Non-Damage Probing and Analysis of ILD Damage at Scrub Marks

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  - Industrial Requirement for Probing Low-k Devices
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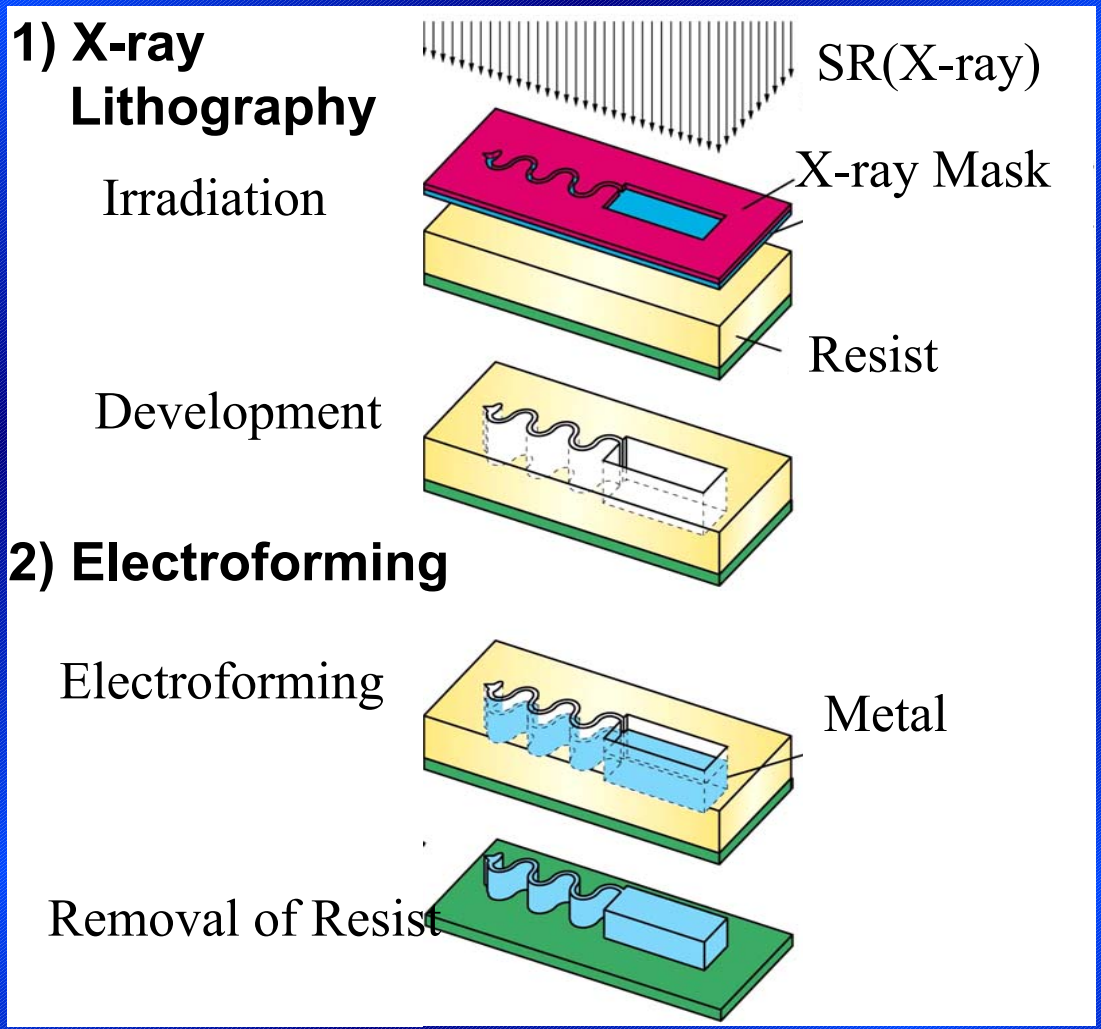
Industrial Requirement for Probing Low-k Devices

- **Low and Stable Load Probing**
  - Low-k materials are more fragile
  - Low and stable probe load is desired to minimize damage to Low-k materials
- **Low and Stable Contact Resistance**
  - High frequency and high power applications require severe contact resistance control
- **Finer Pitch**
  - Roadmap to 100μm pitch requires revolutionary probing approach

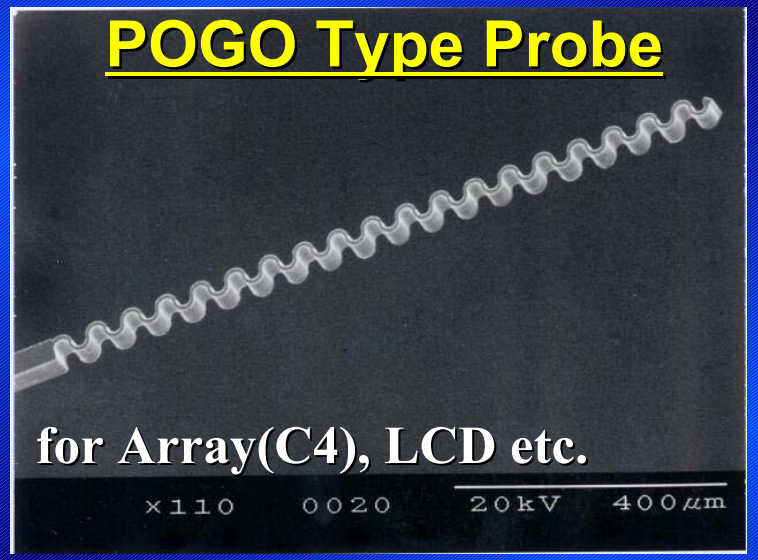
LIGA Process & LIGA Probe

<What is LIGA?>

(Lithographie-Galbvanoformung-Abformung)



POGO Type Probe



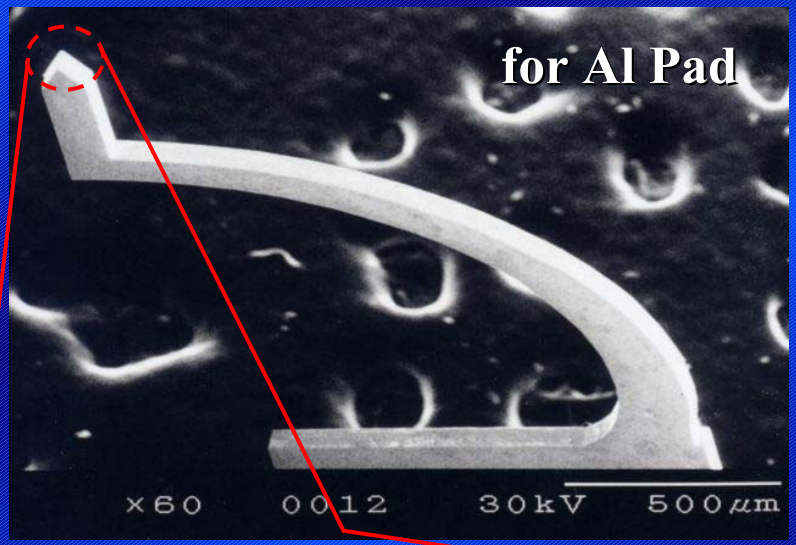
<Advantages>

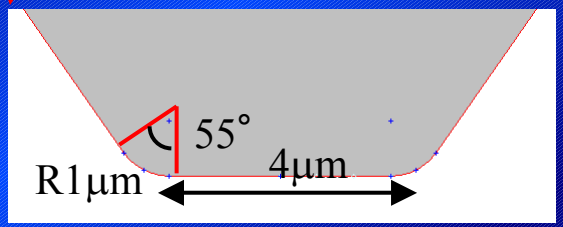
- Little Dispersion of Spring Constant (±15%(3σ))
- Any Form is Possible (Tip/Spring/Support)
- High Hardness/Toughness
- Good Electric Resistance ($1.3 \times 10^{-7} \Omega m$)

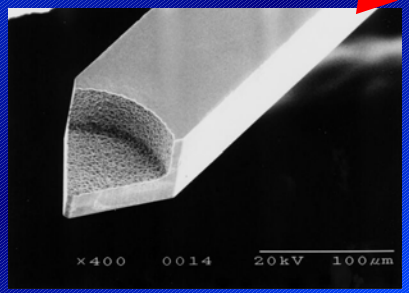
Development of Low-Load Contact Probes

Experiment Condition(1) –Probe Samples-

<Scrub Type Probe>



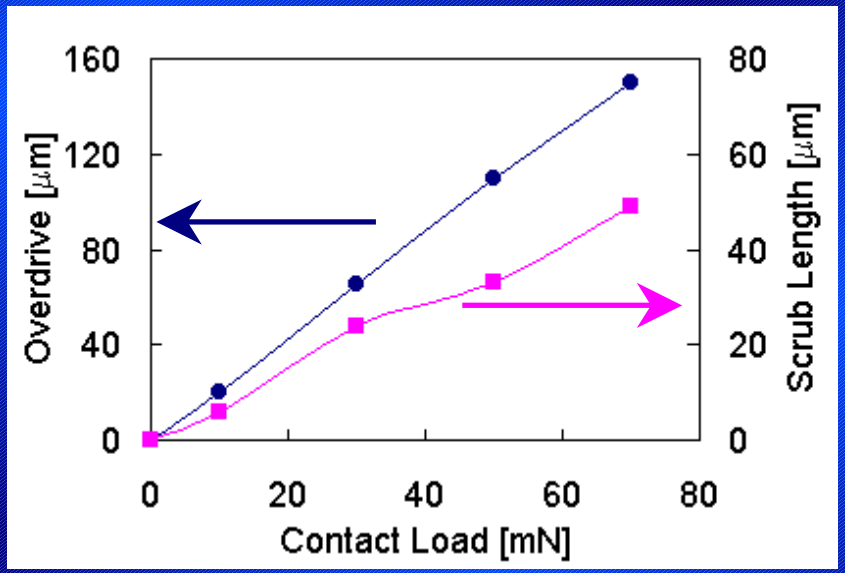




Trapezoidal Tip (μ-EDMed)

