Comparison of Bond Pad Cracking in Harsh Probing with Three Different Probe Cards

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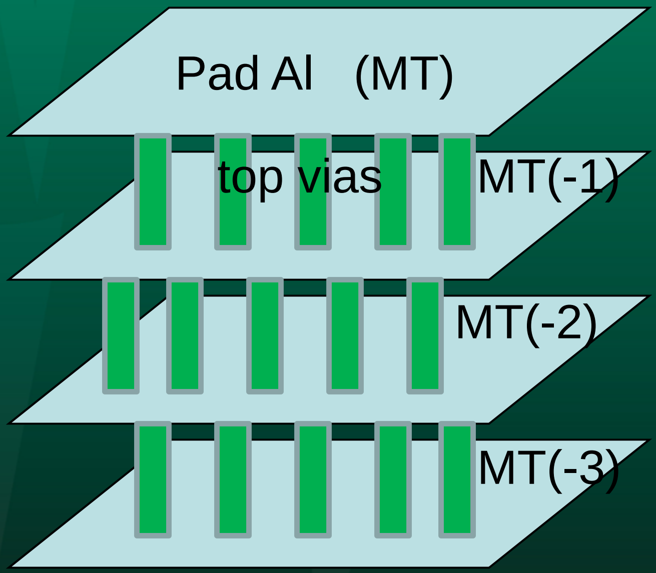
Previous Learning: "Harsh Probing" on Various Pad Structures

- Various pad structures were tested, Al – SiO_2
- Pattern density of MT(-1) is an important factor
- Cracking behavior shows a strong interaction between probing and the MT(-1) pattern
- Probe cracks are shaped like the "heel" of the cantilever probe tip
- Pad "ripple" can be seen with cracking

ref: Hunter, et al, IEEE SW Test Workshop 2011

Previous Learning (cont.):

- **Probe cracks are easily formed in "traditional" bond pad structures having Al – SiO_2 materials**
  - <1µm pad Al thickness
  - ~ 1µm top SiO_2 thickness
- **Only one probe card was used for the previous experiments**
  - cantilever, two tier card
  - 2.5 gf/mil
  - ~1mil tip dia



ref: Hunter, et al, IEEE SW Test Workshop 2011

Reliability Concerns for Pad Cracks

for Circuit Under Pad (CUP):

- **Poor wirebond on large, deep probe mark**
- **Probe cracks in bond pads can lead to:**
  - leakage or shorts in CUP
  - barrier film loss of adhesion in probe mark region
  - weakened wirebond over crack
- **Cracks could propagate during assembly; in use**
- **Ripple in Al films can weaken resistance to EM**
- **…All is worse with *very thin pad Al***

3-Probe Cards Experiment

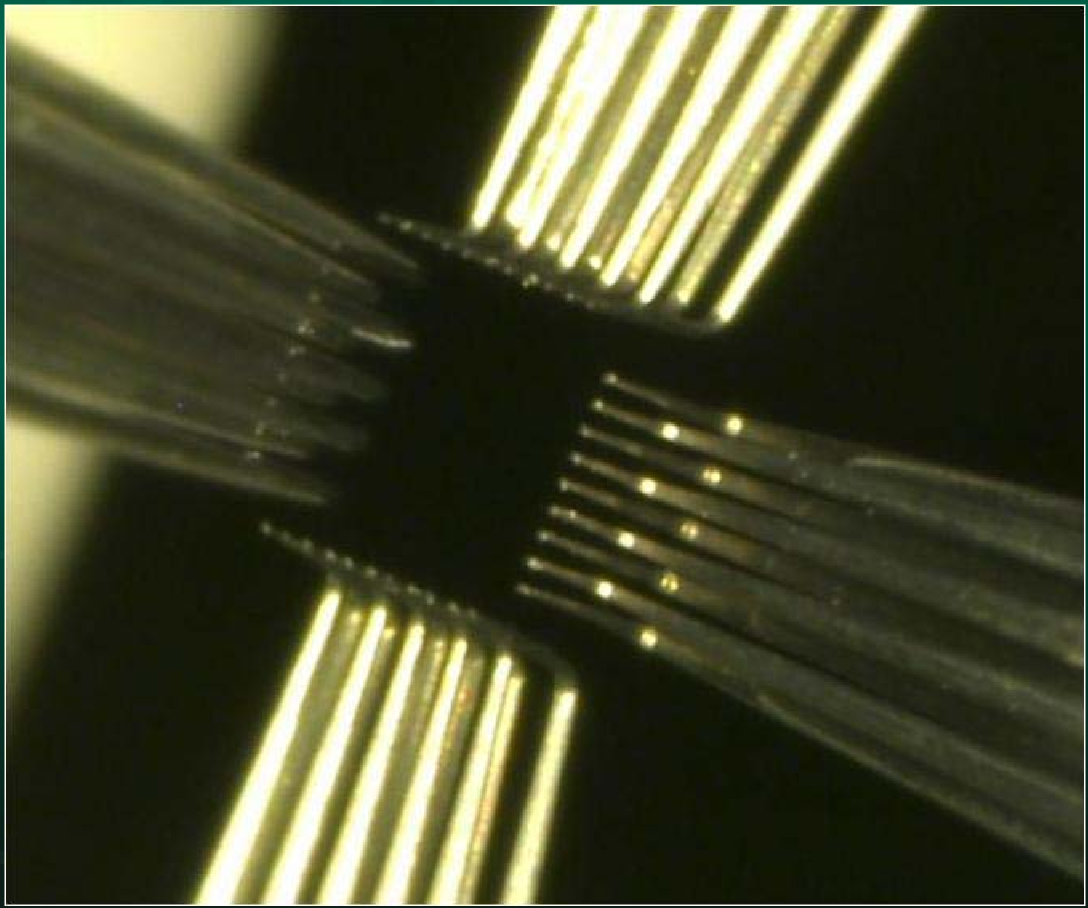
1. **"Low Force" cantilever probe tips**
   - 1.2gf/mil, ~1mil tip dia, 2 tiers, ~105deg bend
2. **"*Small Tip*" Reduced Angle cantilever probes**
   - ~100deg bend angle
   - 1.2gf/mil, ~0.7mil tip dia
   - *has reduced probe mark size in non-harsh probing*
3. **"High Force" cantilever probe tips**
   - like "1." above, but ***twice the force,*** *2.5gf/mil*
   - (same type probe card as used in previous expts)

