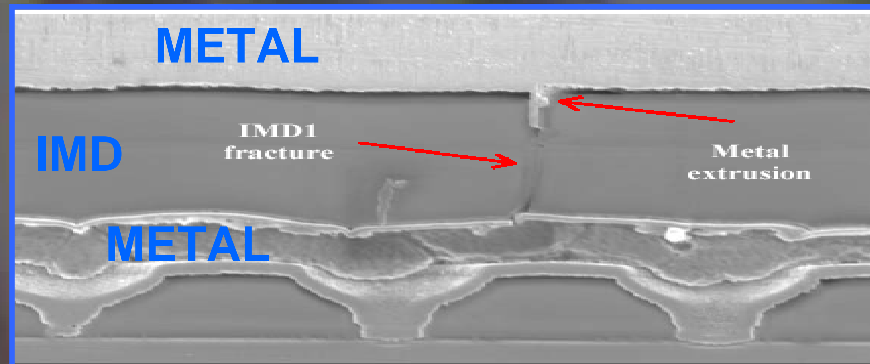
- **Purpose and introduction**
- Mechanical Simulation approach and results
  - 2-D: stress induced by EWS process
  - 3-D: Pad Over Active (POA) behavior under EWS stress
- Simulation-driven needles development
- Future improvements and conclusions

Purpose of the work

- **Validation of EWS simulation** approach in order to:
  - **Evaluate probing equipment behavior** and stress conditions