<Basic Characteristic>

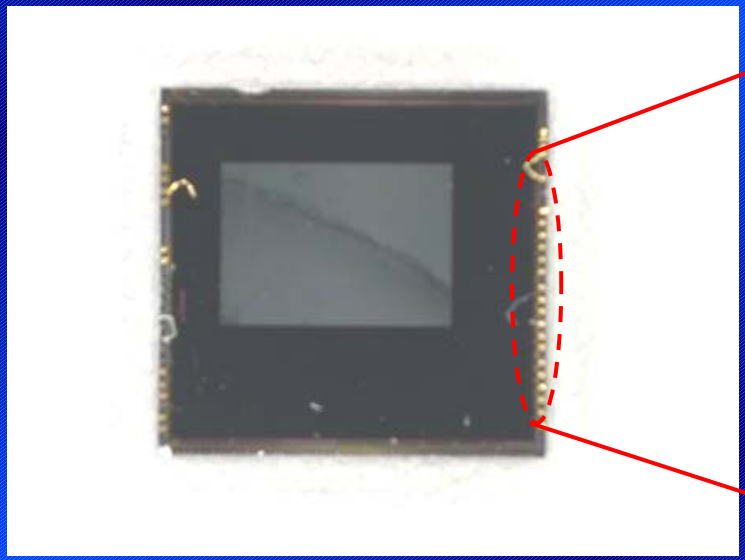
Overdrive, Scrub Length vs Contact Load

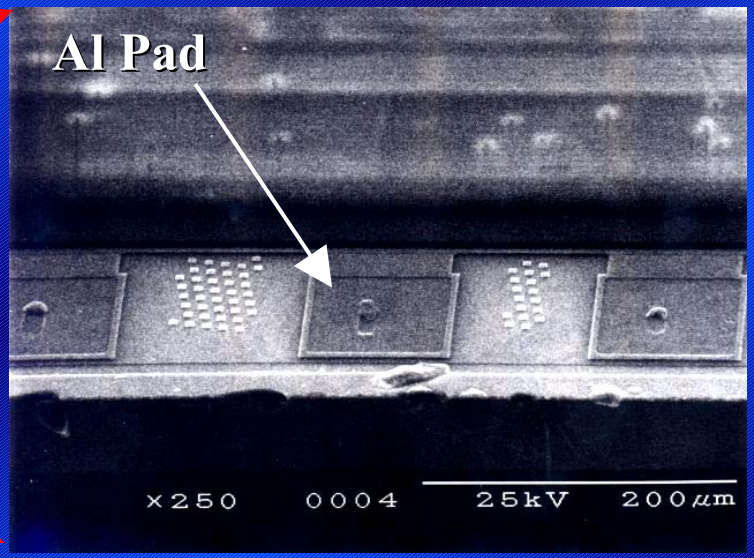


Experiment Condition(2) –ILD Samples-

<CMOS Image Sensor>

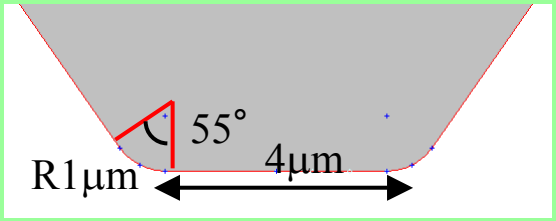
(*Since we couldn't come low-k devices to hand, we chose CMOS image sensor with fragile ILD directly under Al Pads.)

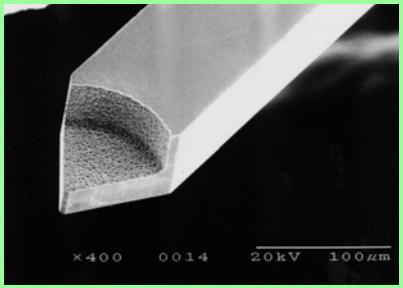




SEM Image of Electrode Pad
(Modulus of ILD : 2.5GPa)

Analysis of ILD Damage(1) –Trapezoidal Tip-

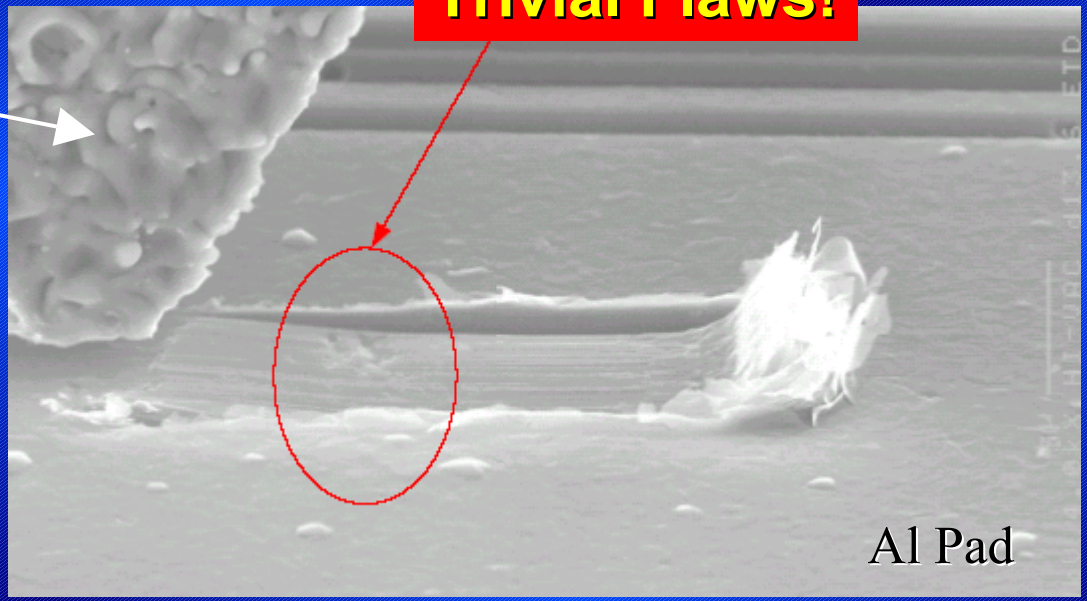




Trapezoidal Tip (μ-EDMed)

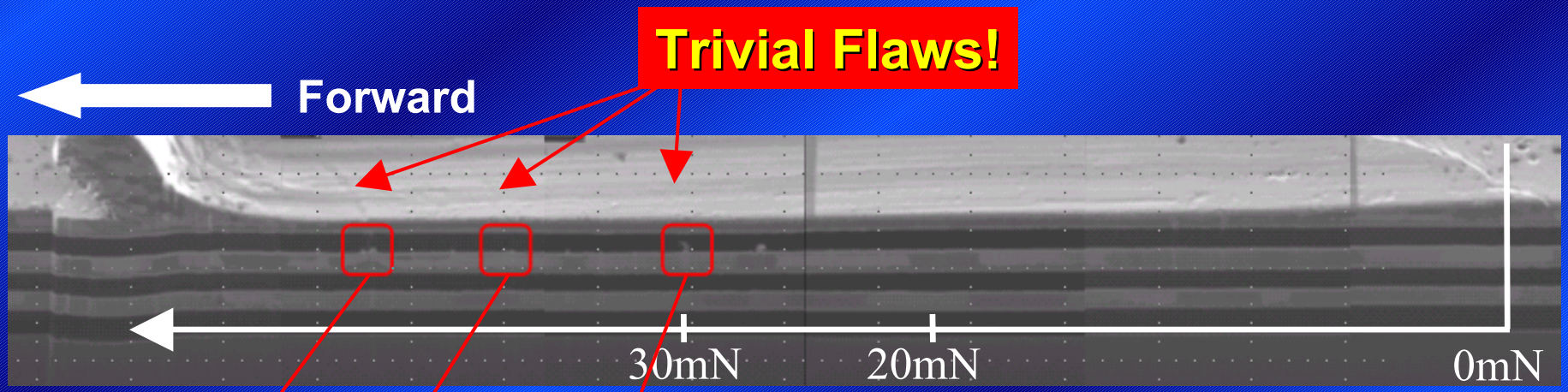
Trivial Flaws!