- ***Probed test die containing many pad designs***

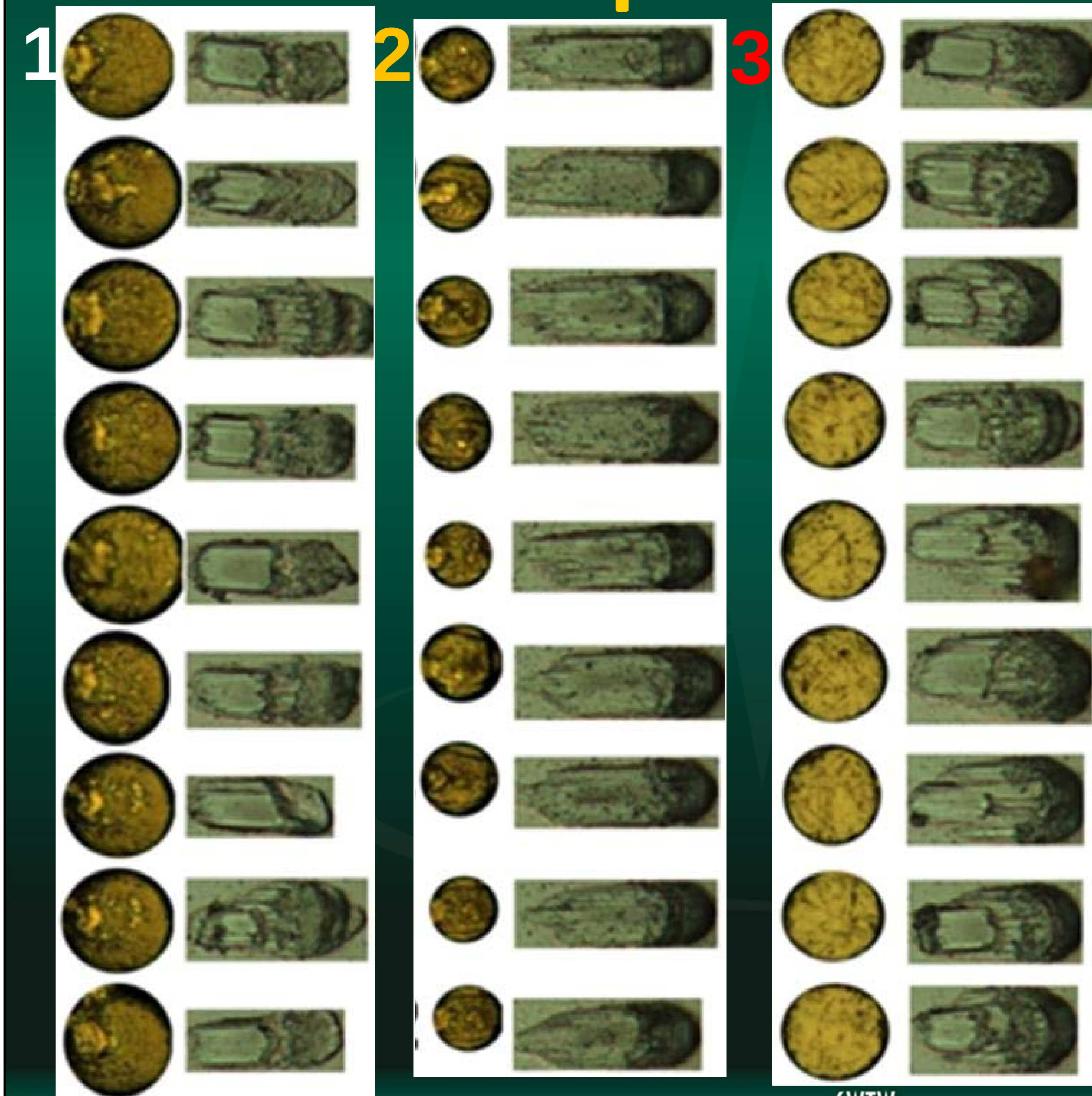
Cantilever Probe Tips

- **Probe tips in two tiers**
- **Probes 40 bond pads in a rectangle on test die**
- ***All probing:***