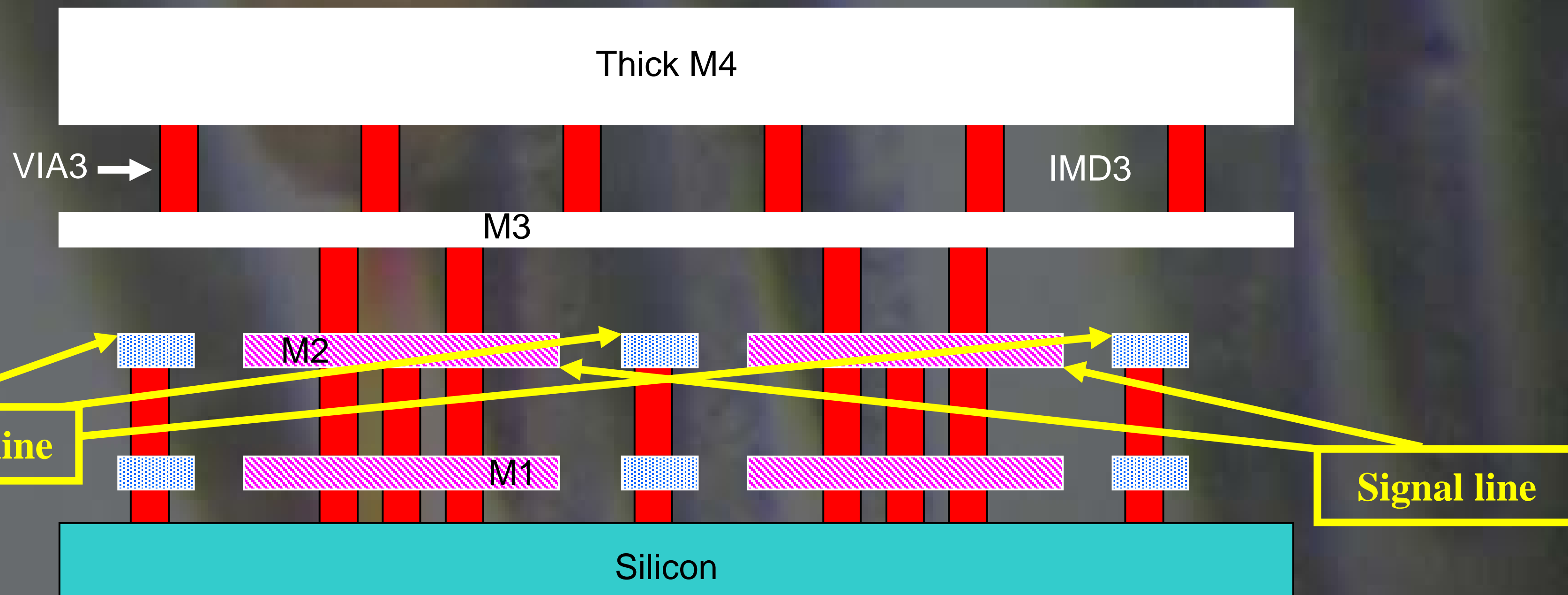
  - **Evaluate POA** critical regions



  - **Provide guidelines** for robust design

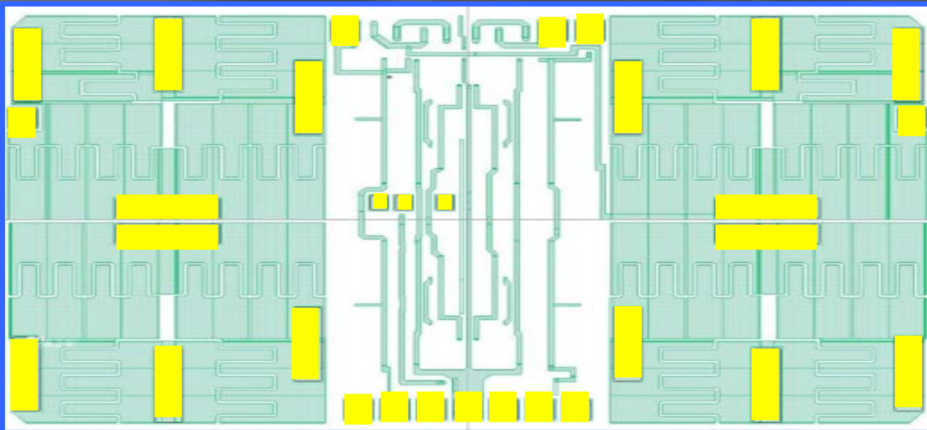
POA description

- Pad Over Active is a pad with active circuitry under itself:
  - **Upper two metal levels** must be shorted together
  - **At least two metals at different voltage** are present under the pad



Smart Power ICs characteristics

- Smart Power ICs are characterized by **high current regimes** (>1A)
- Specific needs to handle these current levels:
  - **Thick top metal level**
  - **Wide probes & bonding wires**
- POA implementation may be critical due to mechanical issues


Layout top view with highlighted pads

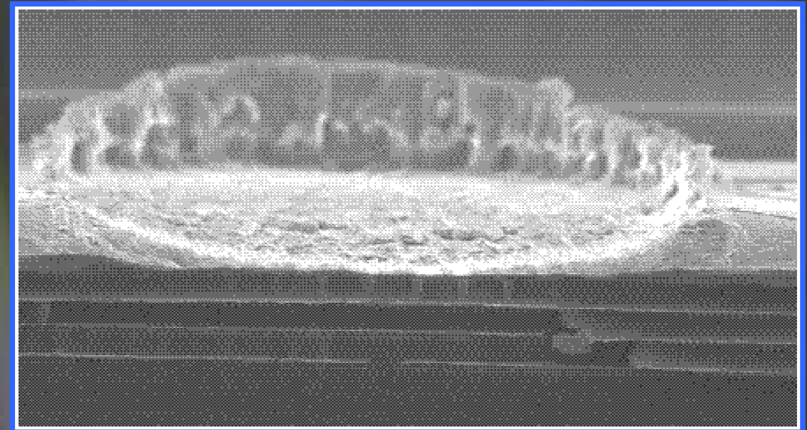

Cross-section of POA after EWS

Table of contents

- Purpose and introduction
- Mechanical Simulation approach and results
  - 2-D: stress induced by EWS process
  - 3-D: Pad Over Active (POA) behavior under EWS stress
- Simulation-driven needles development
- Future improvements and conclusions

Simulation approach

- **Probes behavior and POA structural robustness evaluated by mechanical simulations**

- **Targets**
  - **Reproduction of tip/pad surface contact**

  → 2-D model implemented

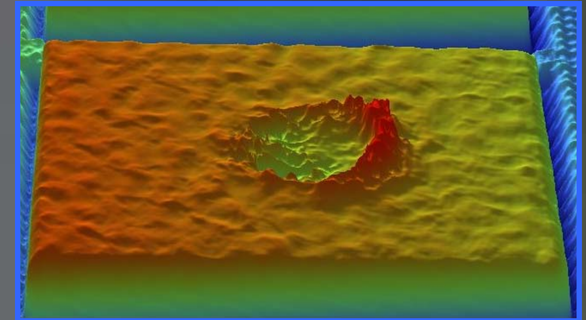
  - **Evaluation of stress propagation in intermetal dielectric (IMD) of POA structures**

  → 3-D model implemented

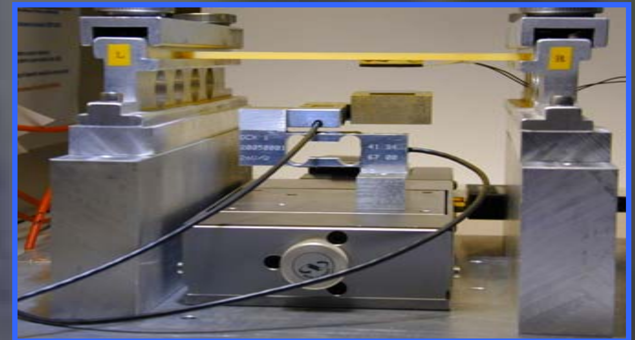
Validation procedure for simulations

Main parameters for validation of simulated data:

- **Probe mark length**
  - Measured by an optical profilometer



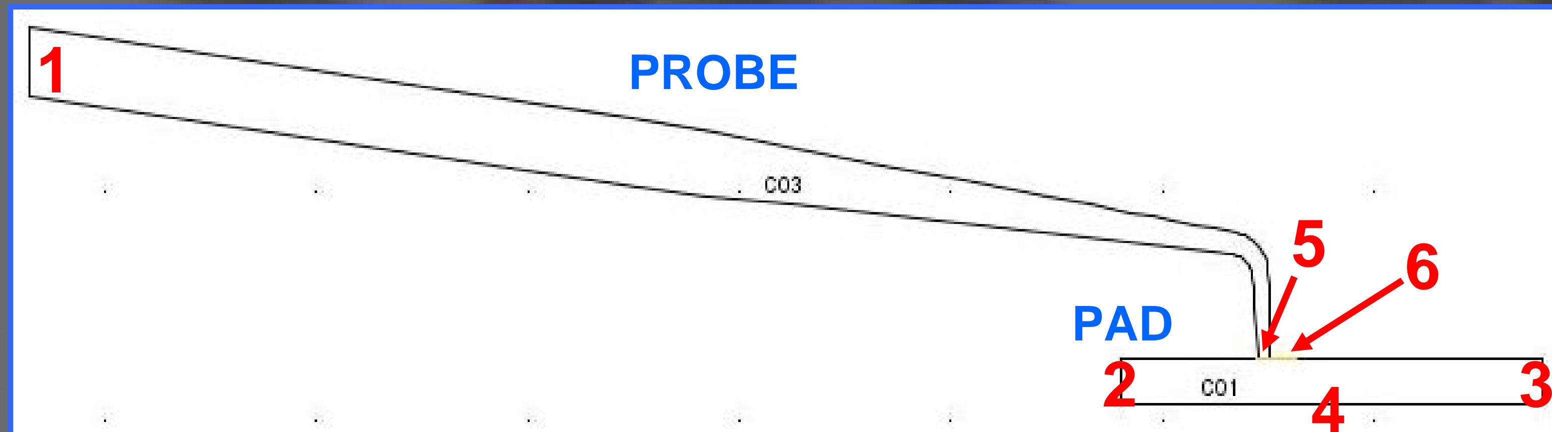
- **Horizontal and vertical tip-pad contact forces**
  - Measured by two force transducers



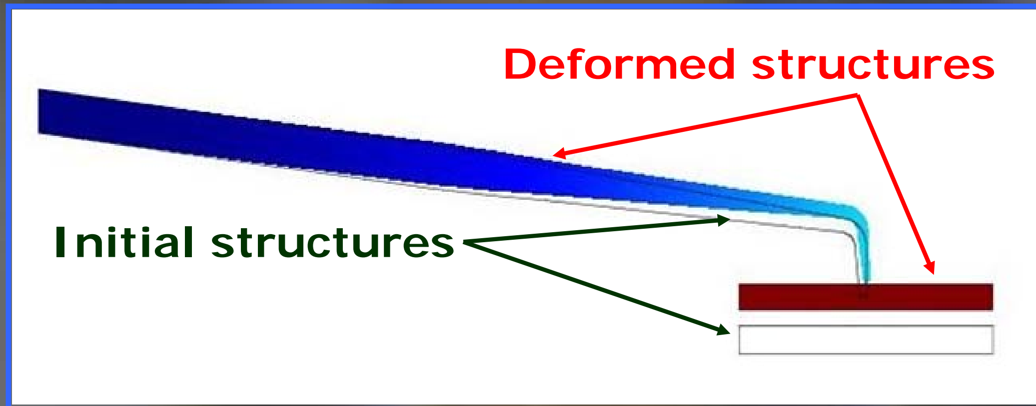
- **Stress in inter-metal dielectrics**
  - SEM analysis after delayering of probed wafers

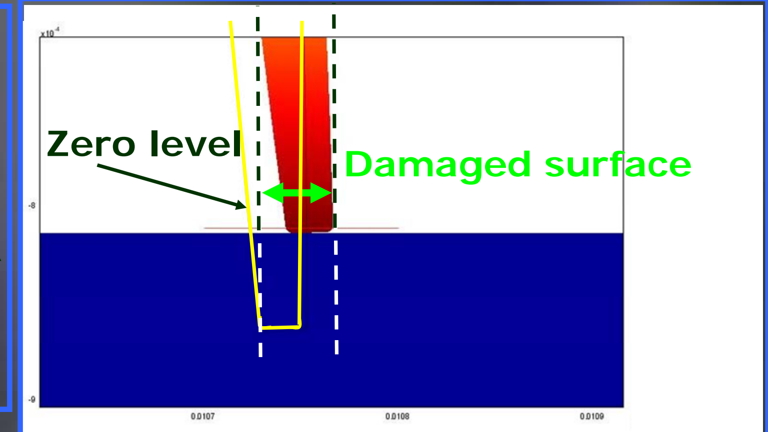
2-D modeling

- **Structure materials**
  - Probe → WRe
  - Pad → Al
- **Applied constraints**
  - Edge 1 → fixed in both direction
  - Edge 2-3 → fixed in X – direction
  - Edge 4 → moved upward (overdrive)
  - Edge 5-6 → contact surfaces