Probe Tip

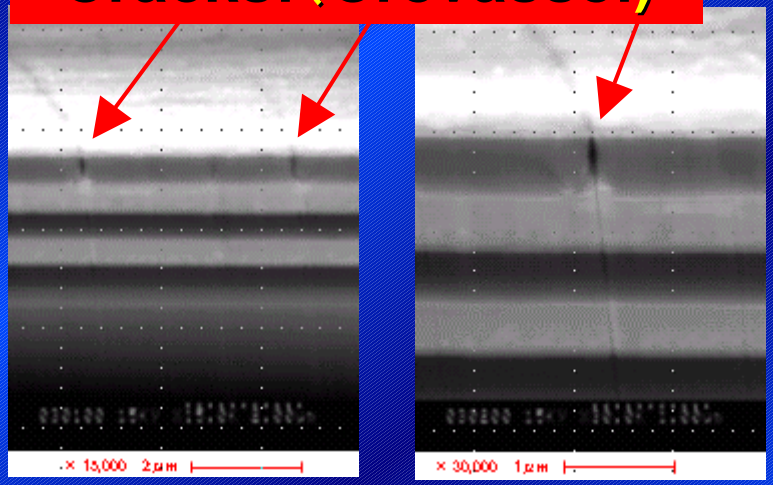


Analysis of ILD Damage(2) –ILD Section Observation-

SIM Image of ILD Section after Probing



Cracks!（Crevasse!）



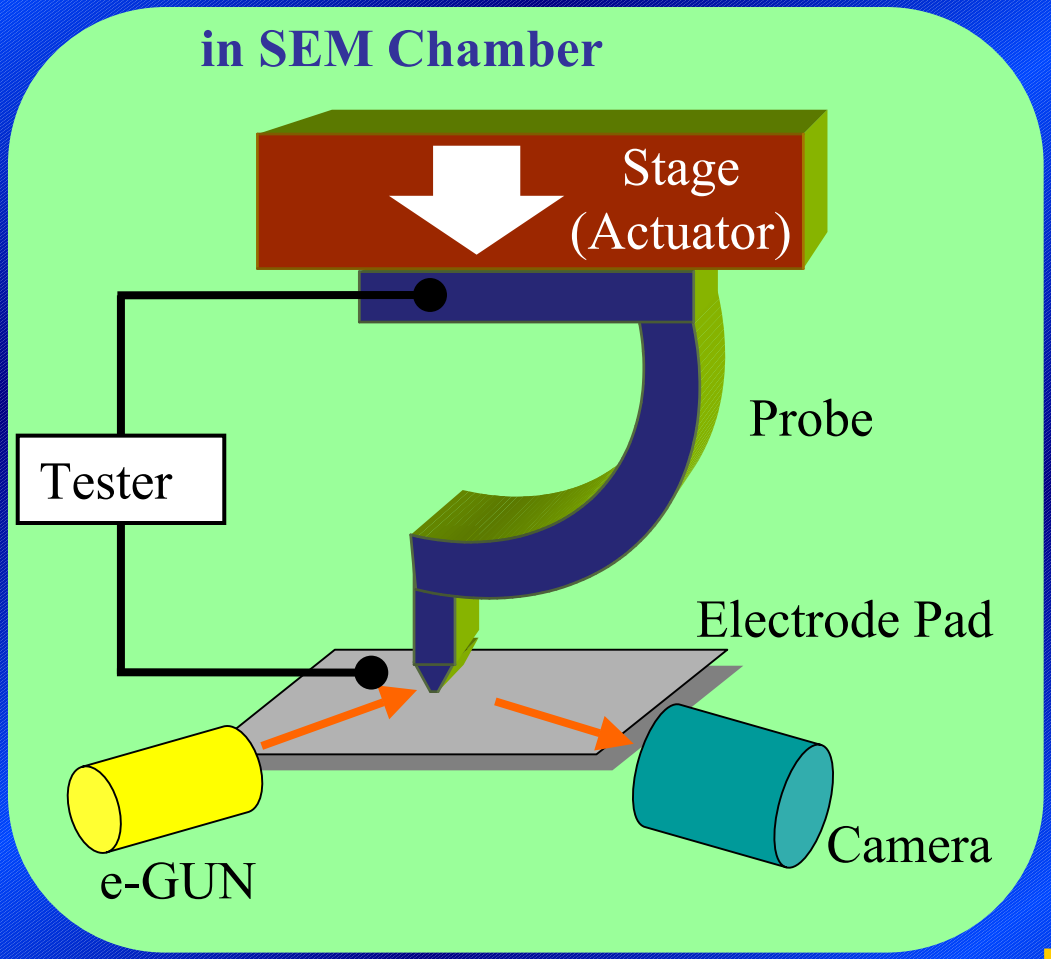
High Contact Resistance

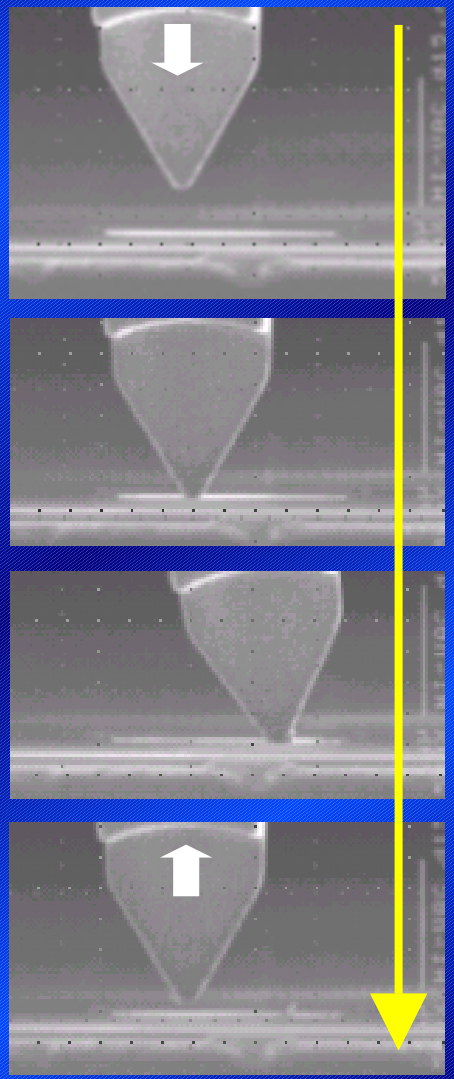
Non-Damage Probing Range (NDPR) : Very Narrow!

How Do Cracks Occur?

Outline of Analysis of Scrub Action

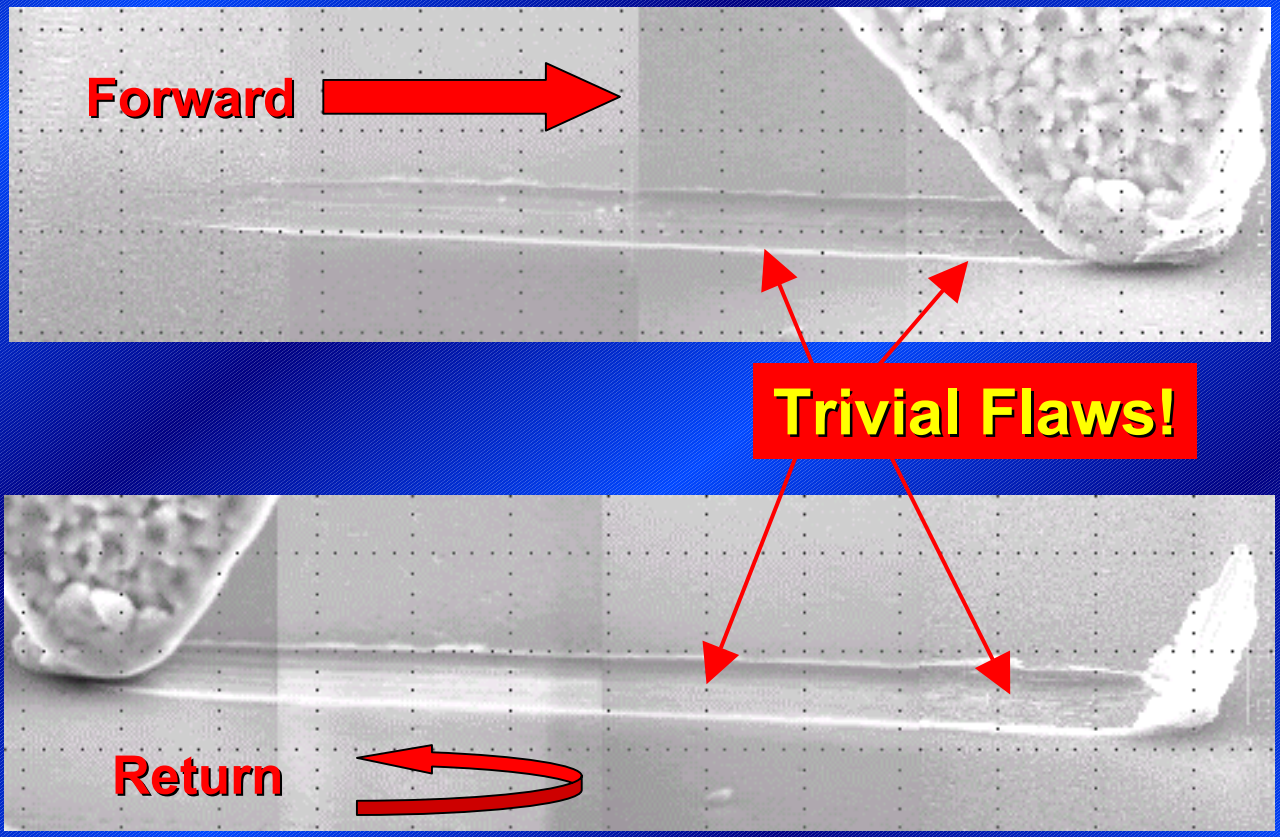
Conceptual Figure of Analysis of Scrub Action





E-SEM Analysis of Scrub Action

Analysis of ILD Damage(3) –How Do Cracks Occur?-



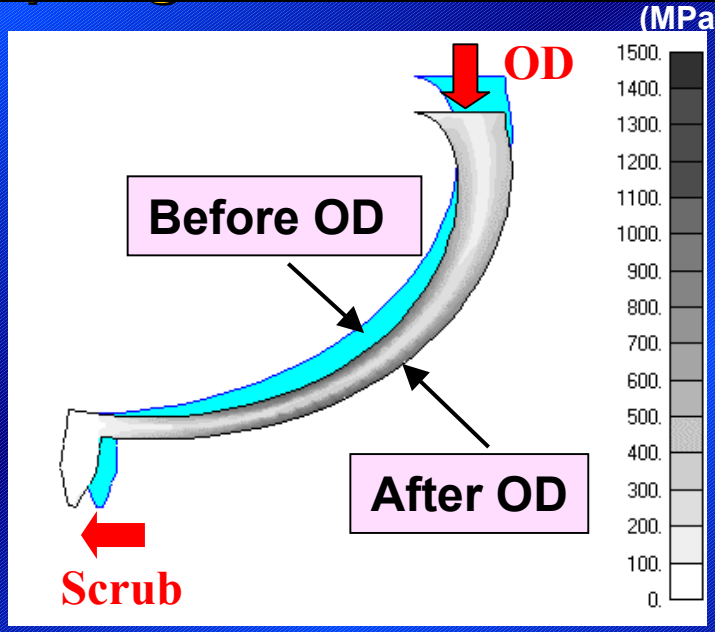
Forward Scrub Only

After Return

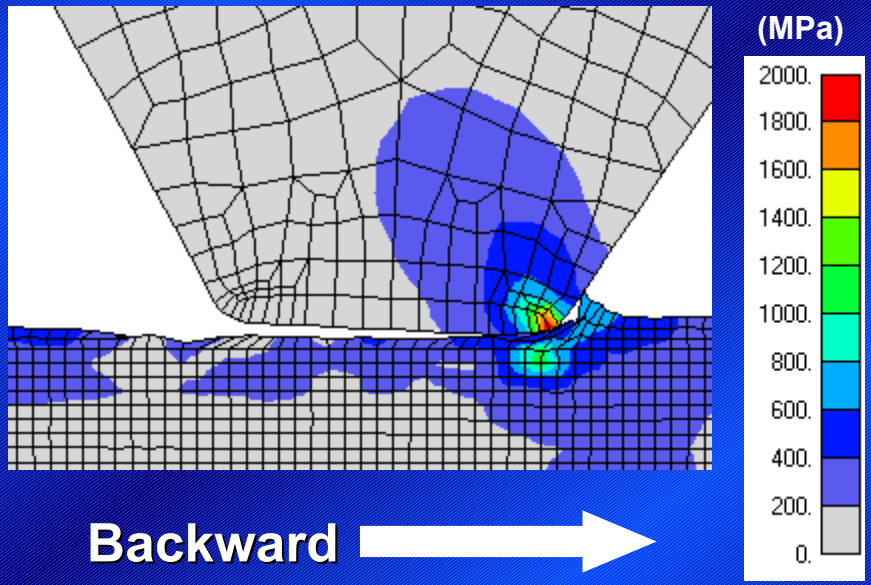
Trivial Flaws on Scrub Surface :
- Occur in Forward Scrub Action.
- Don't Increase in Backward Scrub Action.