6 touchdowns at 4mils overdrive

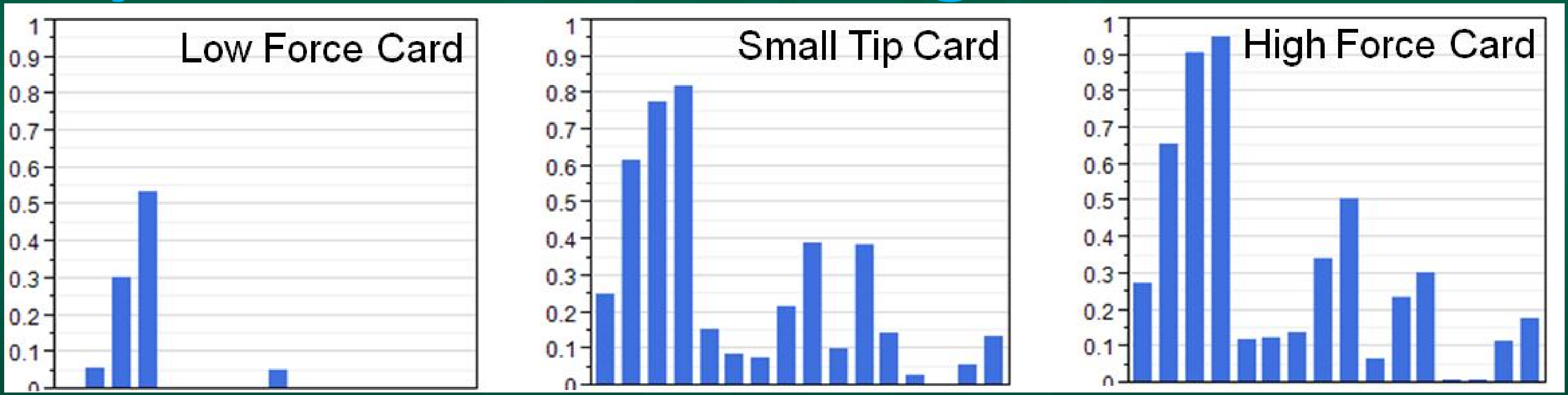


Probe Tips and Probe Marks



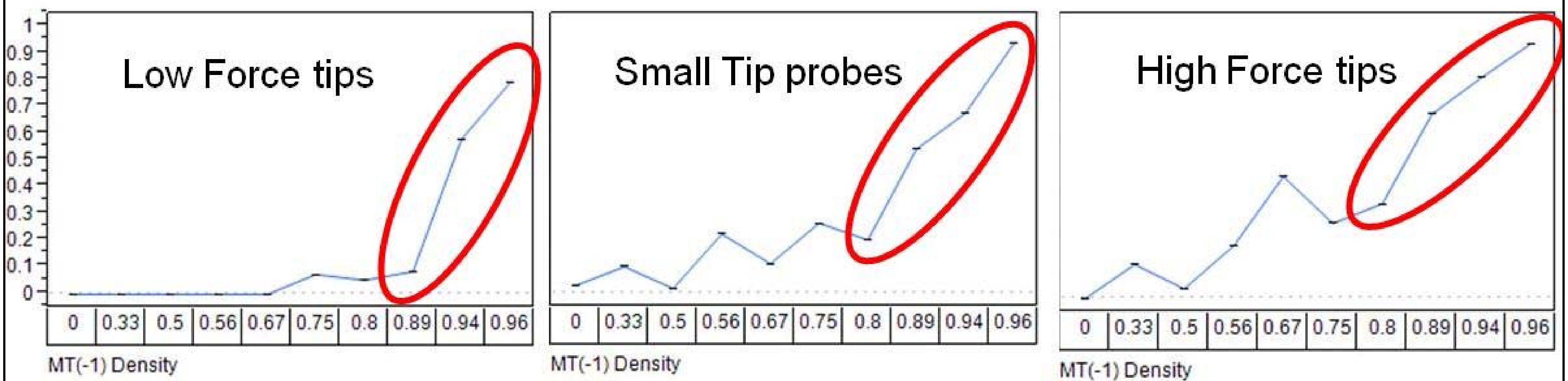
1. **Low Force**
   - 1mil tips
   - *least* cracking
2. **Small Tip**
   - 0.7mil tips
   - longest marks
   - high cracking
3. **High Force**
   - 1mil tips
   - *most* cracking

Fraction of Pads Cracked vs 16 Experimental Pad Designs *by Probe Card*



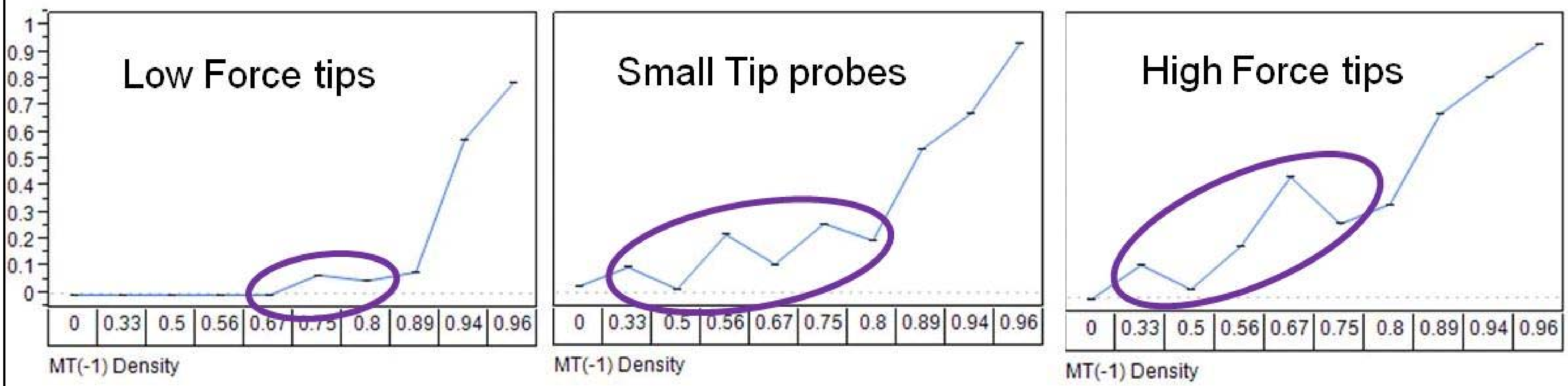
1. **Low Force tips caused the least cracking**
2. **Small Tip probes caused nearly as much cracking as the High Force probes**
   - small tip creating higher stress is more likely for cracks than the reduced tip angle *(0.7mil tip has half the area of 1mil tip)*
3. **Certain pad designs are more susceptible to cracking, regardless of probe tips used**