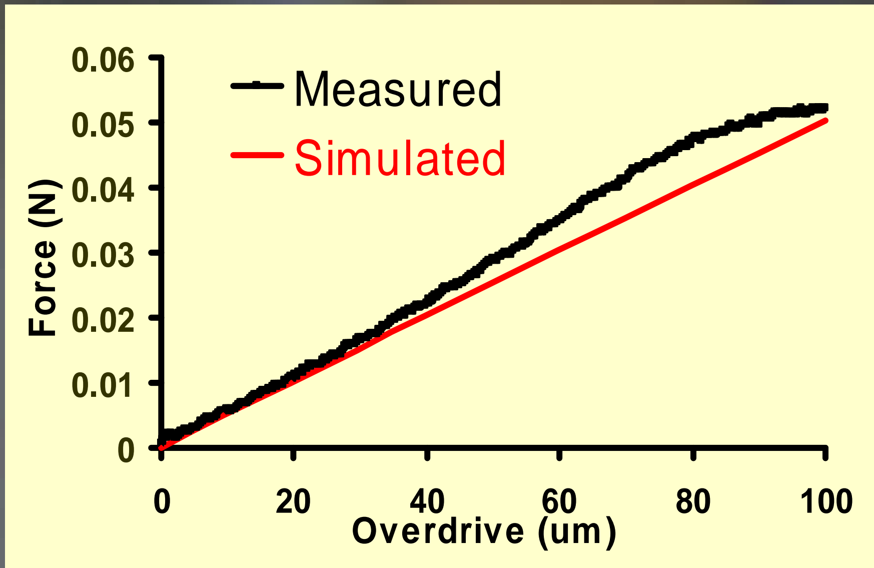
2-D simulation results: probe mark length



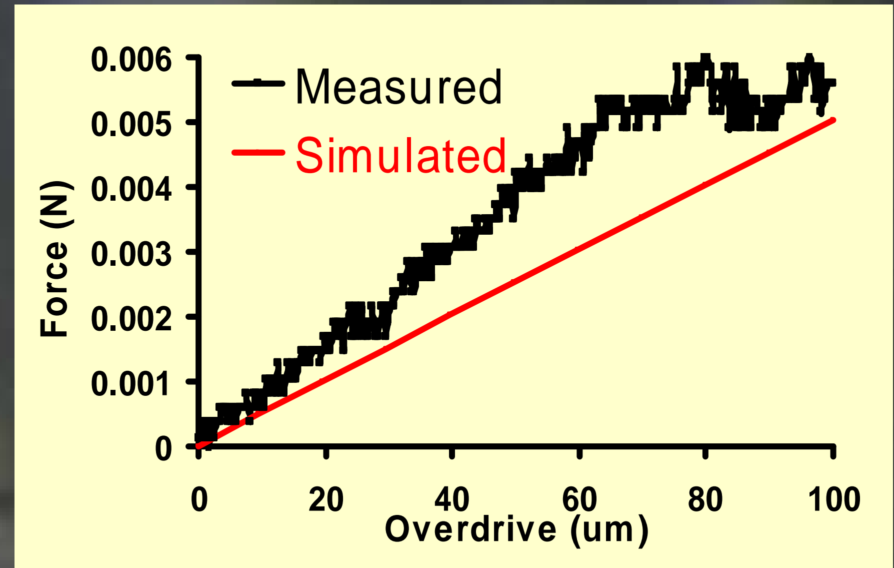


- Overdrive = 75µm
- Probe tip diameter = 24µm
- Tip contact face displacement: 13.47µm
- Probe mark is given by tip contact face plus its displacement: 37.47µm
- Probe mark measured on a wafer: 35.6µm

2-D simulation results: contact forces



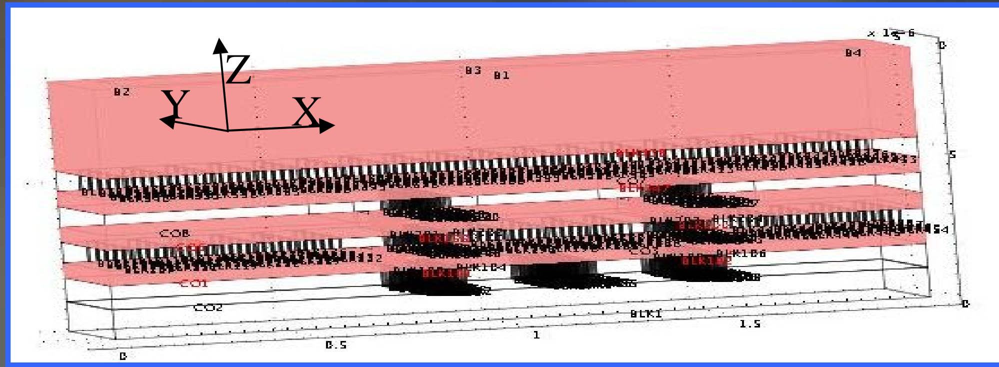
Contact force in **vertical** direction



Contact force in **horizontal** direction

- Simulation: linear rising of the wafer considered (static conditions)
- Experimental: wafer raised up at non-constant speed
- Reasonable agreement obtained
- Some discrepancies can be noticed in the intermediate overdrive region due to different approach