Simulation Technology of LIGA Probe

<Spring-action Simulation>



<Scrub-Action Simulation>

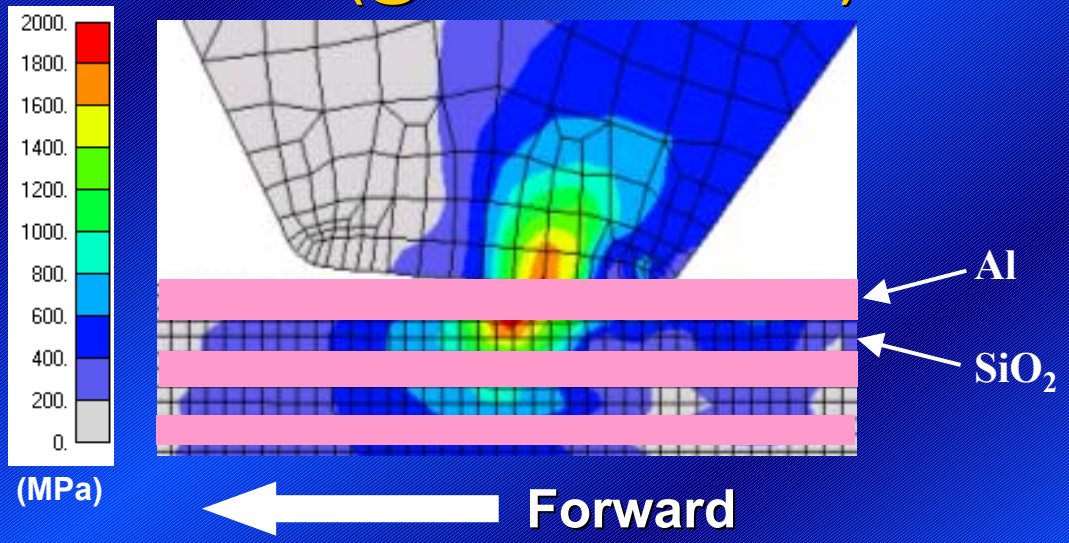


It is Possible to :
- Simulate Scrub Action and Estimate ILD Damage .
- Design Low-load Contact Probes for Low-k Devices.

Simulation of ILD Damage(1) -Trapezoidal Tip-

<TD Model on ILD>

Mises Stress(@Maximum Stress)



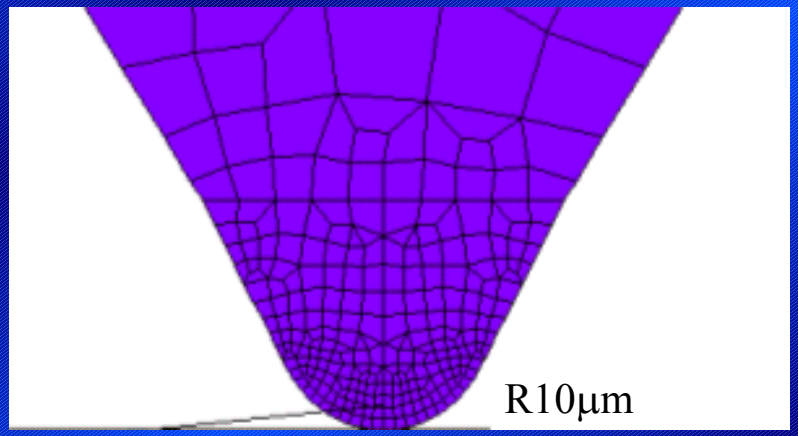
- Maximum Stress Occurs at Forward Scrub Action.
- Rear Edge of Probe Tip Makes Strong Stress to ILD.

It is Suggested that Contact Probes for ILD Shouldn't Have Sharp Edge at Tip.

Development of Low-Load Contact Probes

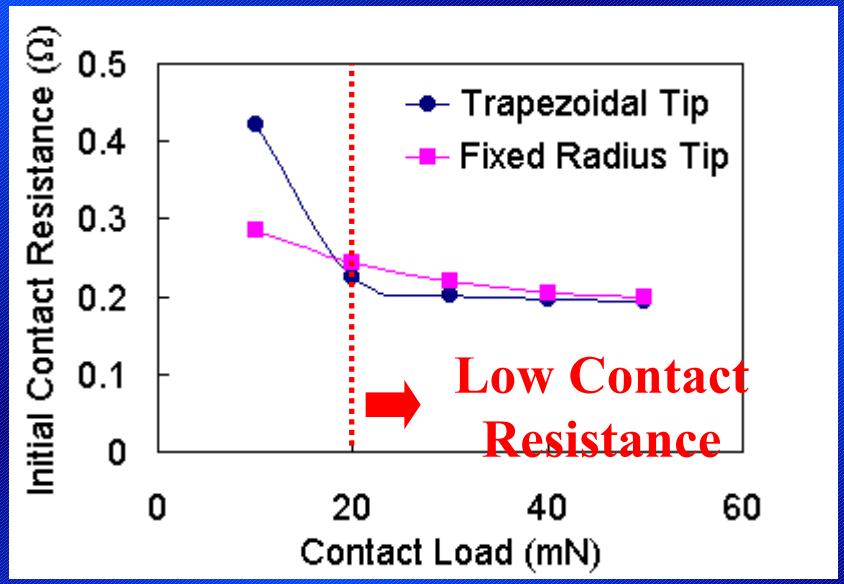
<New Probe Tip Design>

Fixed Radius Tip as a Simple Model
(Spring Design isn't Changed)



<Initial Contact Resistance>

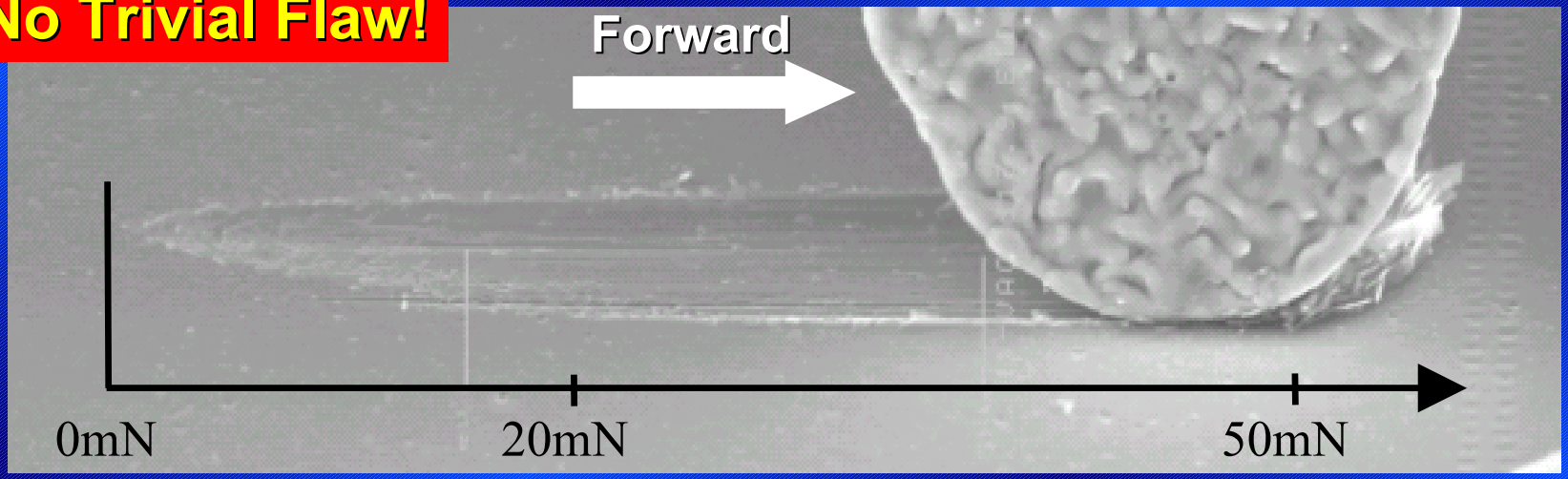
(for Al Pad)



Initial Contact Resistance is Equal.

Analysis of ILD Damage(4) –Fixed Radius Tip-

No Trivial Flaw!



