Adhesion Characterization of $SiCN/SiO_2$ In BEOL And Thin Si/Passivation For TSV Integration Using Nanoscratch Technique

Guohua Wei, Sam Ireland, Junting Liu-Norrod, Jaspreet Gandhi, Irina Vasilyeva, Anurag Jindal, Rita Klein, Tom Mendiola, Harold Krasinski, David Fillmore and Shifeng Lu

Micron Technology, Inc.,

8000 S. Federal Way, Boise, ID, 80707, USA

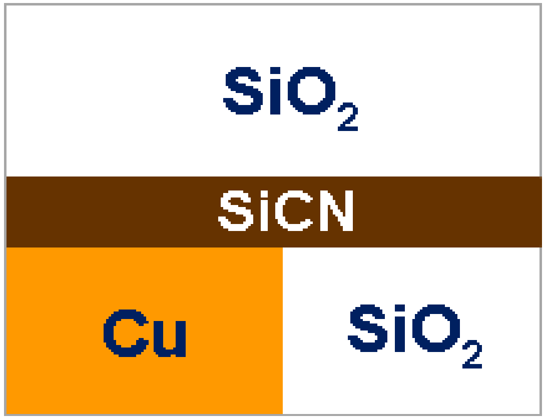
2013 FCMN, March 27

Introduction

- Interfacial adhesion is critical to the reliability of microelectronic/nanoelectronic devices.
- The metrology for adhesion characterization plays an important role in enabling process development and optimization to produce interfaces possessing reliable adhesion.
- The 4 Point Bend (4PB) technique is widely accepted as the standard method for quantitatively measuring interfacial fracture energy [1], even for interface with ultra-thin (3 - 4 nm) adjacent films [2].
- Although it is a powerful technique, there exist interfaces and sample geometries that are challenging for 4PB to measure.

Introduction (Cont'd)

➢ In Back End of Line (BEOL), a dielectric barrier film such as SiCN is adjacent to both Cu and SiO_2 layers**. The SiCN/SiO_2 interface adhesion is challenging for 4PB to measure.**



(a)

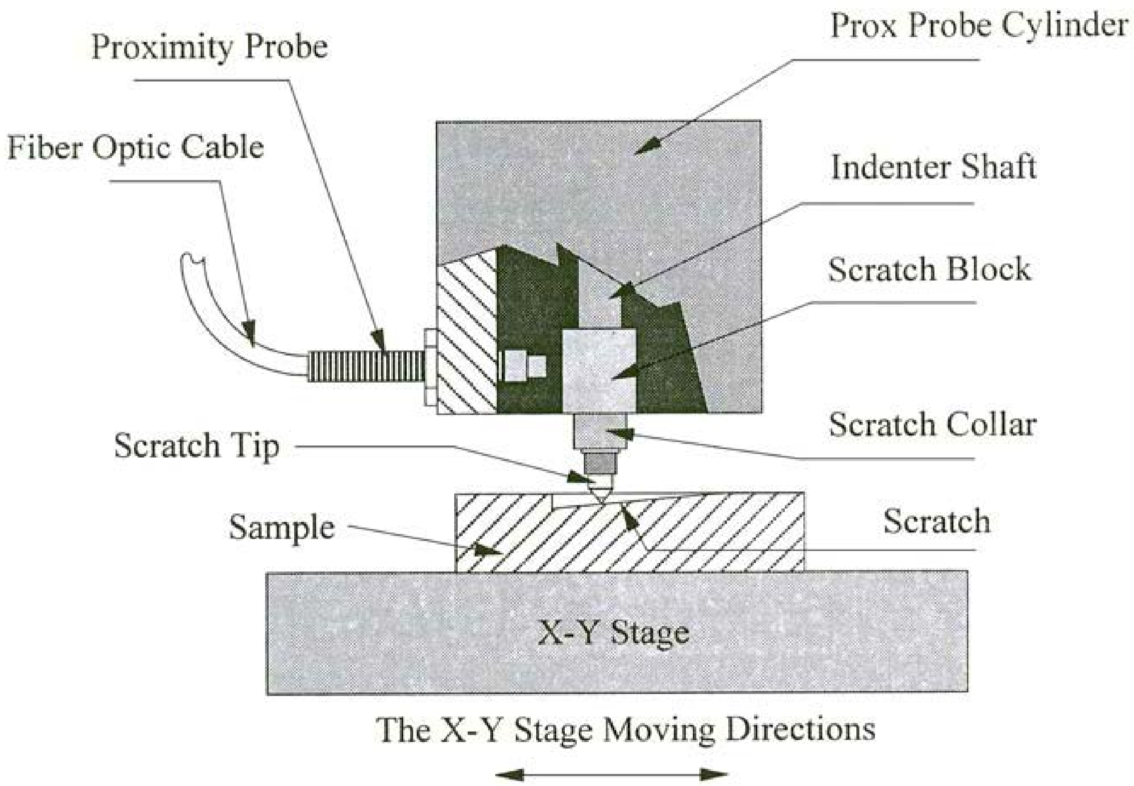
(b)

SEM image showing the SiO_2/SiCN delamination (part of SiO_2 films are gone).