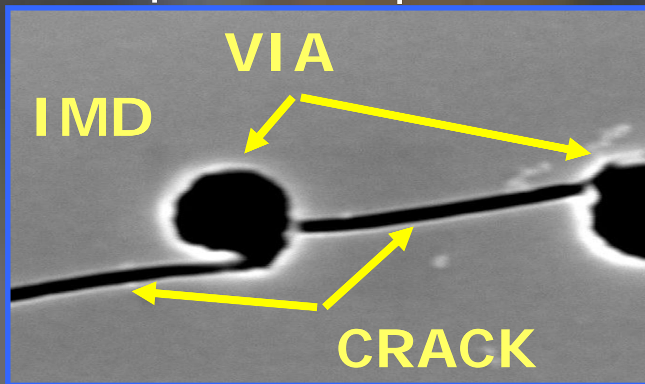
3-D modeling

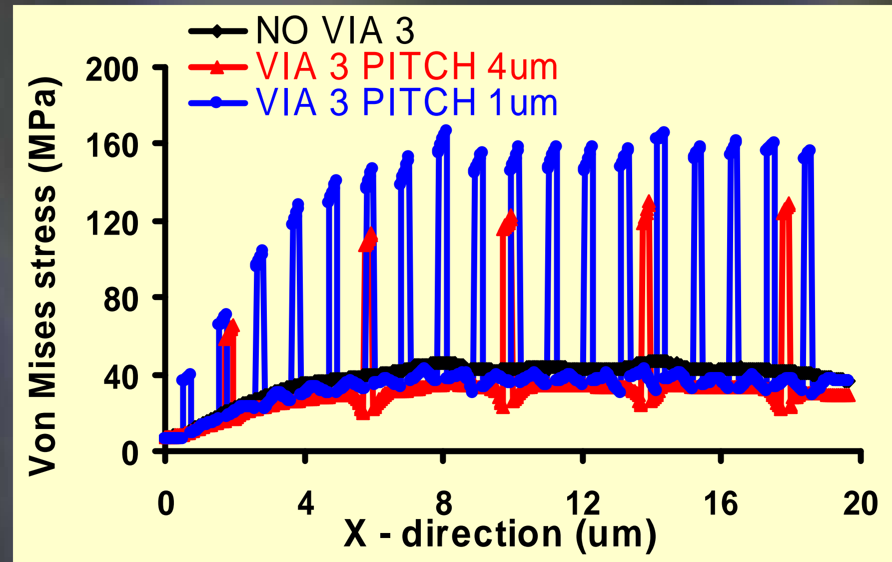


- **Full 3-D pad simulation not feasible**
- Need for simplification strategy:
  - **Pad reduced to a matrix of elementary parts** (exploiting symmetry)
  - **One single element** (~20 x 6μm^2) considered
  - **Simulation constraints**:
    - All lateral surfaces → fixed in X and Y directions
    - Bottom → fixed in all directions
    - Top → pressure in Z and X directions

3-D simulation results /1

- **Three POA structures** considered:
  - Without VIA3
  - VIA3 pitch = 4µm
  - VIA3 pitch = 1µm

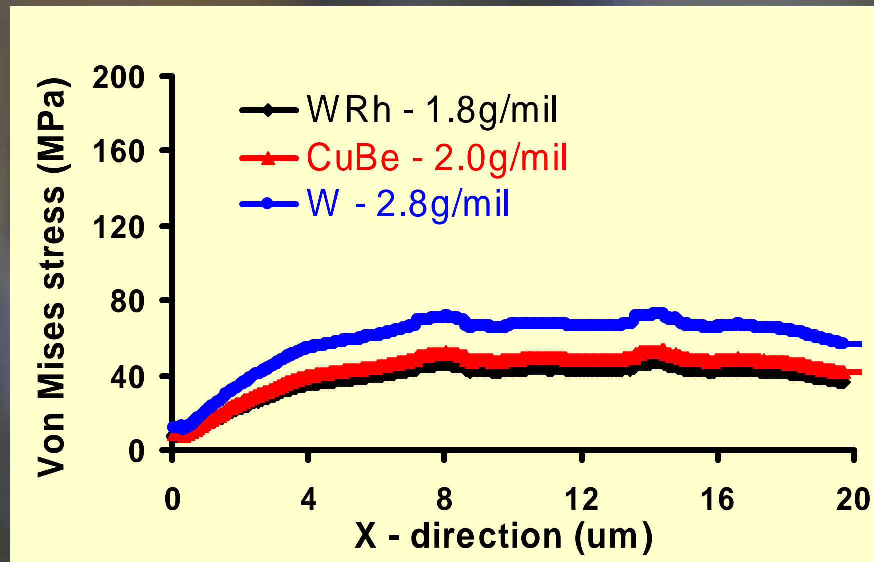




- **Von Mises stress** evaluated along an axis in X direction at the mid-height of top IMD
- **Simulation stress peaks** located at the oxide/tungsten interfaces → **confirmed by physical analysis**
  - **Finer via pitch** induces higher stress peaks
  - **Wider via pitch** reduces local maximum stress

