SW Test Workshop
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General Overview on pad damage:
probe key parameters and other causes.

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Outline

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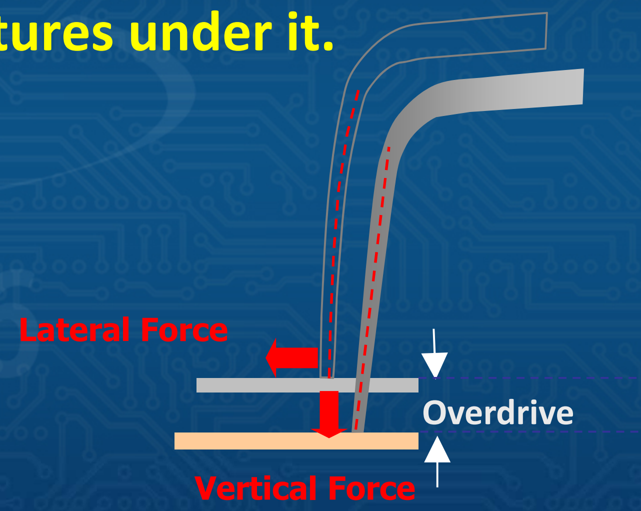
- **Scrub mark mechanics**
  - Pressure and shear stress
  - Tip stiffness
  - Lateral force measurements
  - Scrub and temperature
- **Pad damage**
- **Conclusions**

Introduction

- **The wafer probe test aims to evaluate the device electrical performances before assembly.**
- **Probe touch on pad enables breaking the native oxide layer lied on the pad surface, getting a suitable electrical contact.**
- **The probe impact and the sliding motion on pad could cause:**
  - Crack failures in the structures underneath the probing area.
  - Copper, Nickel or other metallization exposure, cause of bonding failure.
  - Problem of bonding reliability due to large scrub.
- **Few options are possible to decrease the failures described above:**
  - Work on the pad structure and layout.
  - Work on the probing process parameters (Overdrive, chuck speed, number of Td, cleaning process, cleaning sheets….)
  - Work on the needle technologies

Probe action on pad

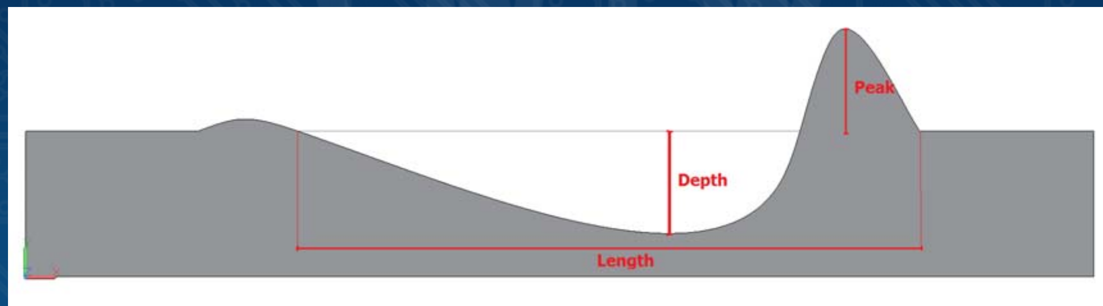
- **The probing process on pad is composed of 4 phases:**
  - Probe impact on pad
  - Probe sliding forward movement (Cantilever and some MEMS probes)
  - Electrical test with probe under static load on pad
  - Probe sliding backward movement (Cantilever and some MEMS probes)
- **During the probing action the tip digs the pad surface transmitting stress to the stacked interconnected structures under it.**
  The stress transmitted are:
  - Compression stress
  - Shear stress



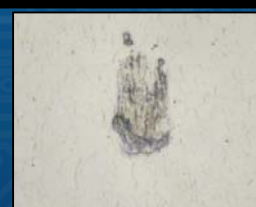
- **Both stresses have to be considered during probe card design, above all the shear stress for cantilever technology**

Scrub mark description 1/3

- **A scrub mark is characterized by 4 elements: length, width, depth and peak.**

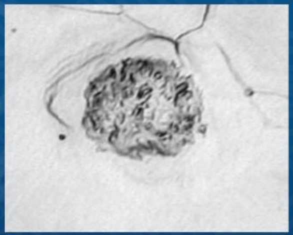
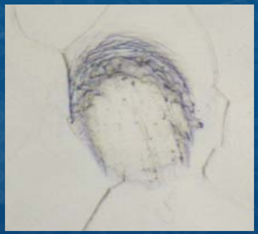
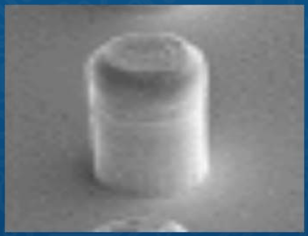