➢ Through-Silicon Via (TSV) integration involves thinning the Si wafer that contains TSVs and then depositing a passivation layer on the back side of the Si. **The adhesion between thinned Si (< 100 μm) and passivation layer is challenging for 4PB to measure.**

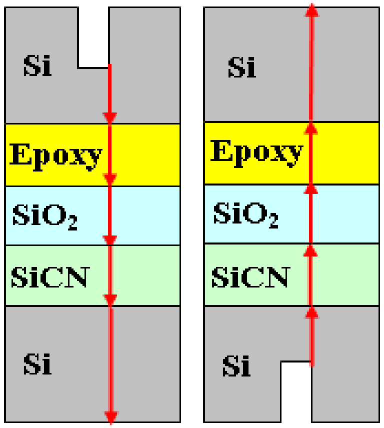
Experimental

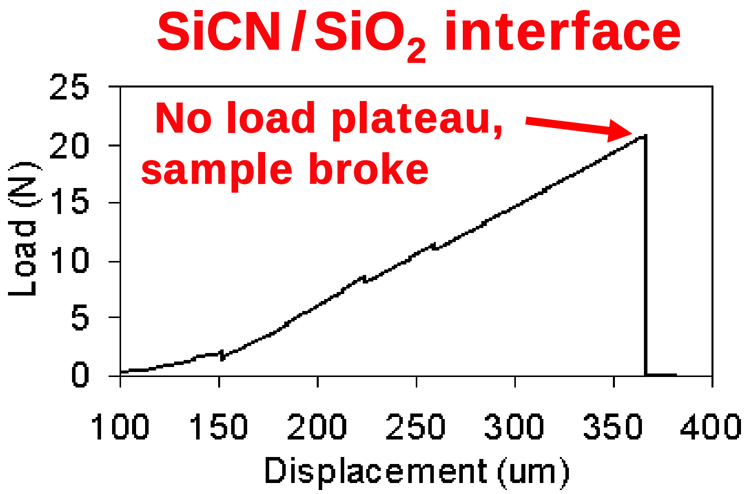
- **Metrology:** Ramping-load nanoscratch technique [3-5], a qualitative method for adhesion measurement

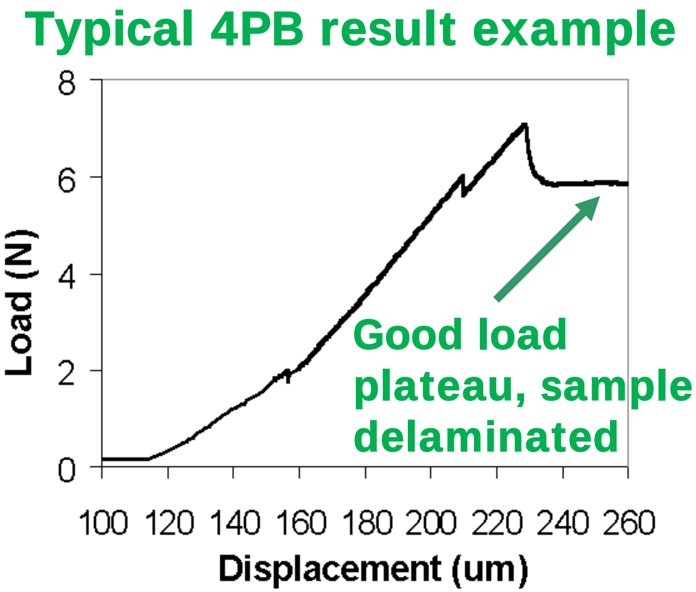


- **Samples**
  - Six Si/SiCN/SiO_2 wafers deposited with different SiCN processes
  - Four Si/ passivation wafers prepared with various thinning and cleaning methods