3-D simulation results /2

- **Three probe card** impact on POA structure without top VIA:
- WRh → 1.8g/mil
- CuBe → 2.0g/mil
- W → 2.8g/mil



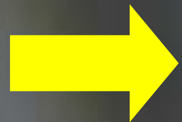
- **Preliminary evaluation of different probe cards feasible at simulation level**

Table of contents

- Purpose and introduction
- Mechanical Simulation approach and results
  - 2-D: stress induced by EWS process
  - 3-D: Pad Over Active (POA) behavior under EWS stress
- Simulation-driven needles development
- Future improvements and conclusions

POA in 0.18μm technology (BCD8)

- **Thinner IMD and metal layers** make more challenging the porting of previous POA structures to new technology node

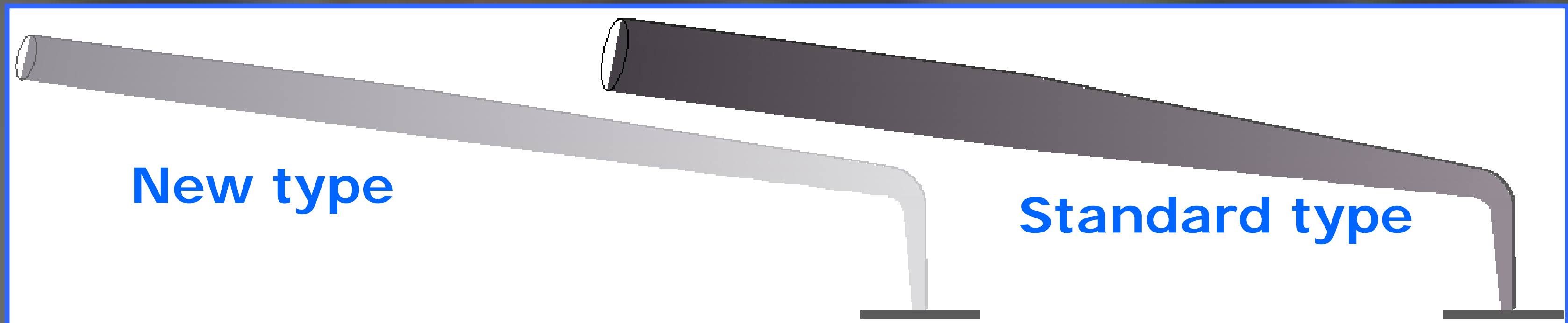


New probe card architecture to be identified

- **Task force built** to solve this issue:
  - **Technology R&D**
  - **EWS R&D**
  - **Probe card supplier**

New needles type

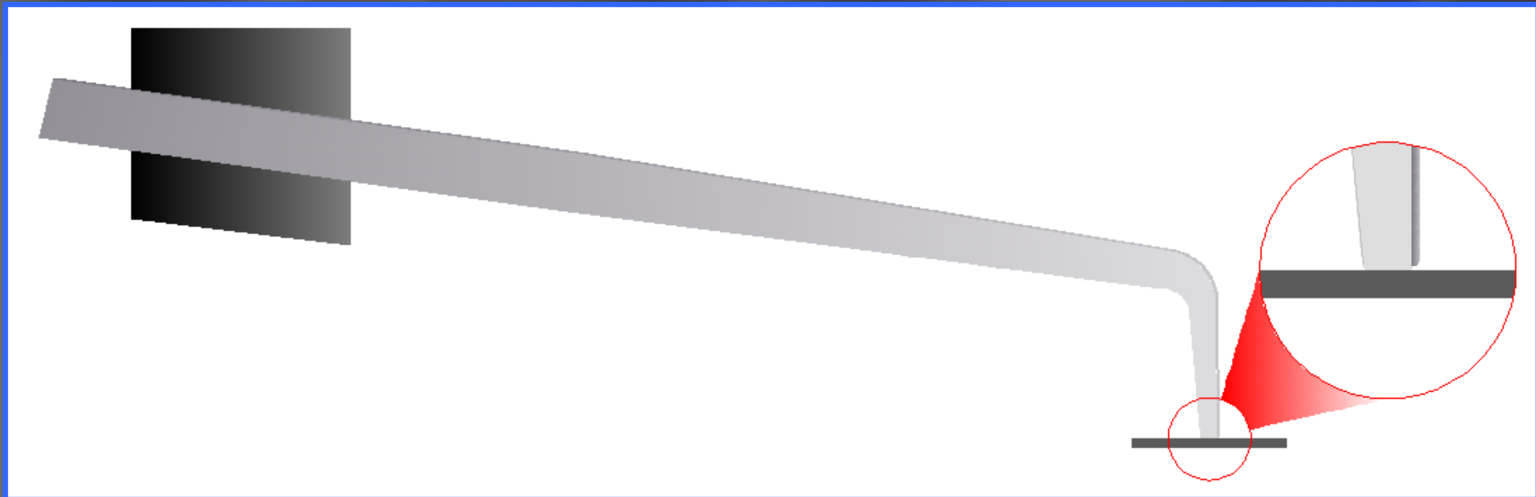
- **New needles** developed to allow:
  - **Better tip/pad contact**
  - **Less contact force**
  - **Wider probing process window**