- **Cantilever scrub description; 3 comparing cantilever technologies**

Key Parameters	STD - flat	Helium	NoScrub
Scrub mark picture			
Notes	• Fat tip shape is used • **Scrub is not deep** • Scrub peak is limited • **Shear stress is high**	• Slim tip shape is used • Scrub quite deep • Scrub peak is taller than STD scrub • Shear stress is low	• NoScrub tip shape is used • **Scrub deeper than STD scrub** • Scrub peak is taller than STD scrub • **Shear stress is low**

Scrub mark description 2/3

- The table below reports some scrub examples obtained by different TPEG™ MEMS probes

MEMS probe type	TPEG™ Pointed NoScrub	TPEG™ Pointed Scrub	TPEG™ Flat
Scrub mark picture			

Scrub mark description 3/3

- **Scrub shape depends on the pad contact surface:**
  - Material
  - Hardness
  - Thickness
  - Roughness of the pad surface
  - Native oxide layer
- **One of the most used material for the pad contact surface is Aluminium, but not all the Al pads are the same**
  - Aluminium thickness may change
  - Aluminium grain size and metallurgy may change leading to different hardness
- **The probe action, the scrub shape, the polishing recipe and testing process should change in function of the pad**

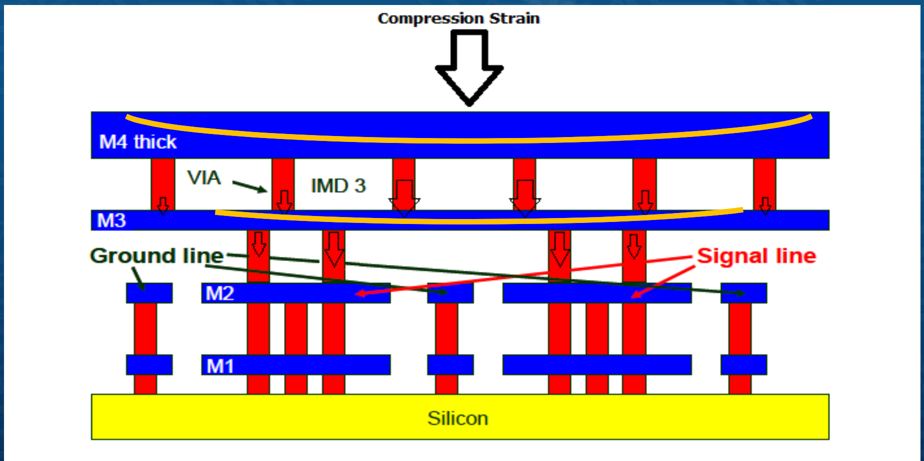
Pressure and Shear Stress 1/2

- **The vertical force alone is not the only leading factor causing cracking and it should be considered tied to another important probe characteristic as the probe contact diameter.**
  - The contact pressure is a key parameter that should be considered since early design phase.
- **The shear stress transmitted by the probe is underestimated but it gives the main contribution to the tensile stress in the inter-metal dielectric.**
  - The tip stiffness has to be considered during cantilever design since the beginning.
- **Vertical probes without scrub action give only compression stress to the structures under pad. As a consequence, vertical probes can work with higher pressure than cantilever.**
  - Some MEMS probes show a scrubbing action on pad. In those cases the shear stress has to be considered.

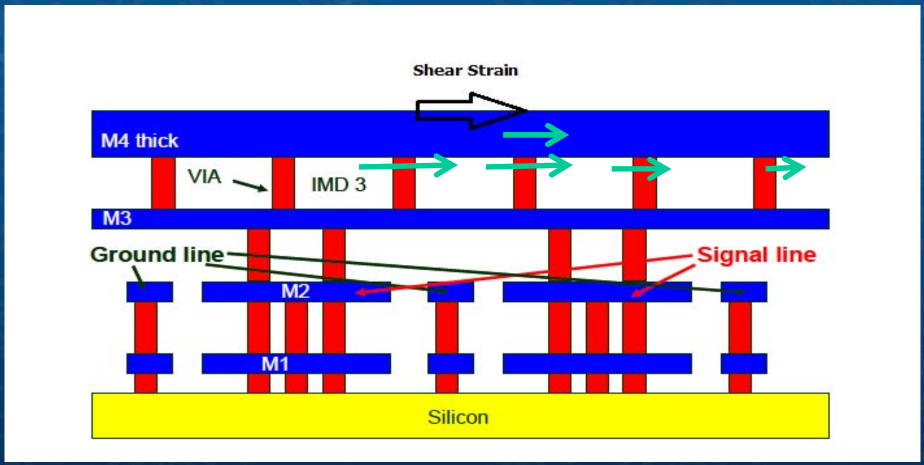
Pressure and Shear Stress 2/2

- Vertical force induces Internal Metals bending deformation and Vias compression.
- Shear stress induces traction in the Internal Metals and Vias deflection.
- Typically, the structures under the pad are more sensitive to shear stress than compression strain.