High Contact Resistance

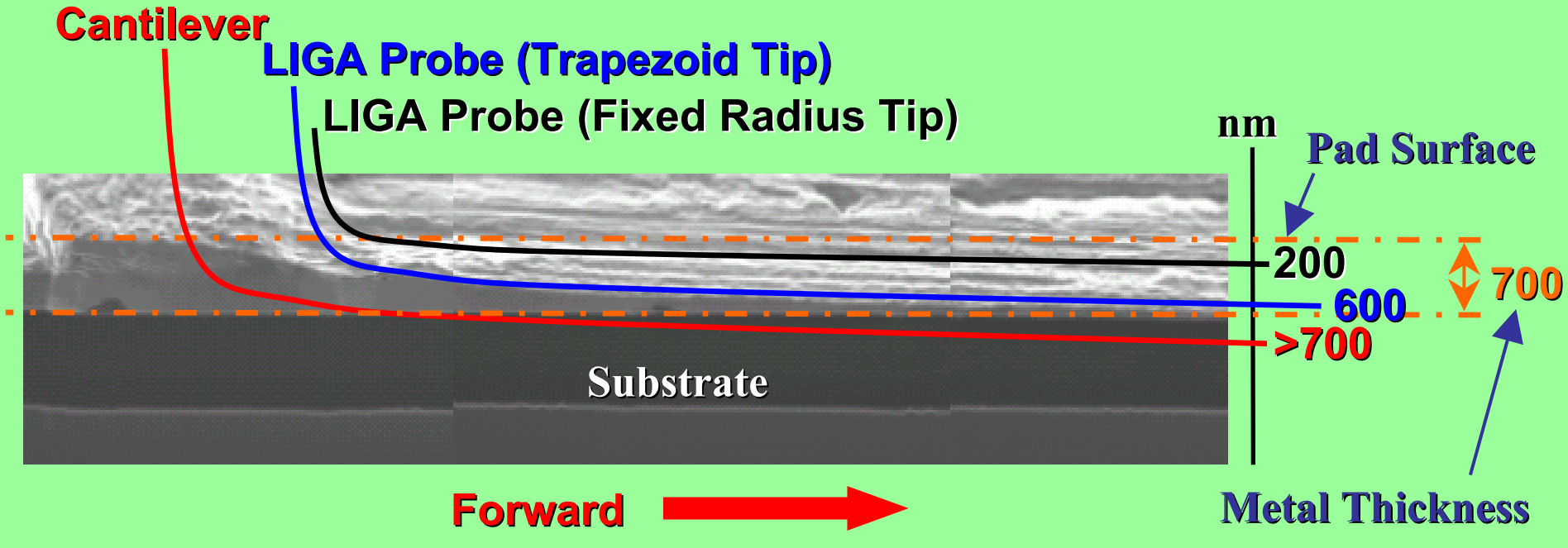
NDPR Spreads!

- There is No Trivial Flaws on Al Pad!
- Non-Damage Probing Range(NDPR) Spreads!

It is Suggested that Tip Form is More Important than Probe Load to Non-Damage Probing.

Analysis of ILD Damage(5) –Why is Small Damage?-

Depth Profile at Al Scrub

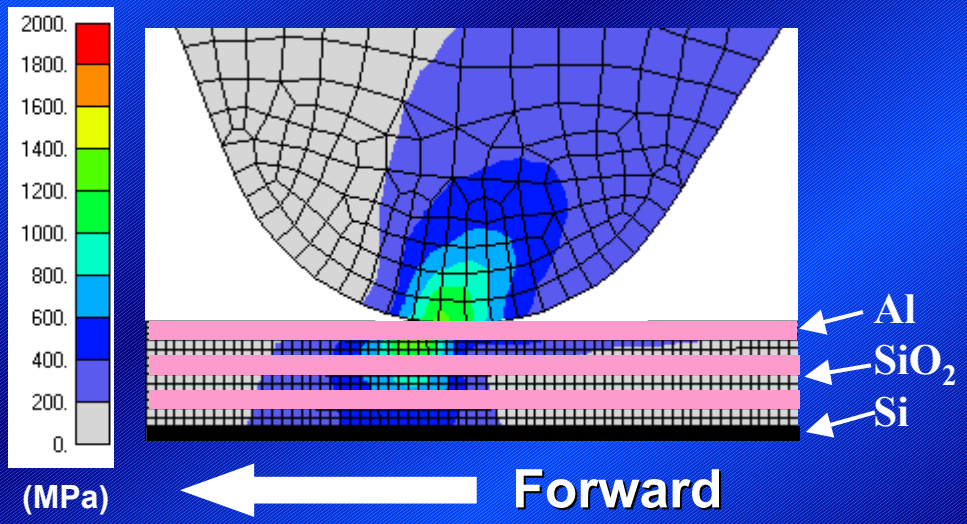


- Low-Load LIGA Probes Scrub the Pad Surface Thinly.
- There is No Substrate Atom in Scrub Surface.

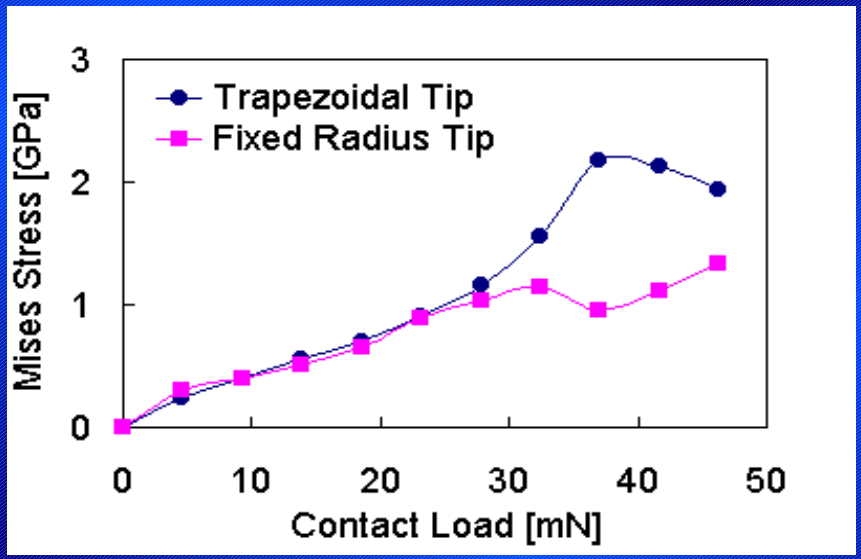
Simulation of ILD Damage(2) -Fixed Radius Tip-

<TD Model on ILD>

Mises Stress(@Maximum Stress)



<Mises Stress vs Contact Load>



At Fixed Radius Tip, ILD Stress at Forward Scrub Cuts Down.

But at Fix Radius Tip :

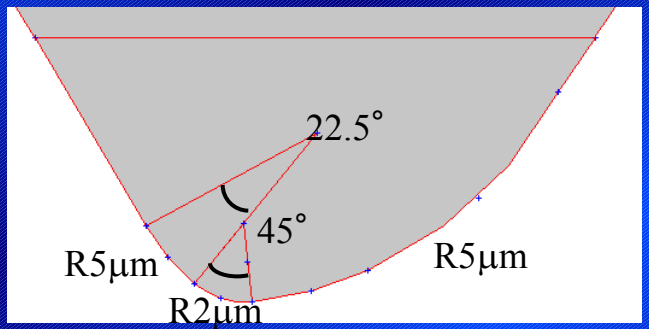
- Much Debris May Adhere to Tip.

- Contact Load May Rise & NDPR May Become Narrow.

Simulation of ILD Damage(3) –Advanced Tip Design-

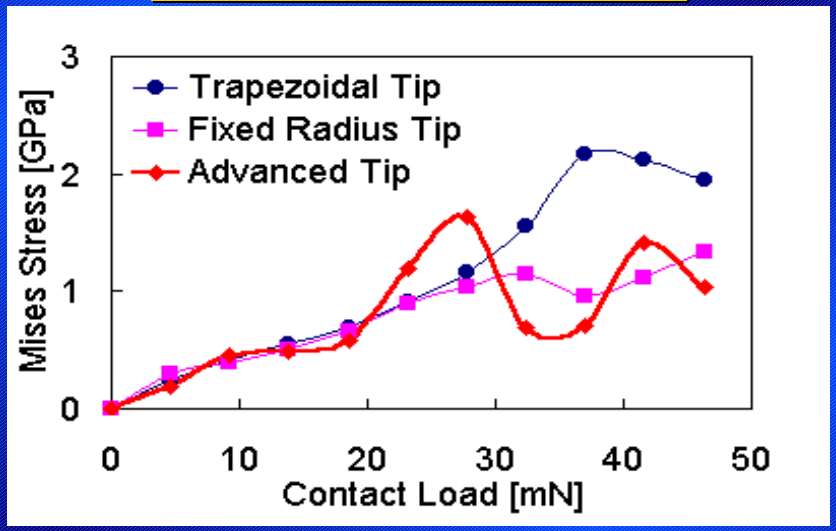
<Advanced Tip Design>

Cleaning-Free Tip



Forward

<Mises Stress vs Contact Load>



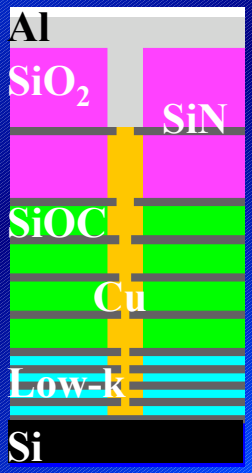
- Advanced Tip Have Higher Stress than Fixed Radius Tip.
- At Advanced Tip, ILD Stress is Changed Sharply.

We'll Optimize Tip Form with the Performance of Non-Damage and Cleaning-Free.