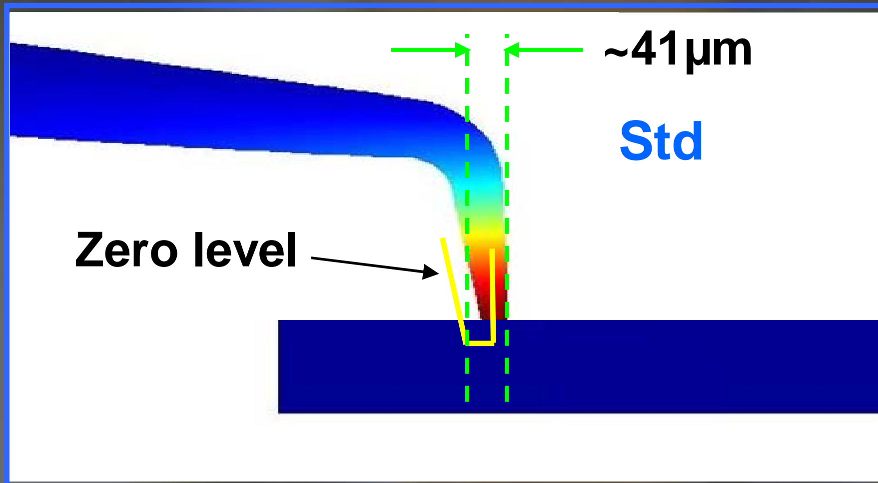
- New needles are characterized by:
  - Thinner body
  - Longer tip

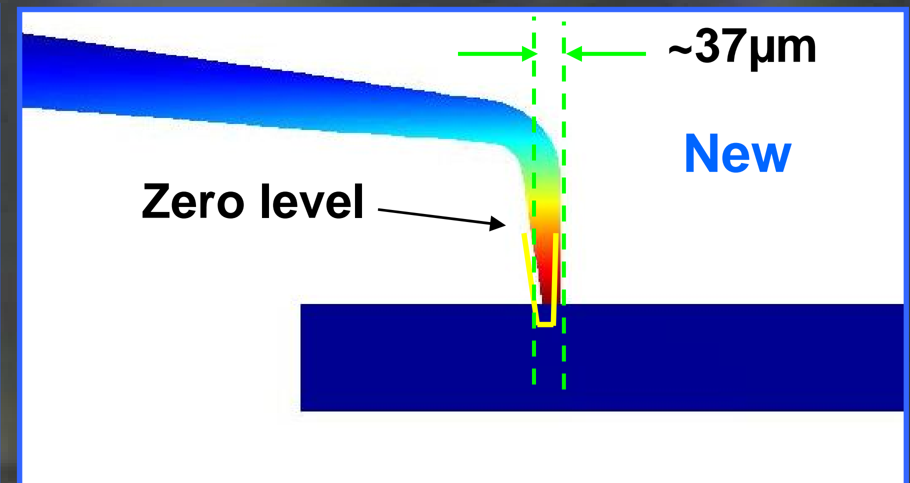
New 2-D modeling

- **Structure materials**
  - Probe → WRe
  - Pad → Al
  - **Ring** → Epoxy



Std vs. New needles: probe mark





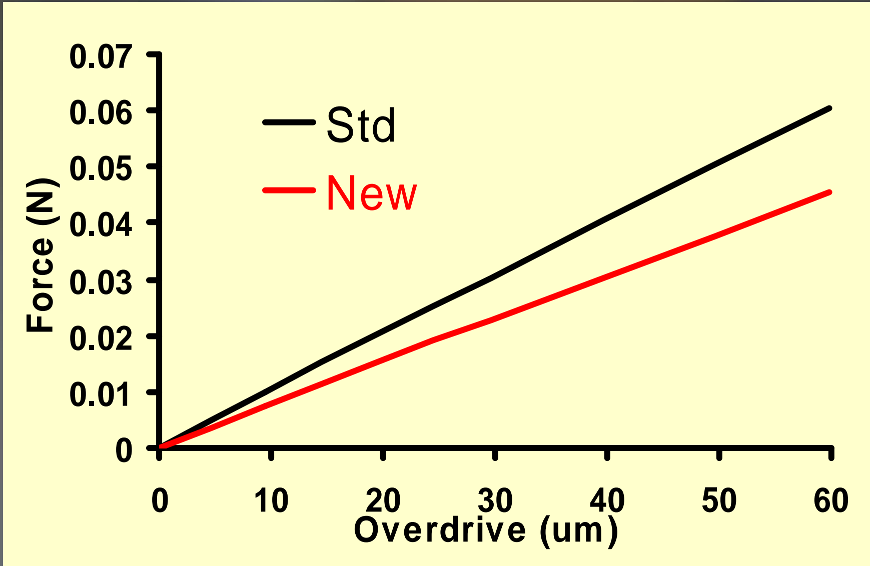
Displacement in X – direction (overdrive 60µm)