Compression strain

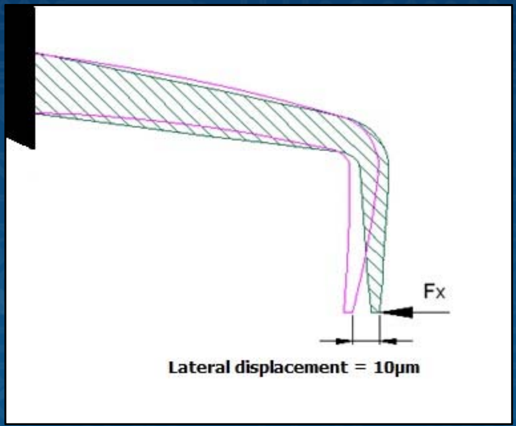


Shear strain



Cantilever Tip Stiffness

- **The main parameters useful to control the tip stiffness and shear stress are:**
  - Tip length (Cracks appear more often on pads probed by the first level).
  - Tip shape
  - Needle material



- **The tip stiffness can be evaluated measuring the force when a lateral tip displacement is imposed like shown in the picture on side.**

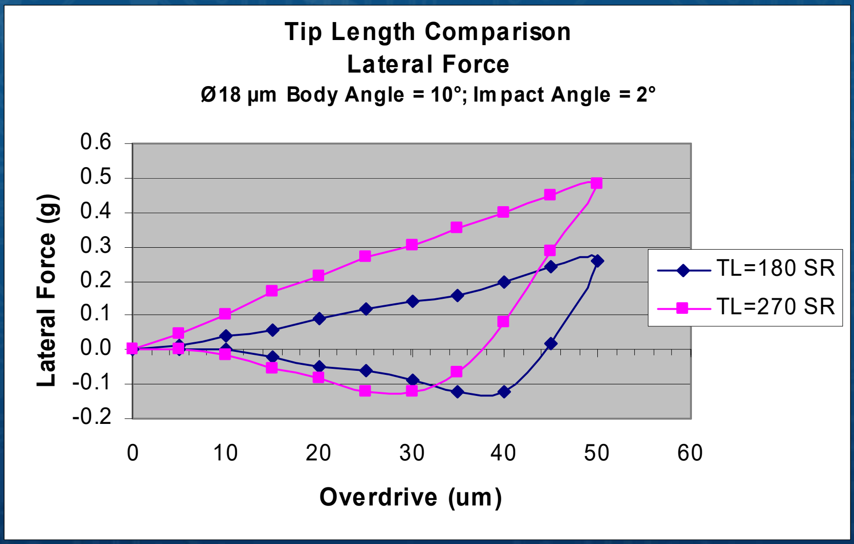
- **Below an example where 2 probes with different tip lengths have been measured.**

Probe	Needle type	Contact Diam (µm)	Tip length (µm)	Force Fx
Probe C	WR4mils	18	180	1,4 g
Probe D	WR4mils	18	270	0,8 g