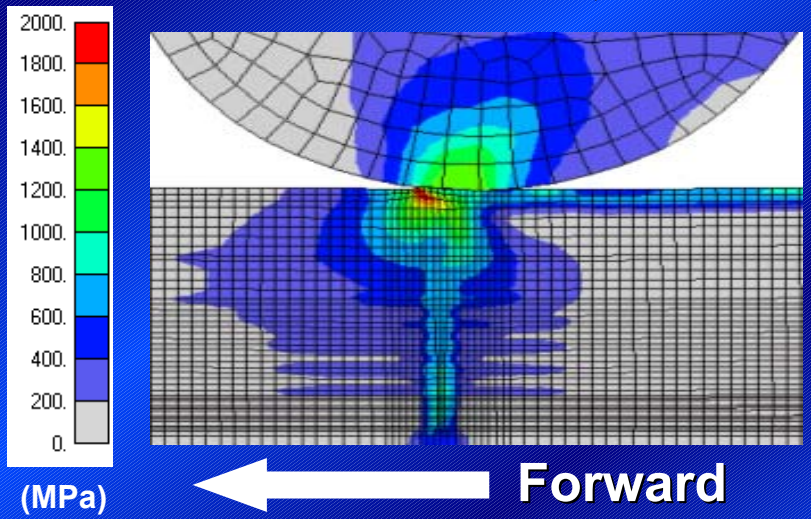
Simulation of ILD Damage(4) –Probing Low-k Devices-

Low-k Devise
(*There are more fragile materials at the lowest layer)

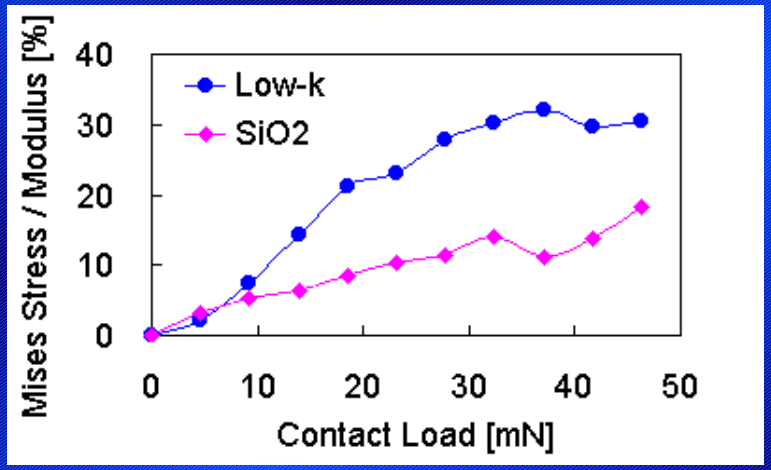
<Low-k ILD>



<TD Model on Low-k Materials>
Mises Stress(@100μm_OD)



<Mises Stress/Modulus vs Contact Load>



Using This Simulation Technology, It is Possible to Propose the Suitable Contact Probes for Low-k Devices.

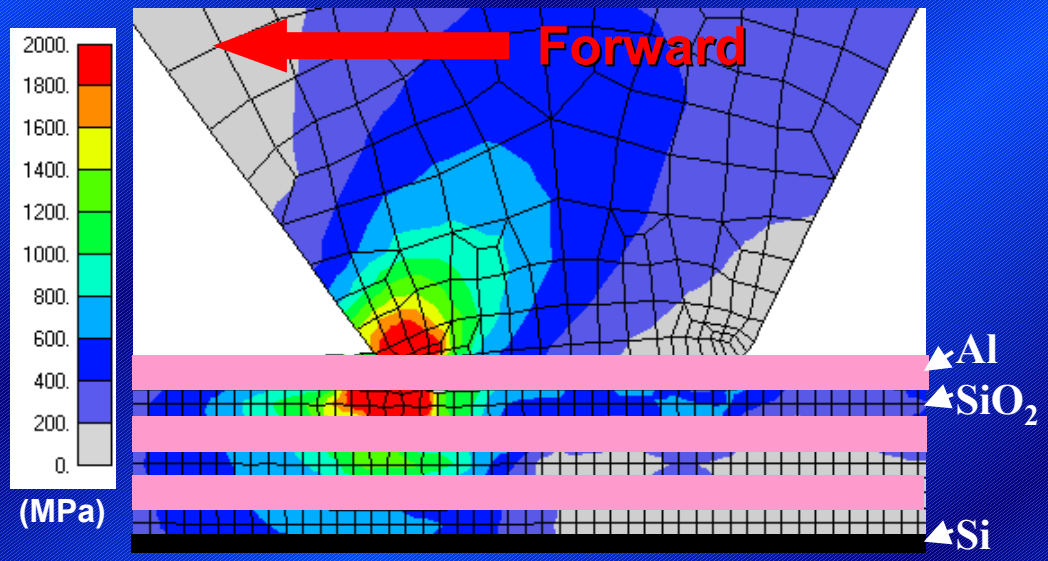
Conclusions

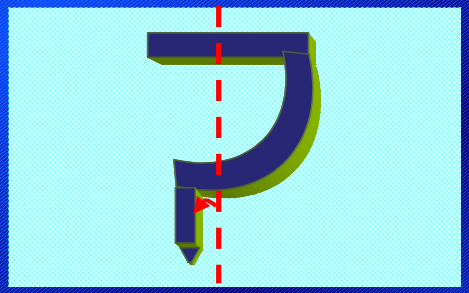
- We clarified that tip form is more important than probe load to non- damage probing. Moreover, we succeeded in realizing wide NDPR.
- Probes with wide NDPR absorb height dispersion of electrode pad in devices and that the wafer probing is complete without ILD breakdown. Moreover, we think that probes with wide NDPR are also available for probing Low-k devices.
- The following two points are very important for probing Low-k devices;
  - It is necessary to use the contact probes with little dispersion in tip form and spring properties. From this point of view, LIGA probes are very advantageous.
  - It is necessary to design low-load contact probes on the basis of exact simulation and investigation of scrub action.

Spare

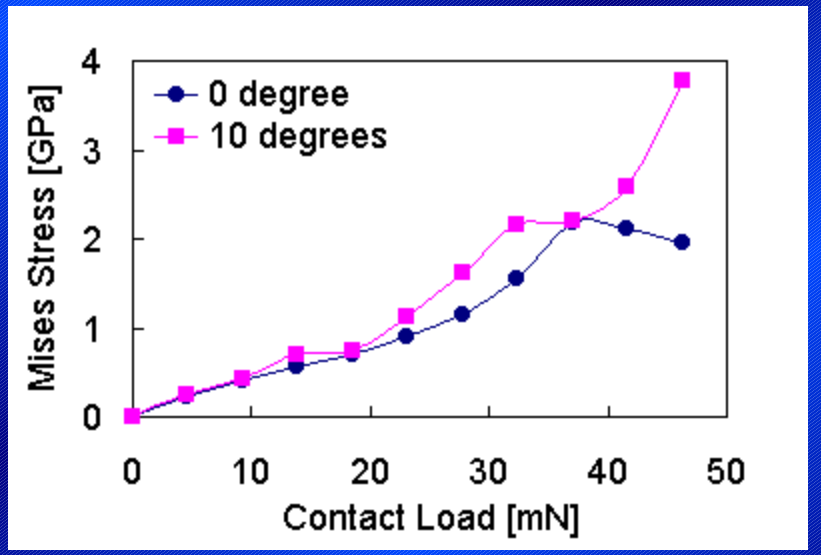
Simulation of ILD Damage –Inclination of Trapezoidal Tip-

<Inclination TD Model>
(10 degrees in a back side)
Mises Stress(@Maximum Stress)





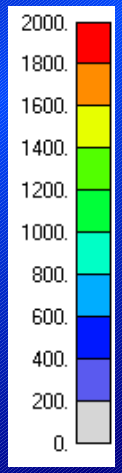
<Mises Stress vs Contact Load>



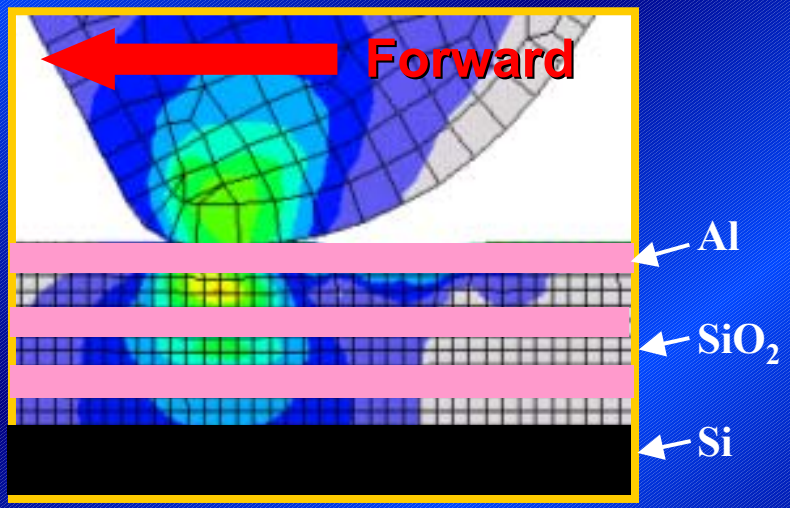
Trapezoidal Tip Form is Sensitive to the Inclination of Probe.