Fraction of Pads Cracked vs MT(-1) Pattern Density *by Probe Card* (1)



- **Cracking increases with increasing MT(-1) pattern density, regardless of probe card**
- **Cracking threshold starts at lower MT(-1) density in harsher probing**

Fraction of Pads Cracked vs MT(-1) Pattern Density *by Probe Card* (2)



- **Harsh probe scrub *perpendicular* to the MT(-1) metal stripes causes more cracking though pattern density is lower**
- **Under high probe stress, there is similar interaction with the MT(-2) stripes pattern**

Summary of Cracking Results (1)

- **High Force probes caused the most cracking**
  - probe mark width tends to be less than the tip diameter
- **Small Tip probes also caused high cracking**
  - reduced tip area causes higher stress
  - increased latent damage observed
  - smaller curvature of probe cracks
  - probe mark width tends to match the tip diameter
    - possible effect from reduced bend angle in *harsh probing*
- **Low Force probes caused the least cracking**
  - probe mark width is much less than the tip diameter

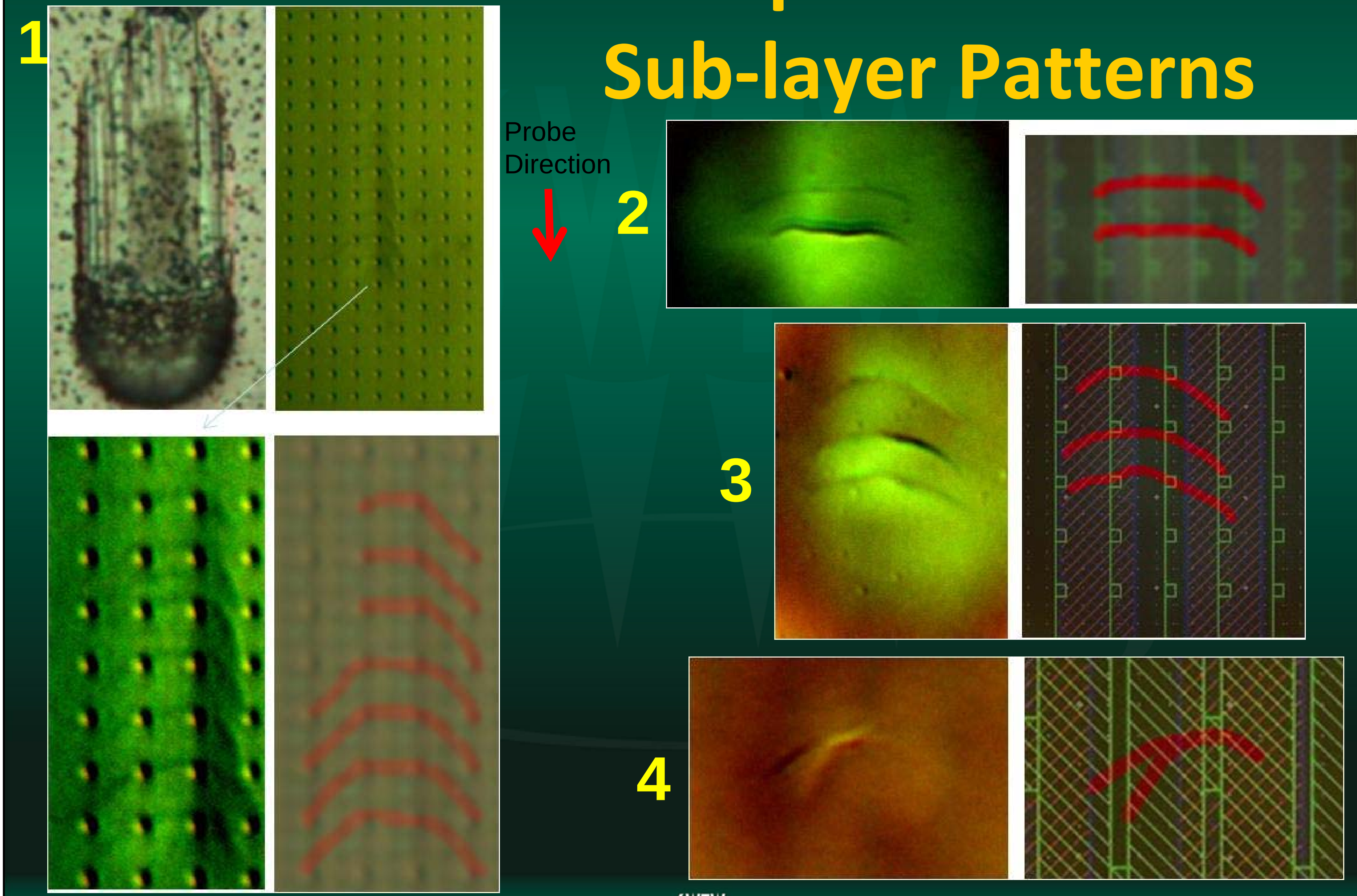
Summary of Cracking Results (2)

- **Main results among the 3 cards can be explained simply by probe stress**
  - High Force and Small Tip probes produce similar stress and cracking
  - Low Force probes exert less stress and cause less cracking

Summary of Cracking Results (3)