- **The probe with longer tip is less rigid than the shorter one.**

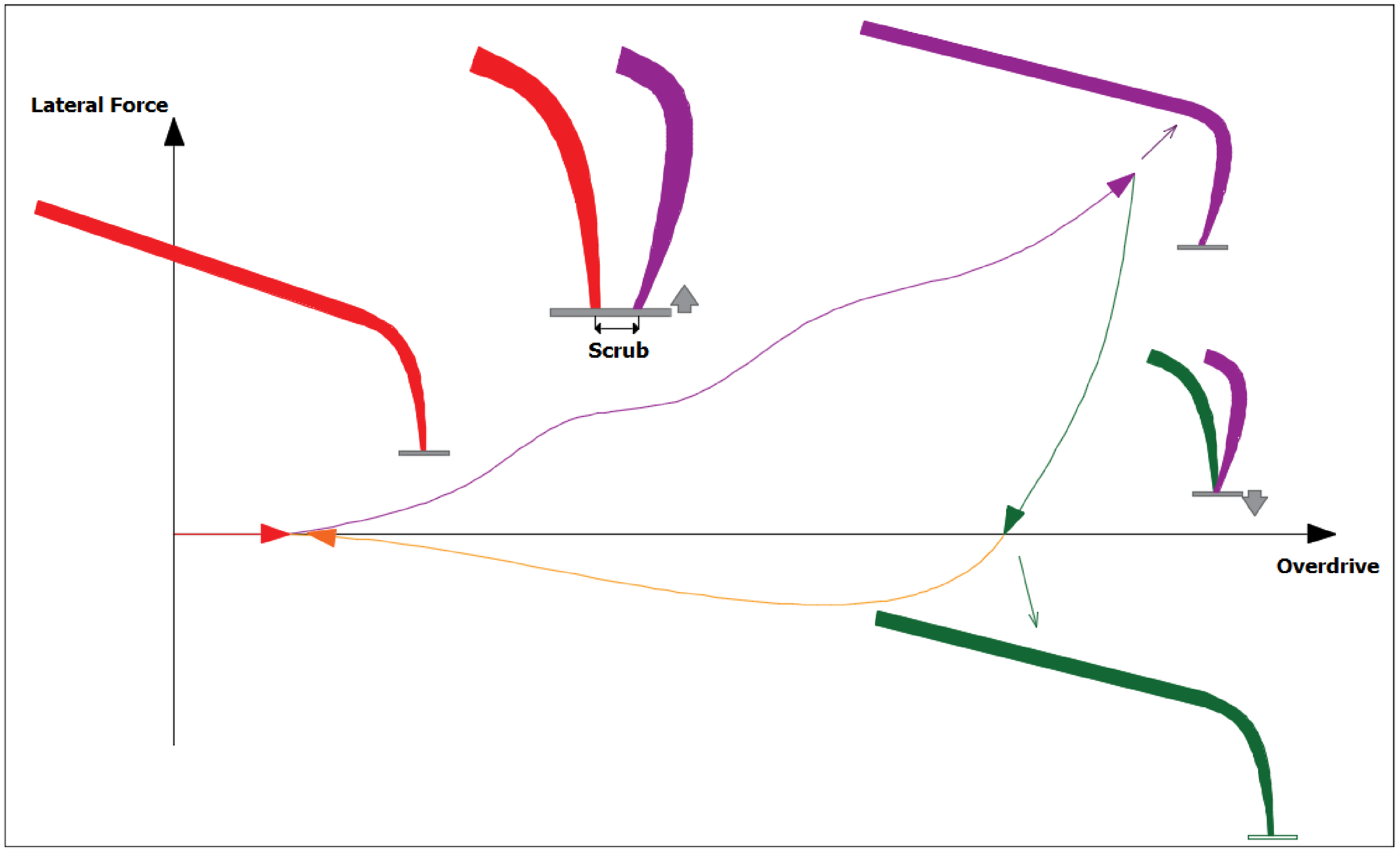
A lab experience

- In order to investigate the stress transmitted to the pad during the probing action a machine with 2 force gauges has been realised to measure vertical and lateral forces
- The lateral force characteristic will be described in the next slides.
- All the measurement has been performed on little samples of blank wafer with 1,5 µm of Al thickness.



Lateral force cycle during a TD 1/3

- The picture below shows the cycle described in the previous slide



Lateral force cycle during a TD 2/3

- **Lateral force cycle description:**

  – Red line
  The needle slides on the pad surface after the impact with the pad and the lateral force measurement doesn’t increase.
  Harder the Al pad layer is, longer the tip sliding movement will be.

  – Purple trend
  The lateral force rise is due to the tip deflection that increases with the overdrive.
  The diagram shows a rise wave trend. These waves occur when the tip lateral force achieved enough intensity to overcome the pad friction and the resistance of the aluminium peak formed around the tip. When the probe contact surface is in motion the tip deflection decreases, so the lateral force increment rate decreases slowly too.

  If the probe has a stiff tip, all the energy is unload immediately on pad instead of to be accumulated in the tip deflection. The scrub length will be long, the measured lateral force will be low and the pad damage probability will be high.