Simulation of ILD Damage –Advanced Tip Design-

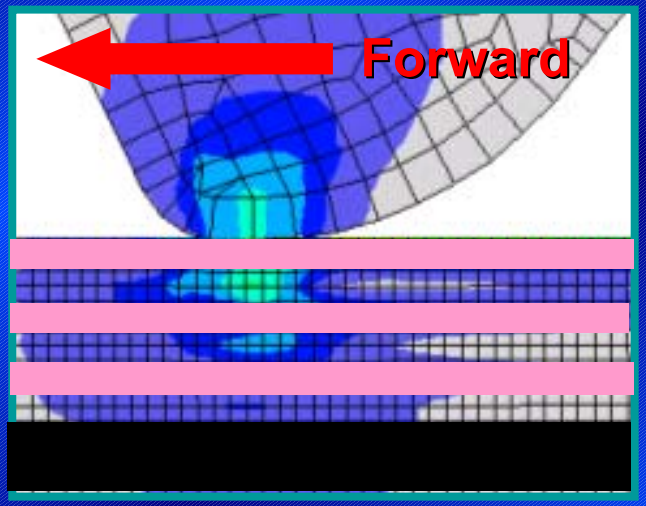
<Maximum Stress>



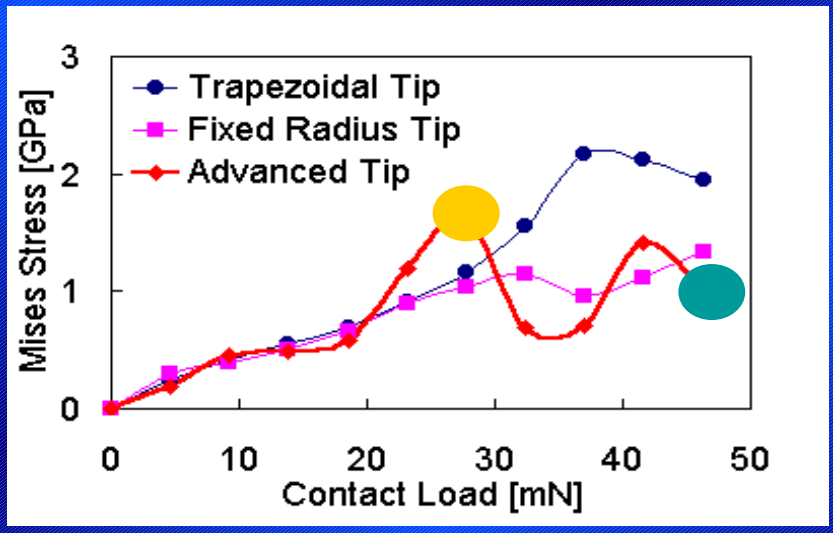
(MPa)



<Load : 47mN>



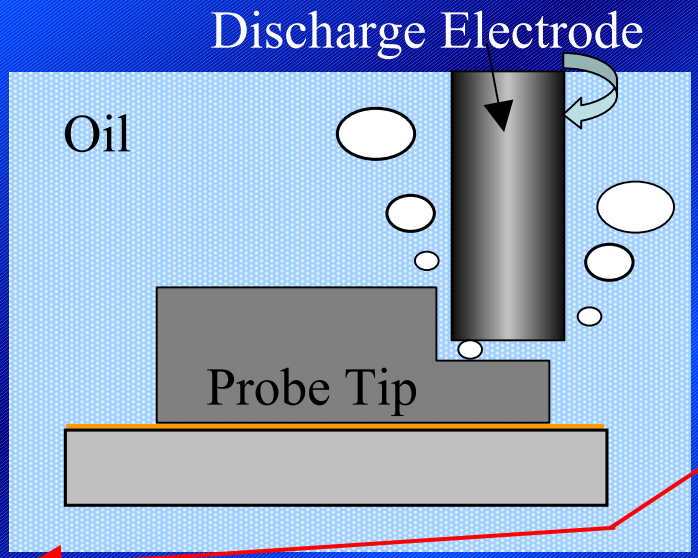
<Mises Stress vs Contact Load>

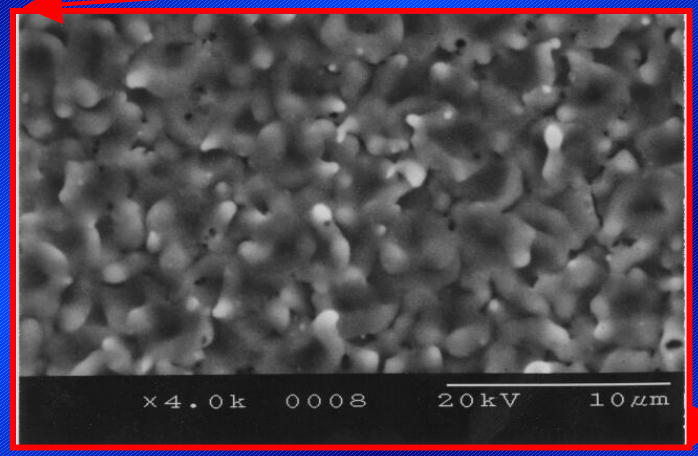


Because of Ever-changing Tip Radius to Contact Al Pad, ILD Stress is Changed Sharply.

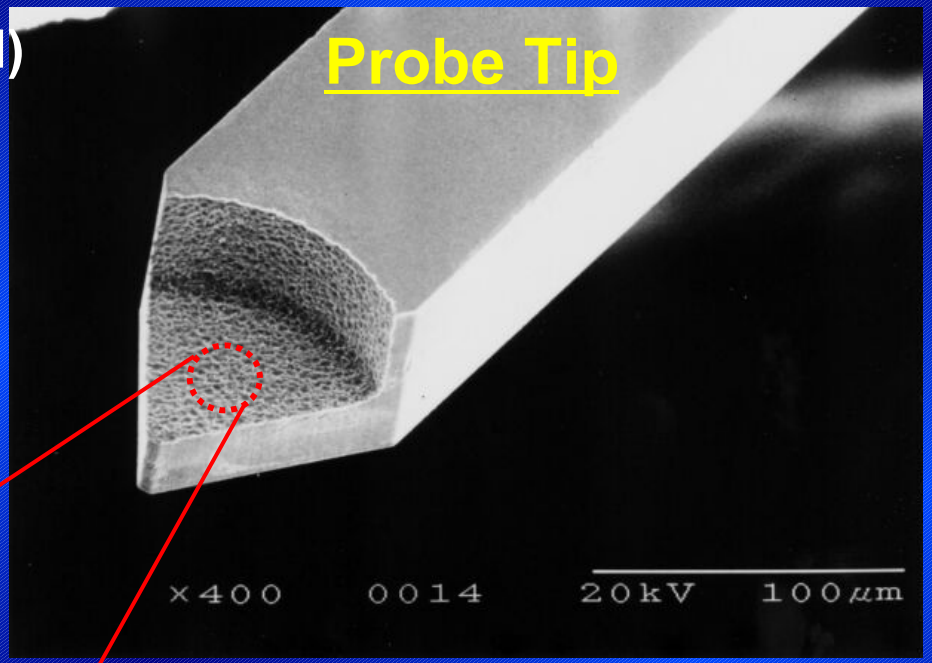
Sharpening of LIGA Probe Tip

μ-Electro Discharge Machining(μ-EDM)

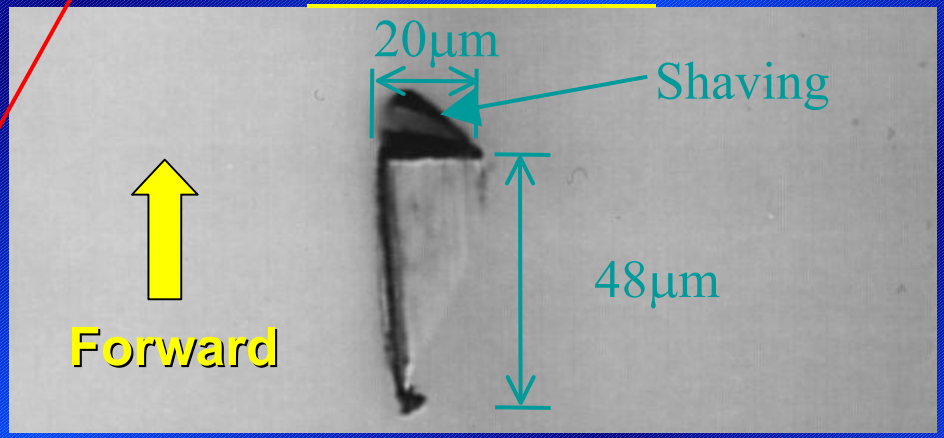




SEM Micrograph of Discharge Scar



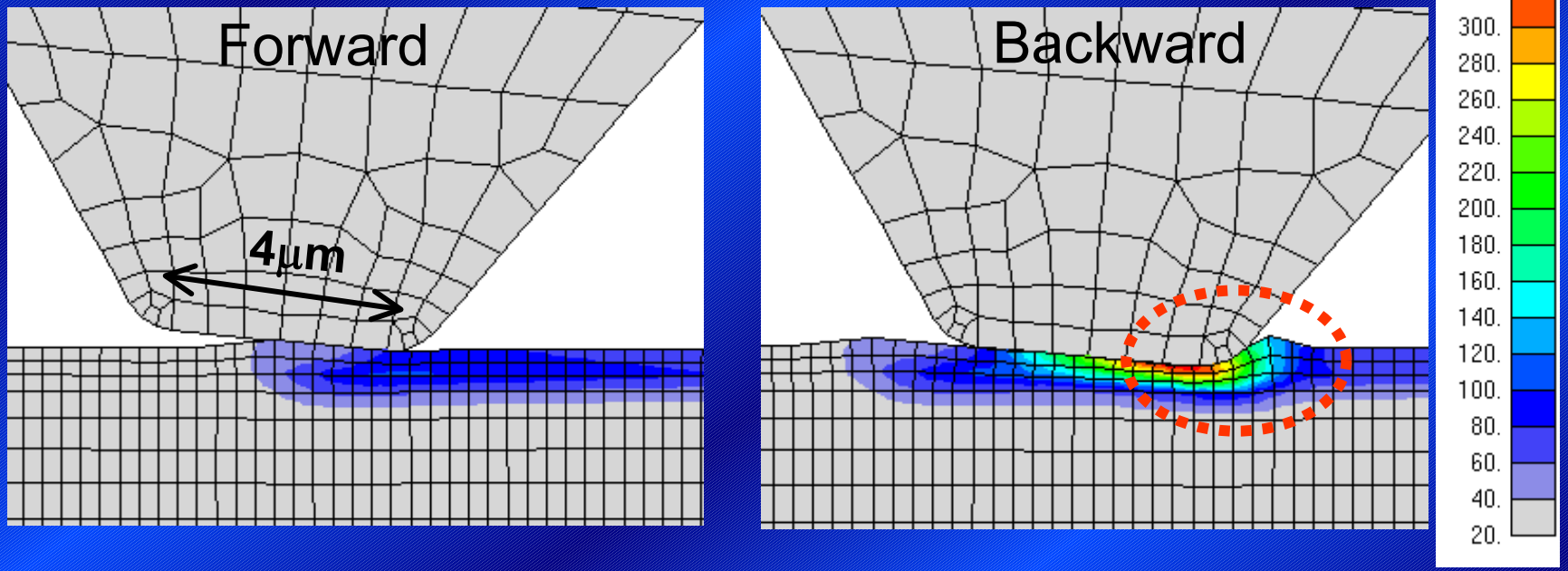
Scrub Mark



Simulation of scrub action

Why do Adhesion and Accumulation of Debris Occur?