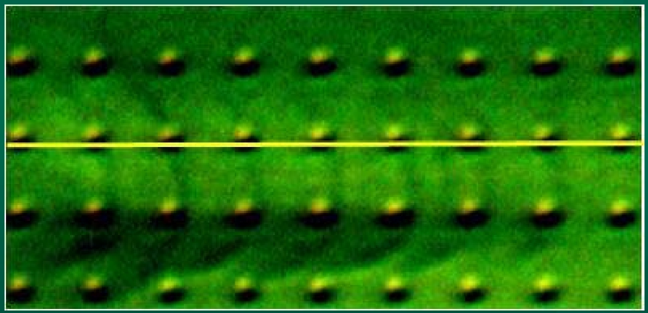
- Probe scrub perpendicular to sub-layer metal pattern stripes causes more tendency for cracks in *harsh probing*
- *Longer* probe tips of Low Force probes caused slightly *less cracking*
- Probe tip length *not* a factor for harsh probe conditions on the "harsher" probe cards
- Larger probe mark area correlates generally to increased cracking
- Probe marks are all very deep (essentially no pad Al remaining in gouge region), due to *6 touchdowns at 4mils overdrive*

Small Tip Pad Cracks and Sub-layer Patterns

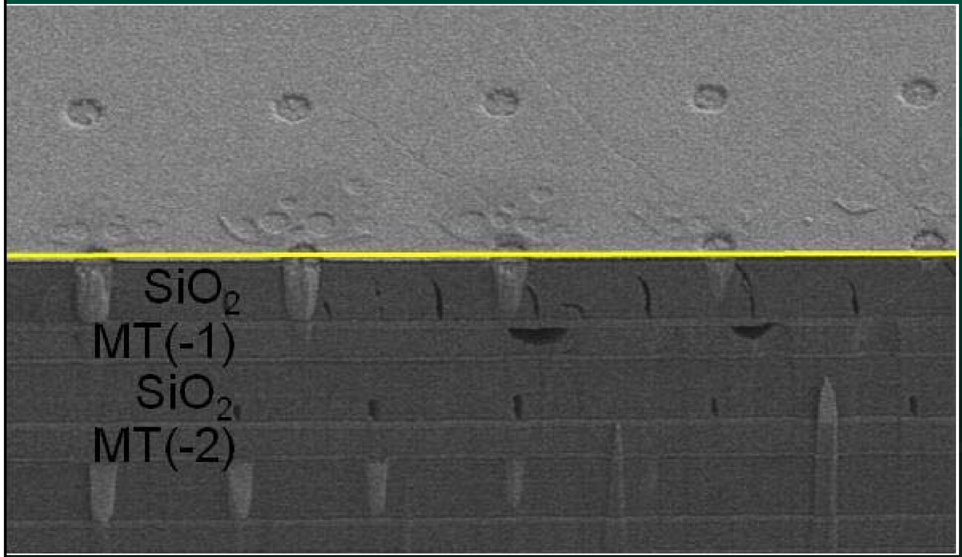


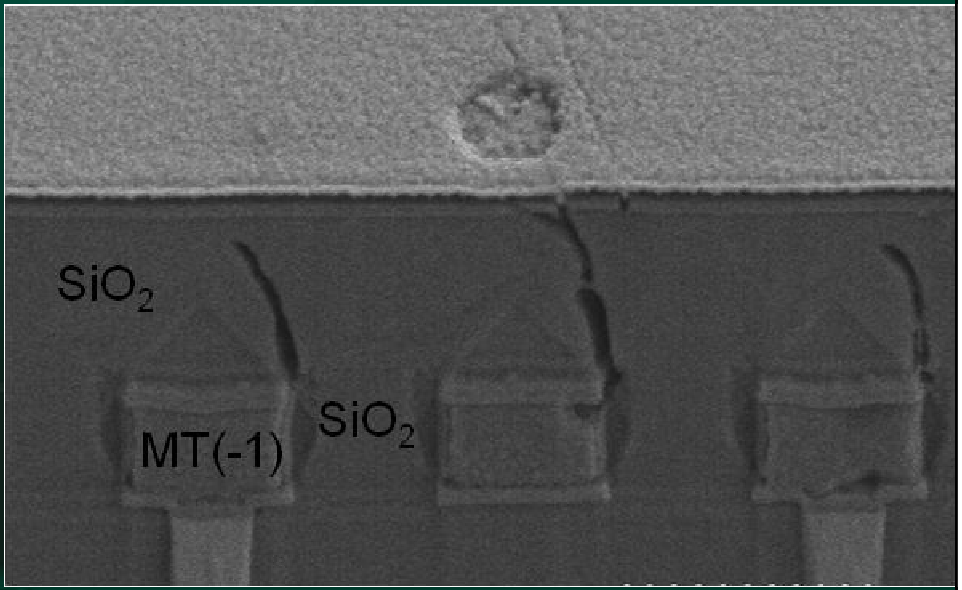
Small Tip Cracking with Top Vias

1

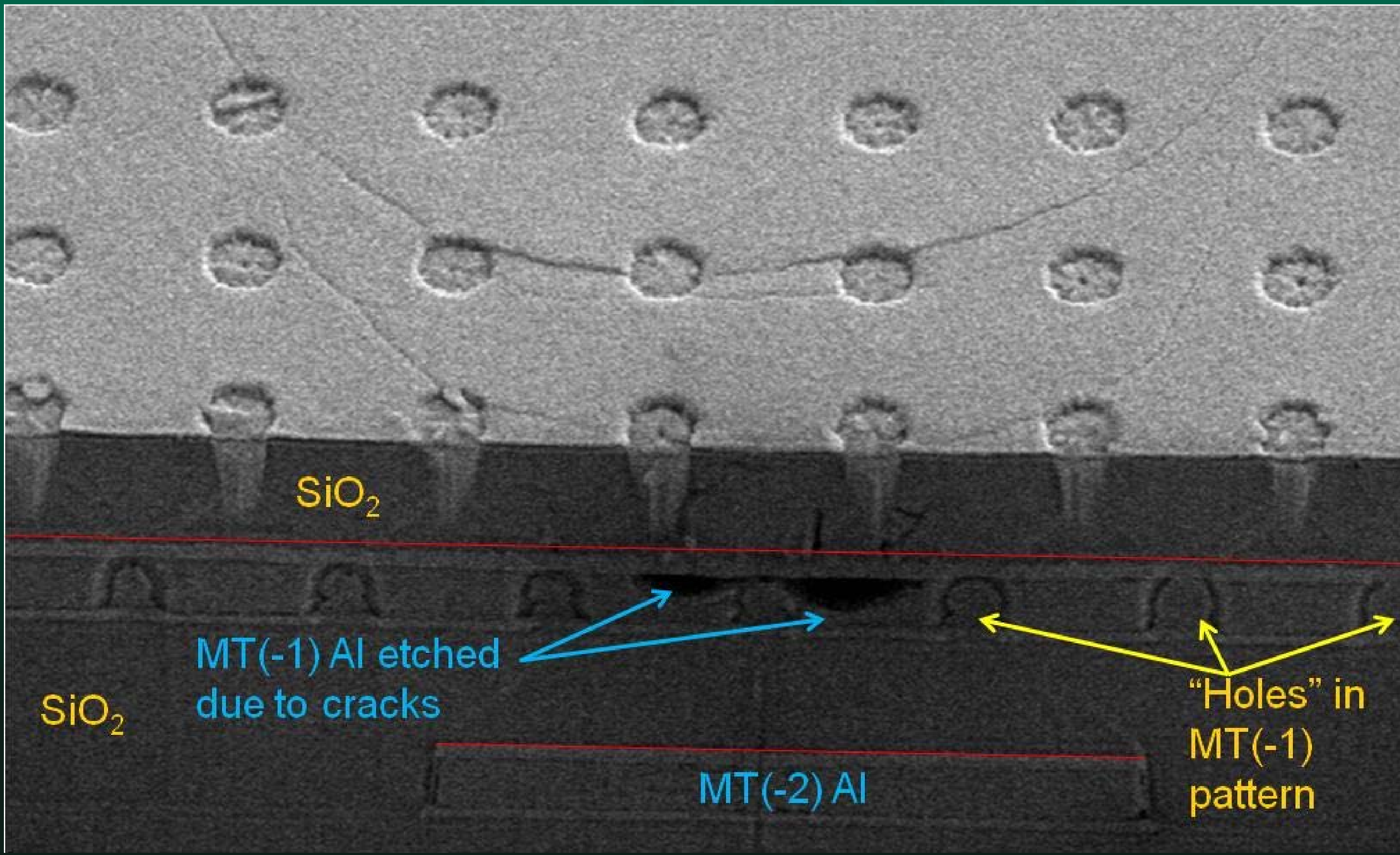


- Cracking example 1 from the previous slide is cross sectioned to reveal latent cracking, not visible in the "cratering" test