Std

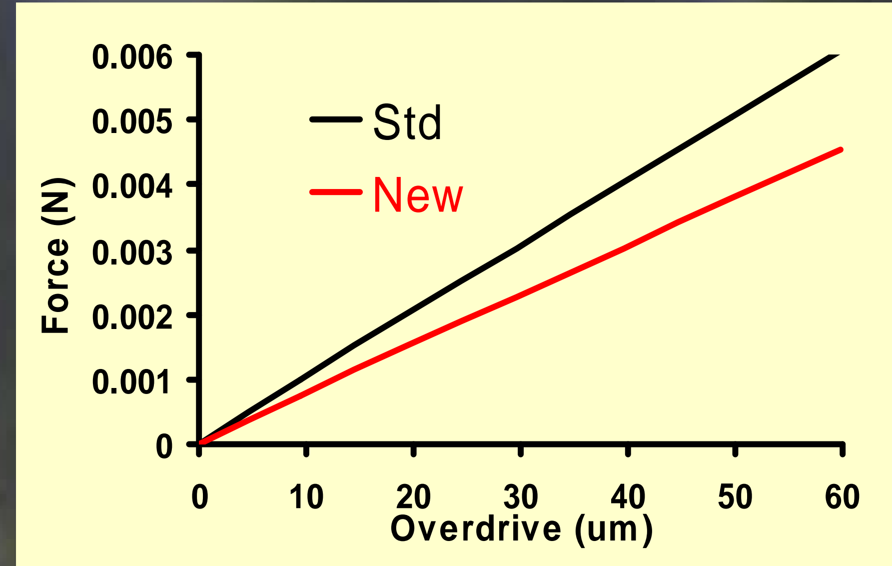
- **Good agreement** at simulation level in both conditions
- **Shorter probe mark length** using new needles

New

Std vs. New needles: contact force



Contact force in vertical direction



Contact force in horizontal direction

- **New needles have less contact force** compared to Std ones
- **Confirmed by physical analysis** on probed wafers:
  - **No cracks in IMD**

BCD8 experimental results

Needles \ TD	4	6	8	10
STD	100%	97.9%	62.5%	28%
NEW	100%	100%	96.8%	31.1%

Mechanical yield (pads without cracks in IMD / total probed pads)*

- **Mechanical yield increased** working simply on needles geometry
- Further improvement: 100% yield @8TD obtained modifying also the pad structure

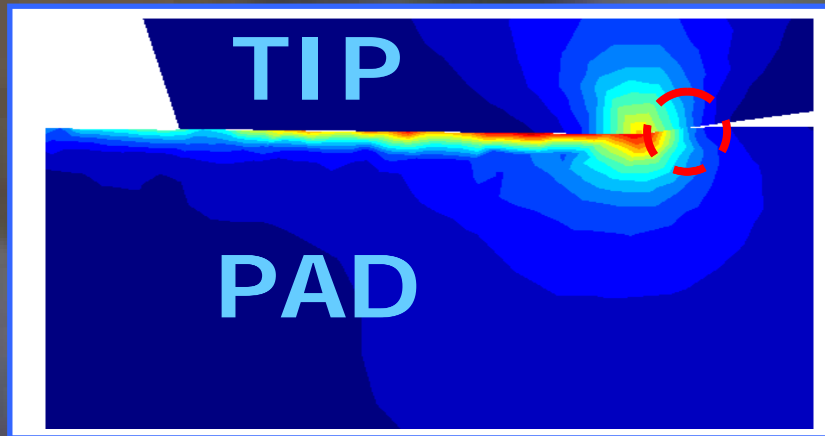
* all pads analyzed by visual inspection after delayering

Table of contents

- Purpose and introduction
- Mechanical Simulation approach and results
  - 2-D: stress induced by EWS process
  - 3-D: Pad Over Active (POA) behavior under EWS stress
- Simulation-driven needles development
- **Future improvements and conclusions**

Improvements

- **Up to now** plastic deformation not taken into account
- Model development running to allow simulation of:
  - **Multiple touchdowns**
  - **Evaluation of temperature influence**



- Slight **metal erosion can be simulated** considering aluminum yield stress level

Conclusions

- 2-D modeling of EWS process developed with **good agreement** between simulated and measured data:
  - Probe mark length
  - Tip/pad contact forces
- Critical points **detected** simulating EWS stress with 3-D model of POA structures
- **POA structures introduced in new technology thanks to guidelines obtained by FEM analysis**
- **Reliable model**: it can be applied in future developments

Acknowledgements

- A special thanks to:
  - **ST Agrate EWS** Engineering Team
  - **Technoprobe** Team
  - **ST Technology R&D** Agrate