Adhesion of SiCN / SiO_2 by 4PB





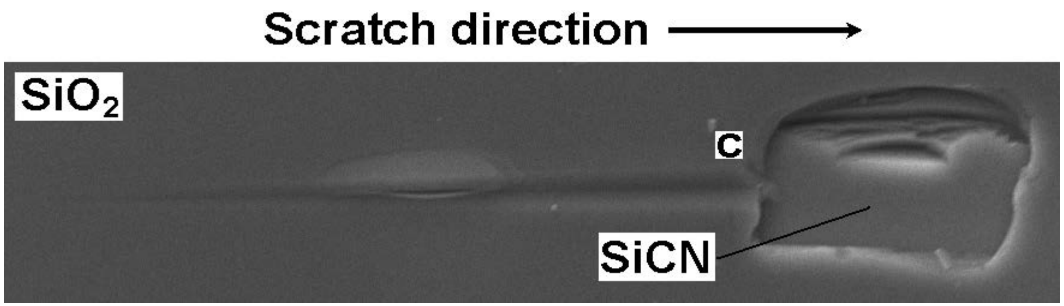


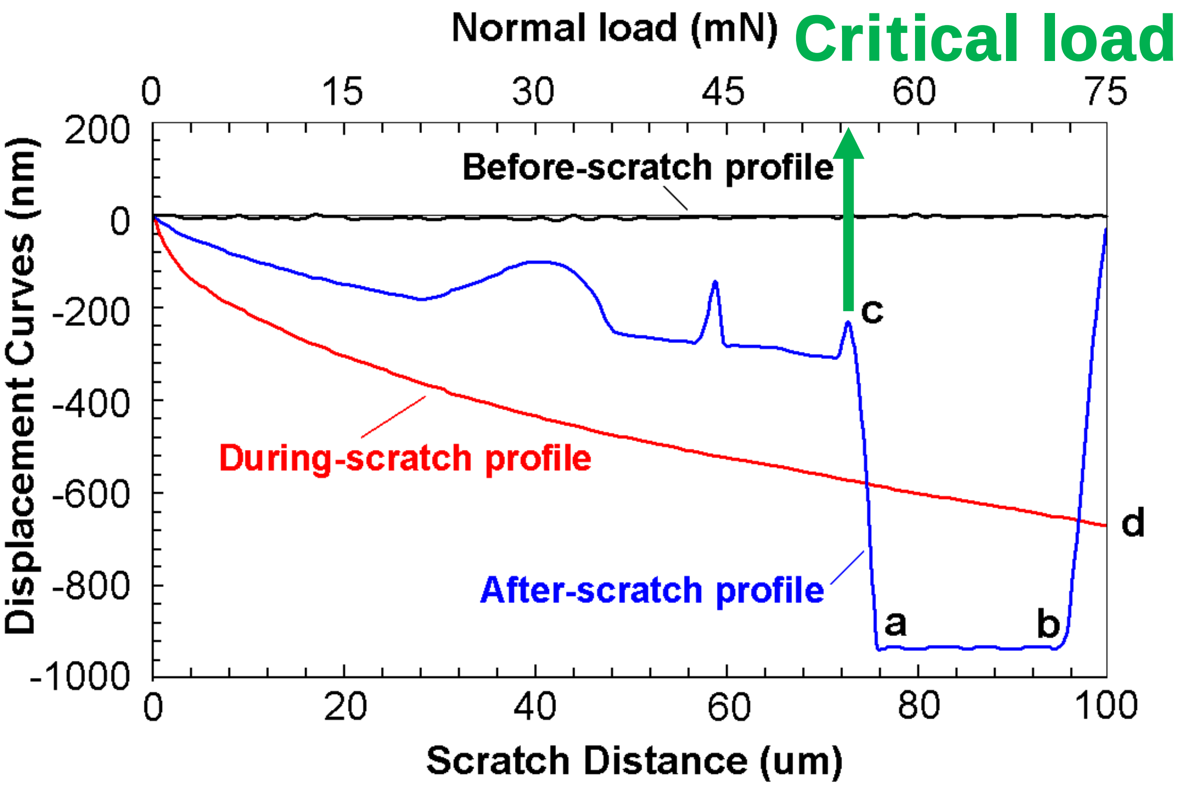
➢ Crack penetrated the SiCN/SiO_2 interface vertically at a high load instead of propagating along it.

➢ Both SiCN and SiO_2 are brittle materials. It is possible that the SiCN/SiO_2 interface fracture toughness exceeds ¼ of that of SiCN and SiO_2, leading to crack penetration across the interface [6].