Lateral force cycle during a TD 3/3

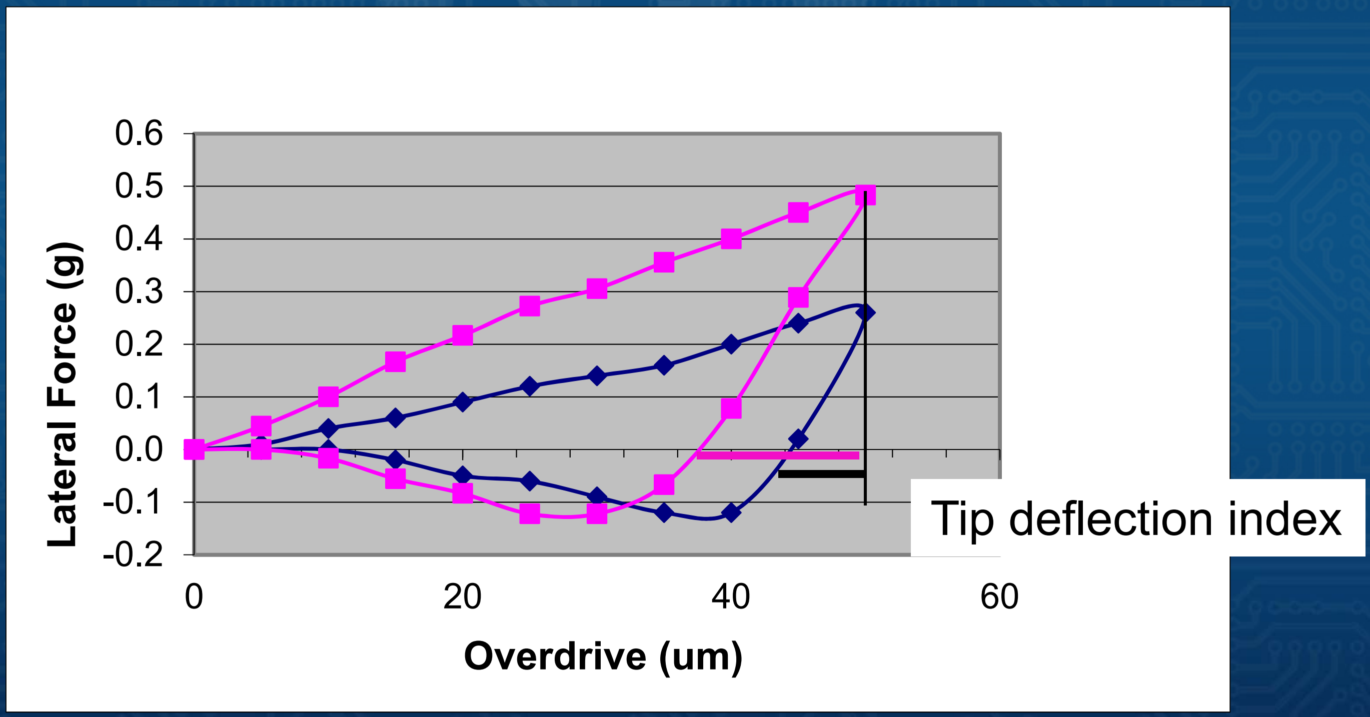
- **Lateral force cycle description:**

– Green trend
When the chuck starts its return movement, the lateral force decreases quickly to zero. In this phase the tip loses the deflection. The return overdrive necessary to cross the x axes is proportional to the tip deflection and tip rigidity.

– Orange Trend
In this phase the probe move back transmitting to the pad a negative shear stress.

Lateral Force Vs. Tip length

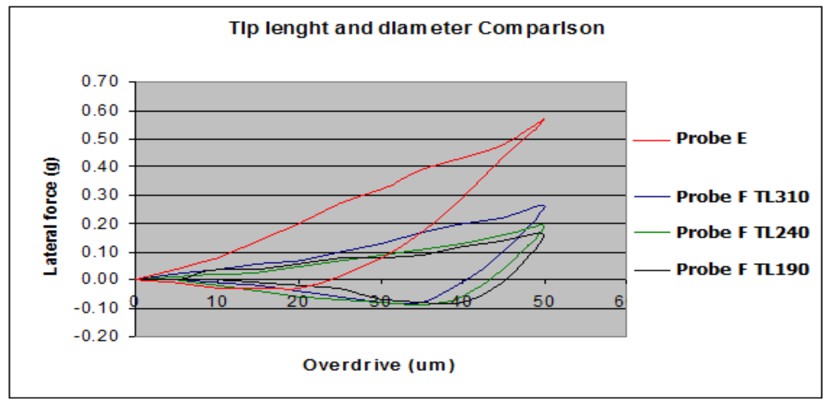
- The area of the cycle represents the energy accumulated in the probe. More is the energy accumulated in the tip, less is the energy transmitted to the pad structures.
- The plot below shows the Lateral_Force vs. OD for two different probe designs



Lateral Force Vs. Pressure and tip wear

- **The lateral force measurement has been performed on many different probe types.**

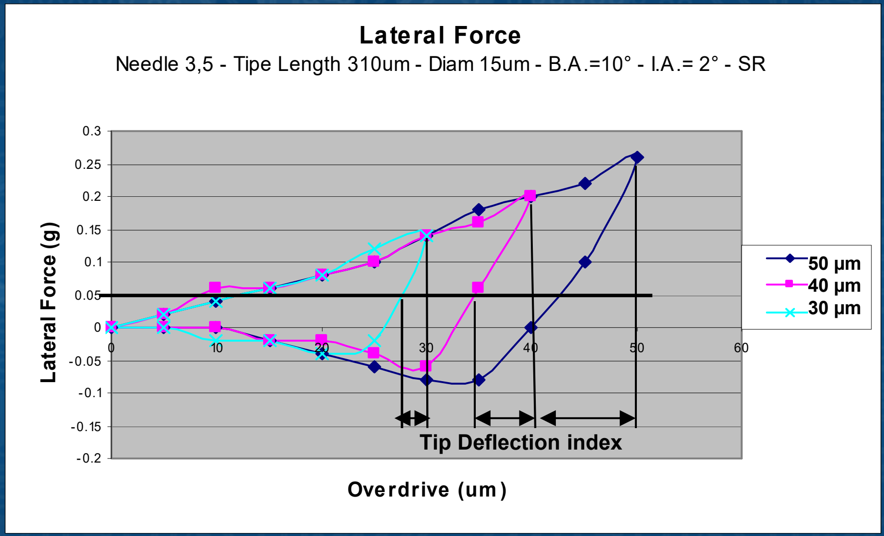
Probe	Needle type	Contact Diam (µm)	Tip length (µm)	Pressure (mg/µm²)
Probe E	WR4mils	15	310	4,8
Probe F	WR4mils	15	310	3
Probe F	WR4mils	15	240	3
Probe F	WR4mils	15	190	3