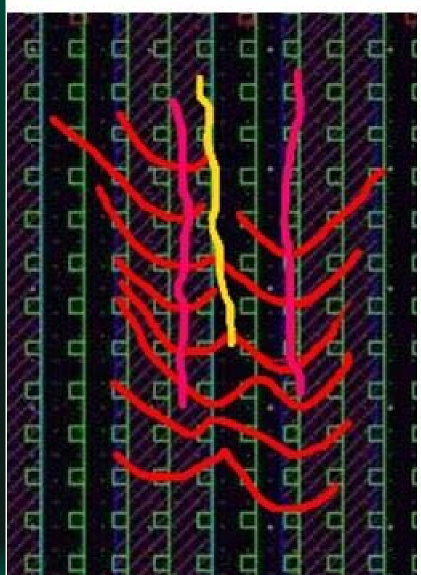


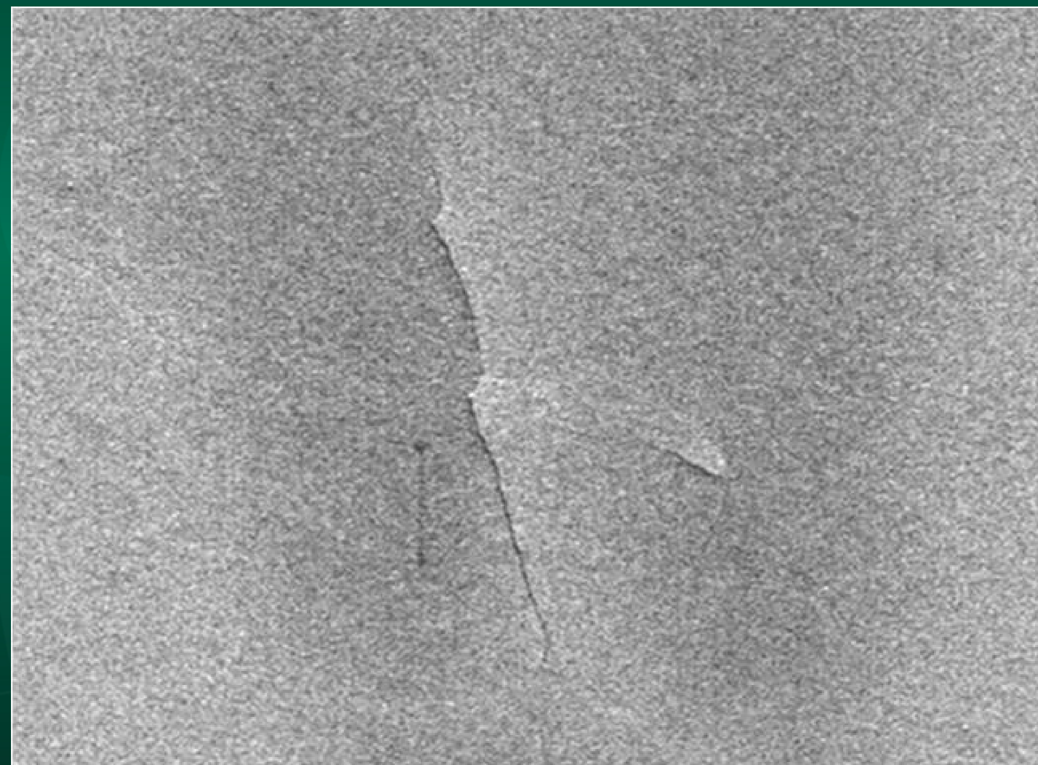


Small Tip Cracking with Dense Top Vias (cut perpendicular)