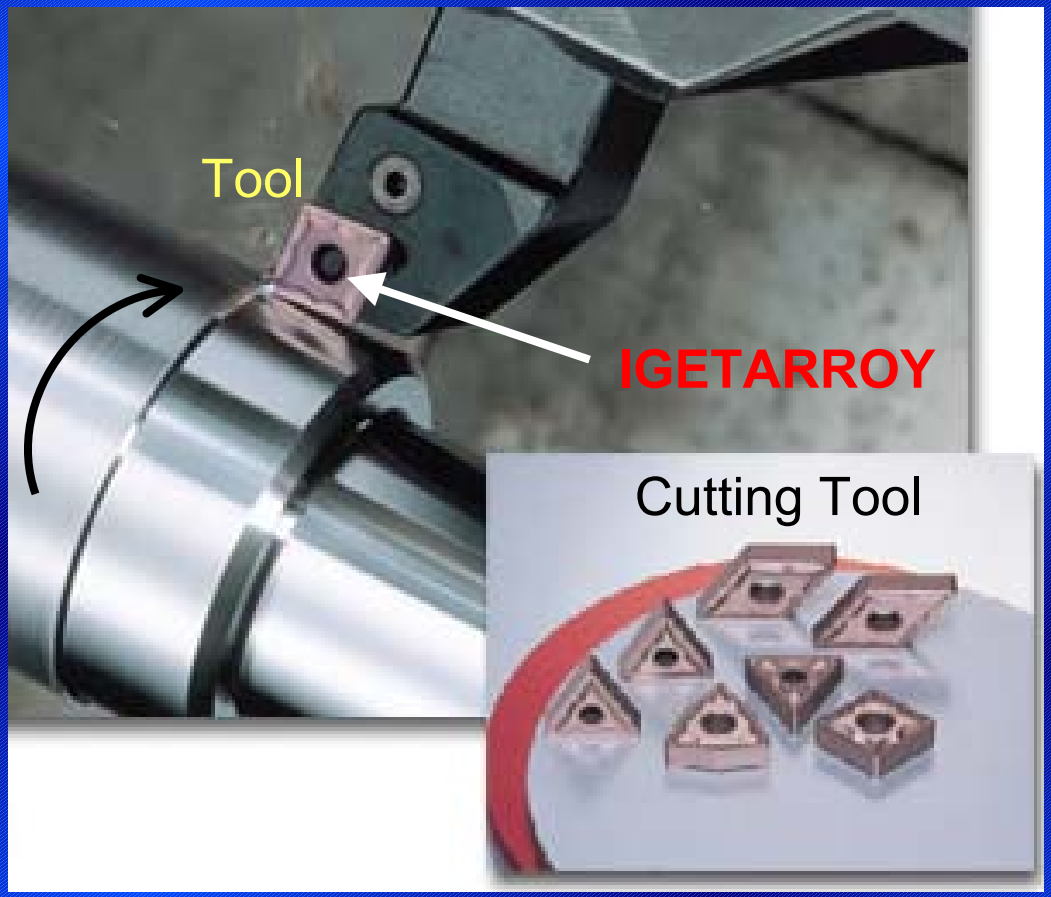
Al Contact Wiping Action of Truncated Pyramid Tip
(Conventional MEMS Probe Tip Fabricated by Si Micro Machining)



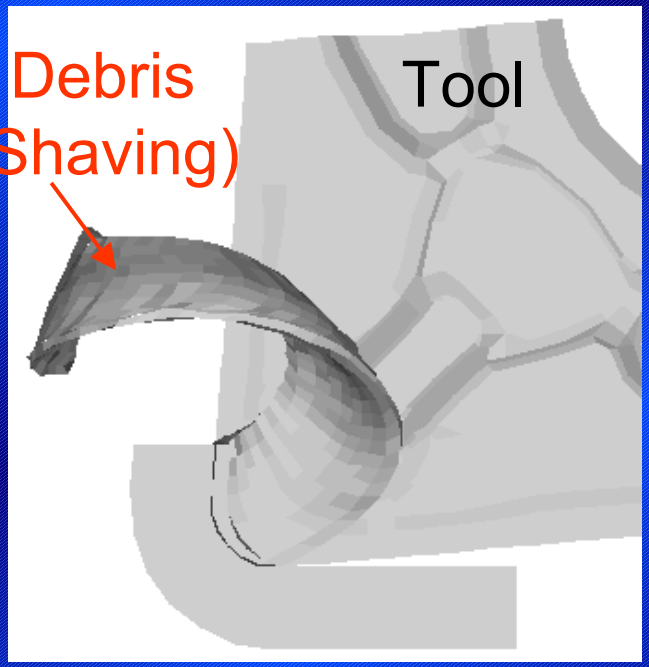
◆Initial Adhesion of Al Debris Occurs at Backward Scrub Action.
→ Al Debris Increase the Debris Adhesion at Next Contact.

Backward Scrub Action is Useless for Electrical Contact.

Cutting Tool Simulation Technology



3D Machining Simulation



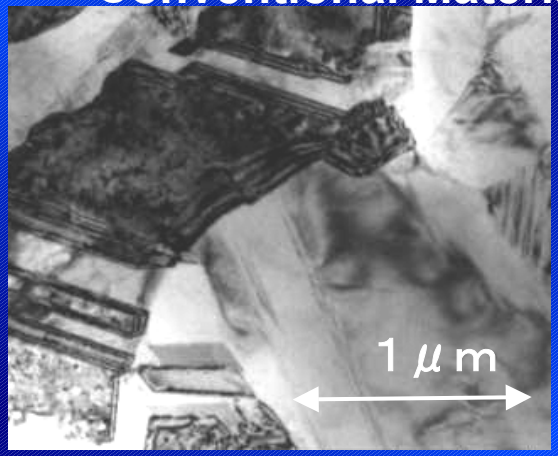
For Cutting Tool Shape Design & Cutting Condition Analysis

Scrub Simulation

Ni Grain Size Control

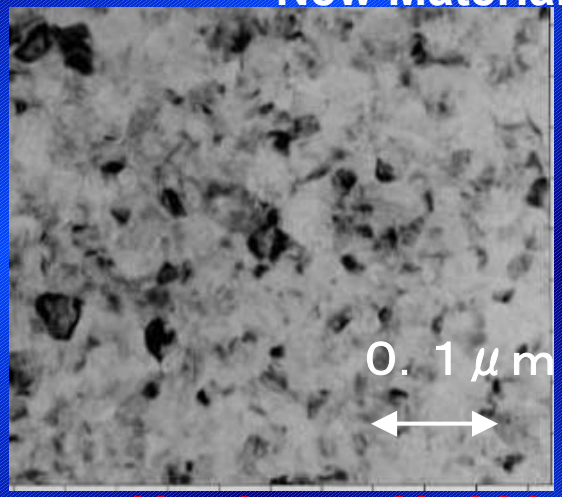
<Grain TEM Photograph>

Conventional Material



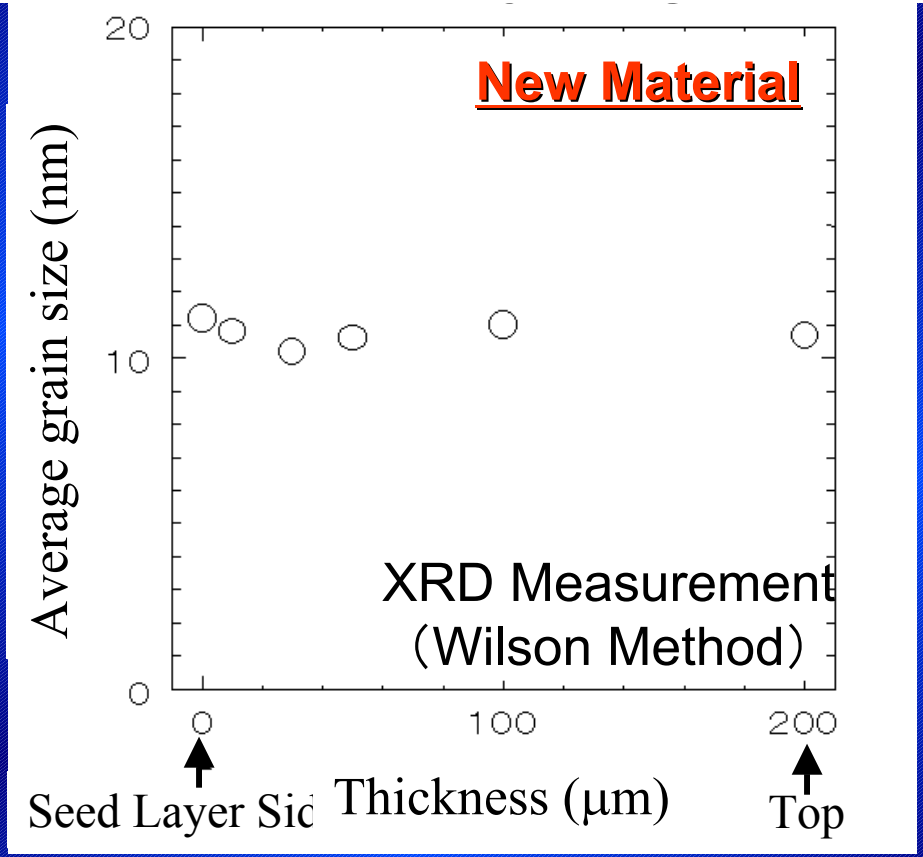
Hardness:Hv400-500

New Material



Hardness:Hv620

Grain Size Uniformity along Thickness



Miniaturization of Grain Size

→ High hardness: up to Hv600

Good Uniformity