- The lateral force is proportional to the pressure.
- Probe E scrub is deeper and shorter than Probe F TL310 scrub.
- Probe F –T.L. 310 scrub mark is deeper and shorter than Probe F - T.L. 190 scrub

Lateral Force and Overdrive

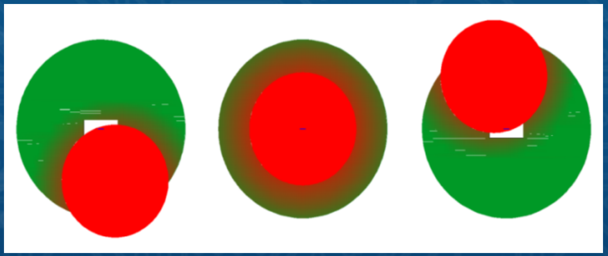
- **The lateral force is function of the Overdrive.**
  - Looking at the diagram below it is possible to observe that the tip deflection and the max measured lateral force increase with the overdrive.



  - The Overdrive can't overtake a max value that is specified by probe card vendors, to avoid the plastic probe deformation.

Scrub and temperature 1/4

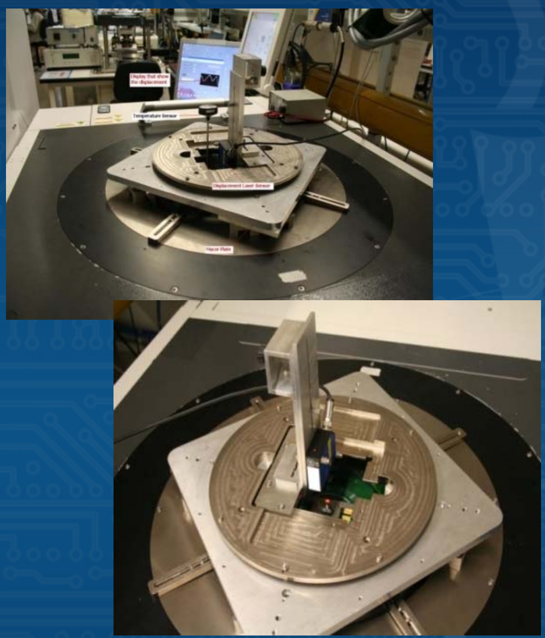
- **Temperature variation makes everything dynamic:**
  - Prober and probe card are made of different components.
  - Each component is made of different materials with different thermal expansion coefficient.
  - When there is a temperature change all the mechanical elements, fixed together, expand with the final result of a structural deflection.
  - Thermal gradients are also present depending over x,y,z location and are changing during probing over time

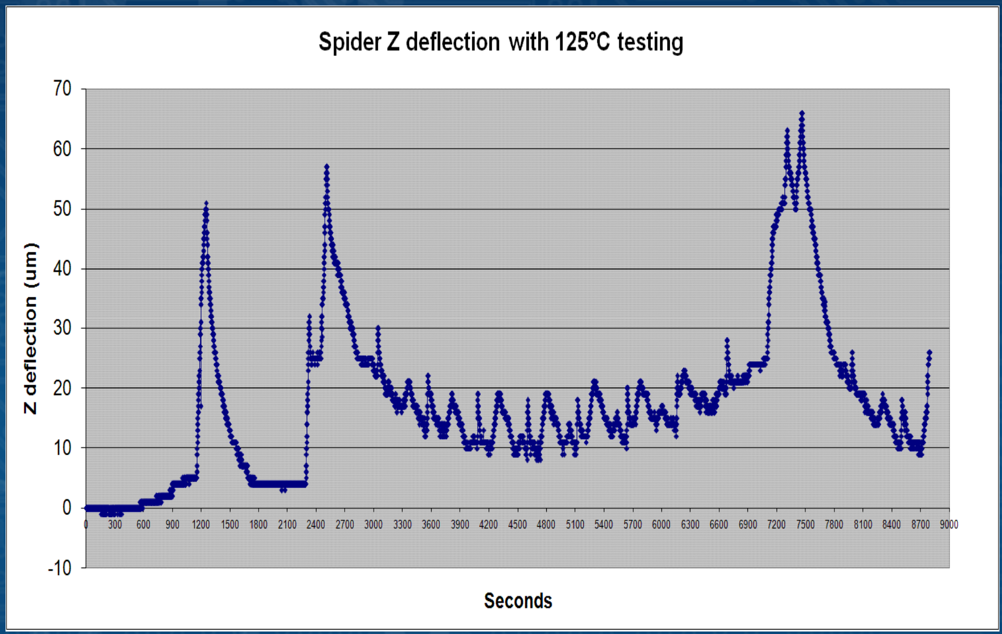


  - On-line cleaning, visual inspection, wafer change and every time that the hot chuck isn't under the card induce a temperature variation of the probe card, which is reflected in the probe head Z position change.