High Force Cracking Example



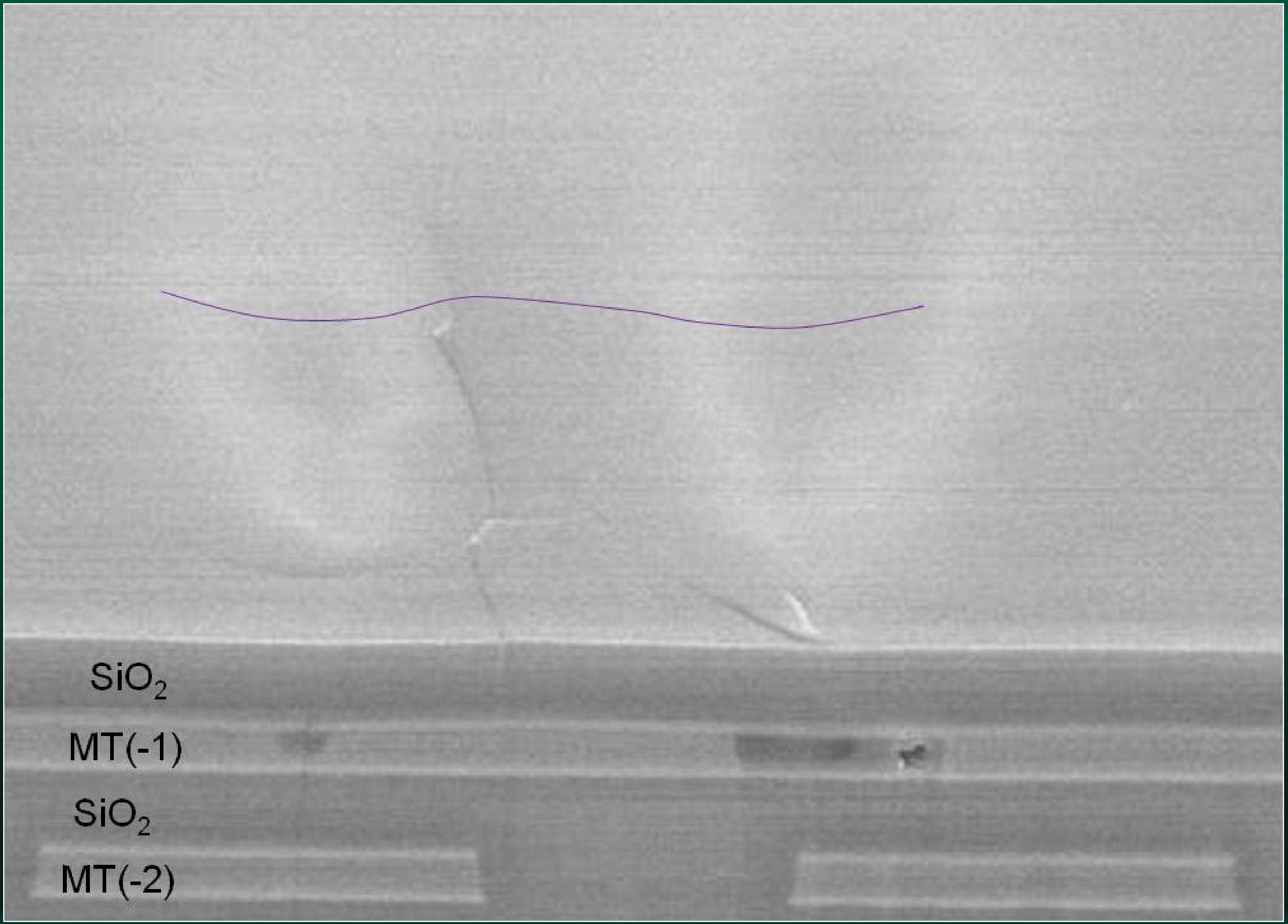


Probe direction

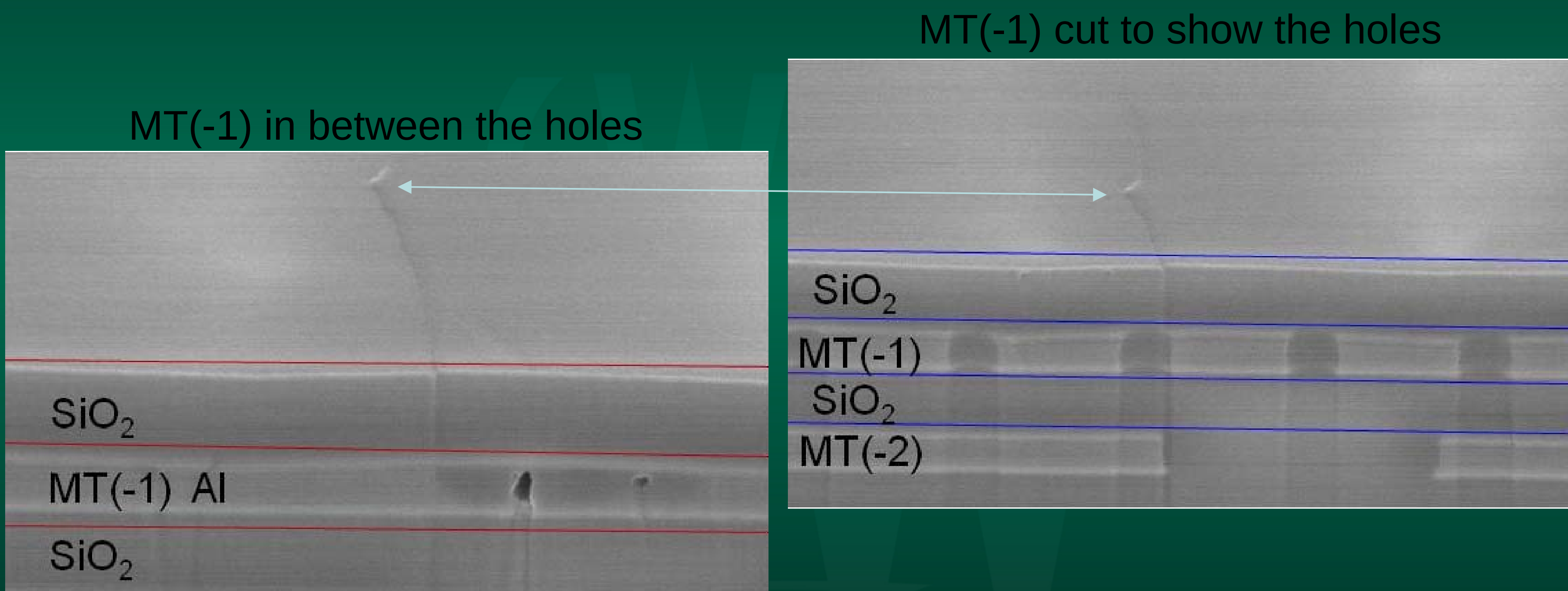
- “Regular” probe cracks are split, accompanied by a perpendicular crack corresponding to the MT(-2) pattern

•Red: cracks relate to the array of holes in MT(-1) but split where no MT(-2)
•Pink: valleys above MT(-2) metal
•Yellow: Crack along the ridge, transition between MT(-2) metal and SiO_2

Cross Section of High Force Cracking



Two Cuts of High Force Cracking



- *Lines are drawn to highlight the rippled layers*
- *The major crack is on the "hill", corresponding to the MT(-2) metal edge*
- *Minor cracks are in the "valley"*

Pad Cracking Review

- Top SiO_2 bends and cracks during harsh probing with the deformation in sub-layer Al
- Ripple and cracking increase when harshly probing over large regions of sub-layer Al
- Higher probe stress (gf/mil^2) causes increased cracking
- Probe scrub interaction with MT(-1) pattern is most significant in harsh probing
- Probe scrub interaction with MT(-2) pattern is a secondary effect observed in harsh probing

Comparison of Cracks Among 3 Probe Cards in Harsh Probing

- **Low Force tips caused the *least cracking***
- **High Force tips caused the *most cracking***
- **Small Tip probes also caused high cracking**
  - high cracking can be explained by higher stress due to smaller probe tips
  - reduced tip angle doesn't seem to cause major effects in harsh probing
- **Differences in probe mark and cracking performance are reasonably understood**