Scrub and temperature 2/4

- Below a STD probe card Z deflection measured during a full wafer test.





- Test at high temp can increase the pad damage risk due to the probe card deflection and the consequent poor overdrive control.
  The real Overdrive used could be higher than the programmed one.

Scrub and temperature 3/4

- The Aluminium layer, at high temperature, became softer cushioning the tensile stress transmitted to the structures under pad.
- The scrub mark will thus change especially in terms of scrub depth. Below some measurement obtained with NoScrub Technology on blank wafer with 1,5 µm of Aluminum.

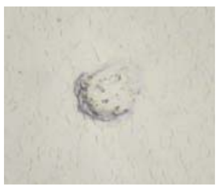
	50 µm OT 30°C	50 µm OT 150°C
x1		
x3		
x6		

Force	1.4 g
Tip diameter	16 µm

N° TDs	50 µm OT 30°C			50 µm OT 150°C		
	Length (± 4 µm)	Width (± 3 µm)	Z (± 0.15 µm)	Length (± 4 µm)	Width (± 3 µm)	Z (± 0.15 µm)
1TD	17	13	0,6	19	15	0,9
3TDs	18	14	0,65	21	16	1
6TDs	19	15	0,75	22	16	1

Scrub and temperature 4/4

- **Below some experimental scrub measurements on Al Blank wafer with 1,5 µm thickness using TPEG™ MEMS probes.**

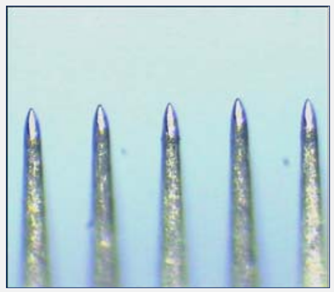
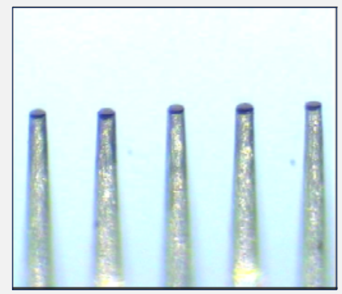
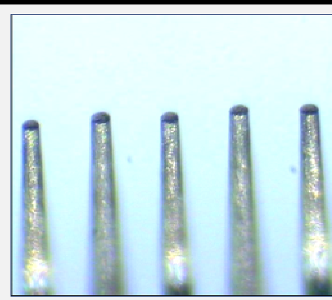
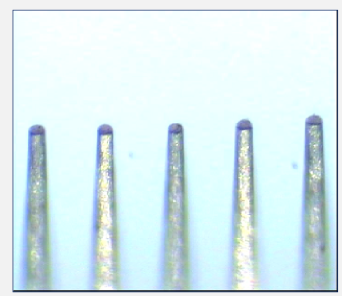
	50 µm OT 30°C	50 µm OT 150°C
x1		
x3		
x6		

Force	4,5 g
Tip diameter	14 µm

N° TDs	100 µm OT 30°C			100 µm OT 150°C		
	Length (± 4 µm)	Width (± 3 µm)	Z (± 0.15 µm)	Length (± 4 µm)	Width (± 3 µm)	Z (± 0.15 µm)
1TD	23.4	19.8	0.6	27	19.8	0.9
3TDs	25.8	21.3	0.65	28	21.3	0.98
6TDs	26.5	22.0	0.75	28.5	22.0	1.1

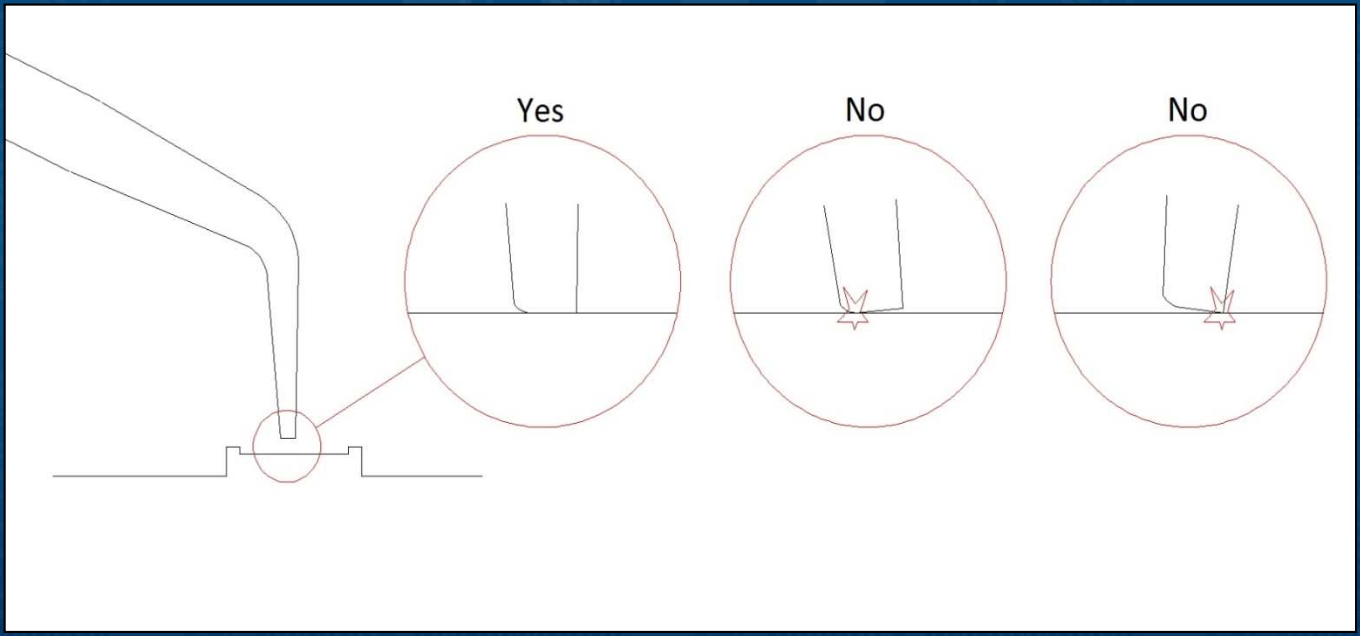
Pad damage and polishing

- **Some cleaning sheets normally used for polishing on-line can reduce the contact diameter increasing the pressure on pad.**
- **Cleaning frequency, overdrive and N°TD have to be set properly to avoid an excessive probe tip dia reduction. The contact surface of the probes doesn’t have to become smaller than the diameter specified by probe card vendor for new probe card.**

ITS Probe Polish 300, after 37500 TD		MIPOX GC8000 PF3 1µm, after 37500 TD	
Sharpened tips are observed. Similar effect is obtained with **Mipox WA6000 SWE**		Tip shape is maintained. The heels looks rounded.	
ITS Probe Lap 3µm, after 35000 TD		**ITS Probe Scrub 3µm, after 35000 TD**	
Tip shape is maintained, good roughness of the contact surface. Similar effect is obtained with **3M pink paper**		Tip shape is maintained, slightly rounded.	

Pad and probe contact surfaces parallelism

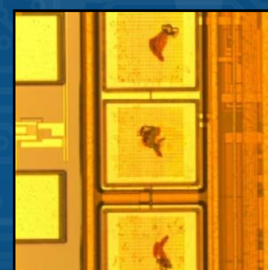
- **The pad damage risk can increase if the probe contact surface isn't parallel to the pad surface. Every kind of probe damage or serious misalignment could cause cracks due to the high pressure concentrated in a little pad area.**



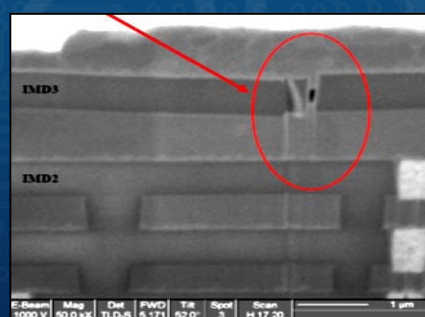
Pad damage analysis

- **Technoprobe has the capability to customise product performances following customer needs. When a new type of pad is developed, it's important to perform some crack test to define the best and reliable solution.**

- **It's common to perform some pad analysis after many TDs, performed on the same pad position, simulating the worst test case.**
  - Physical analysis (Delayering + visual inspection) on probed pad



  - Cross section:



Conclusions

- **Probe pressure on pad is a better parameter to be considered than just vertical force**
- **The shear stress is an important parameter to be controlled for pad damage in cantilever cards. It can be controlled working on:**
  - Probe pressure on pad
  - Tip shape
  - Tip length
  - Needle material (Young modulus, tensile strength and other mechanical characteristics has to be considered for pad damage).
- **Copper, Nickel or other metallization exposure can be avoided using wide and short tips to decrease the digging action.**
- **Probe contact surface finishing and parallelism with the pad have to be considered**

Follow-on Work

- It was demonstrated that a control of the chuck movement can decrease the pad damage probability (Soft Touch)
- Some Technoprobe internal trials show that, changing the chuck speed, it is not possible to observe a relevant modification in the scrub marks.
- Further investigations are needed to study the relationship between impact speed and pad damage.

Thanks for your Support !

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