Summary / Recommendations for Probing Thin Al CUP Pads (1)

- **Prevent pad cracks by *reduced probing stress***
  - larger tip diameter
  - low tip force per mil of overdrive
  - low chuck overdrive
- **No cracking effect found from reduced tip angle in harsh probing**
  - cracking observations are explained by tip diameter
  - (use small probe tips and smaller angle to reduce probe mark area *when not harshly probing*)

Summary / Recommendations for Probing Thin Al CUP Pads (2)

- **Be cautious when using small probe tips**
  - 0.7mil tip causes 2x stress as compared to 1mil
  - monitor for cracking when reducing tip size
  - watch for increased latent damage beneath the probe marks due to high stress to a smaller contact area
- **[Prevent pad cracks by *robust CUP pad design*]**
- **[Thicker pad Al increases the margin against cracking]**

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2011 Conference Presentations for Ref.

1. **Hunter, et al, "Use of Harsh Wafer Probe to Evaluate Various Bond Pad Structures",** ***IEEE SWTW, Jun 2011***
2. **Hunter, et al, "Use of Harsh Wire Bonding to Evaluate Various IC Bond Pad Structures",** ***IMAPS EMPC2011, Sep 2011***
3. **Hunter, et al, "Physically Robust Interconnect Design in Bond Over Active Circuitry for Cu Wire Bonding",** ***IMAPS / SEMI Wirebonding Workshop, Jul 2011***
4. **Martinez, et al, "IC Bond Pad Structural Study by Ripple Effect",** ***IMAPS 2011, Oct 2011***
5. **Hunter, et al, "*Bond Over Active Circuitry Design for Reliability*", IMAPS 2011, Oct 2011**