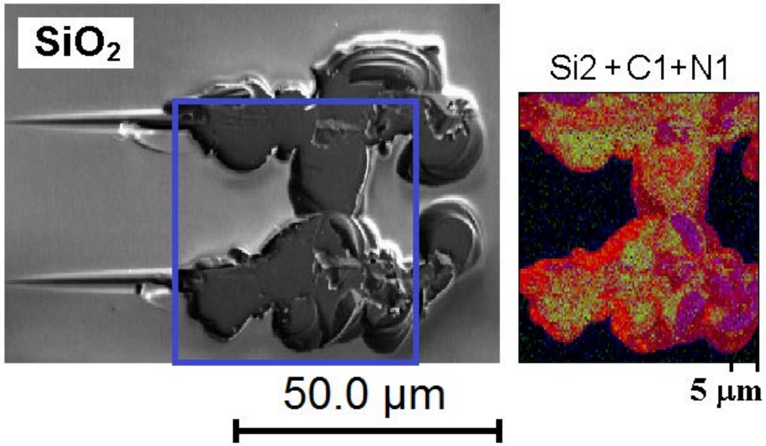
Adhesion of $SiCN/SiO_2$ by Nanoscratch

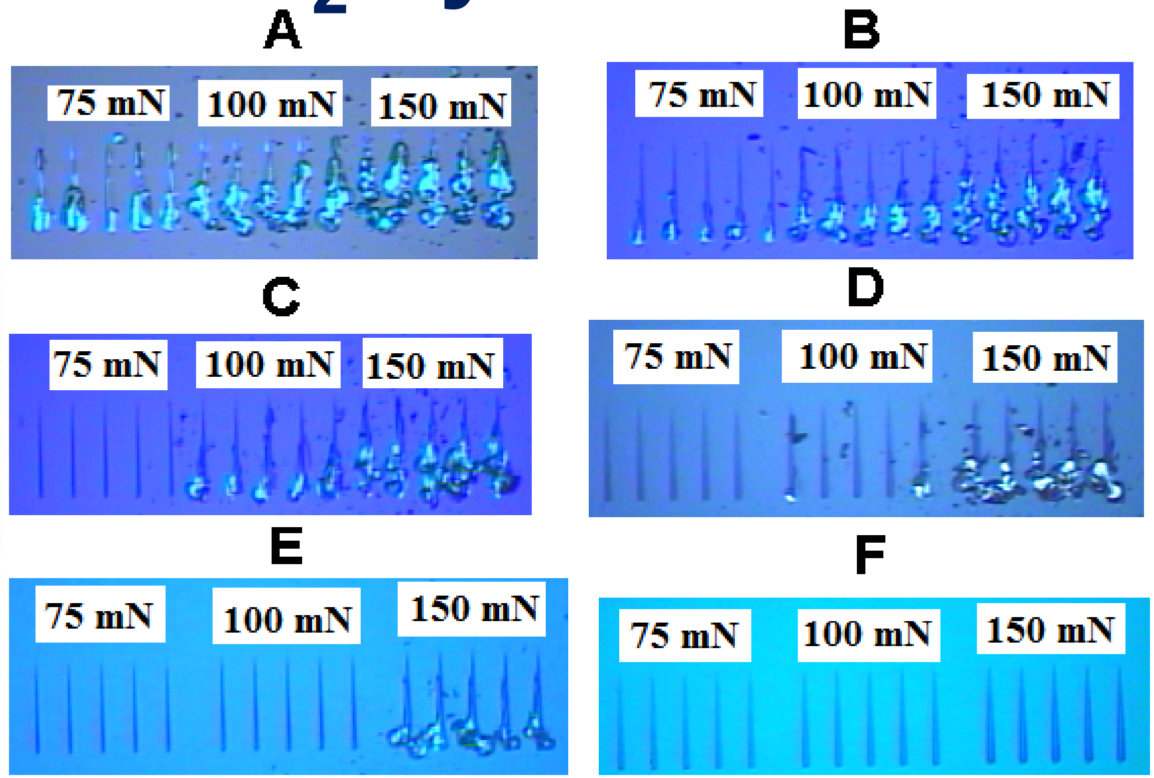
- **Point d:** maximum *in situ* depth < SiO_2 thickness ➡ scratch tip did not penetrate into the $SiCN/SiO_2$ interface during the entire nanoscratch test
- **Point a to b:** residual scratch depth close to SiO_2 thickness ➡ SiO_2 delaminated
- **Point c:** critical position ➡ delamination initiated





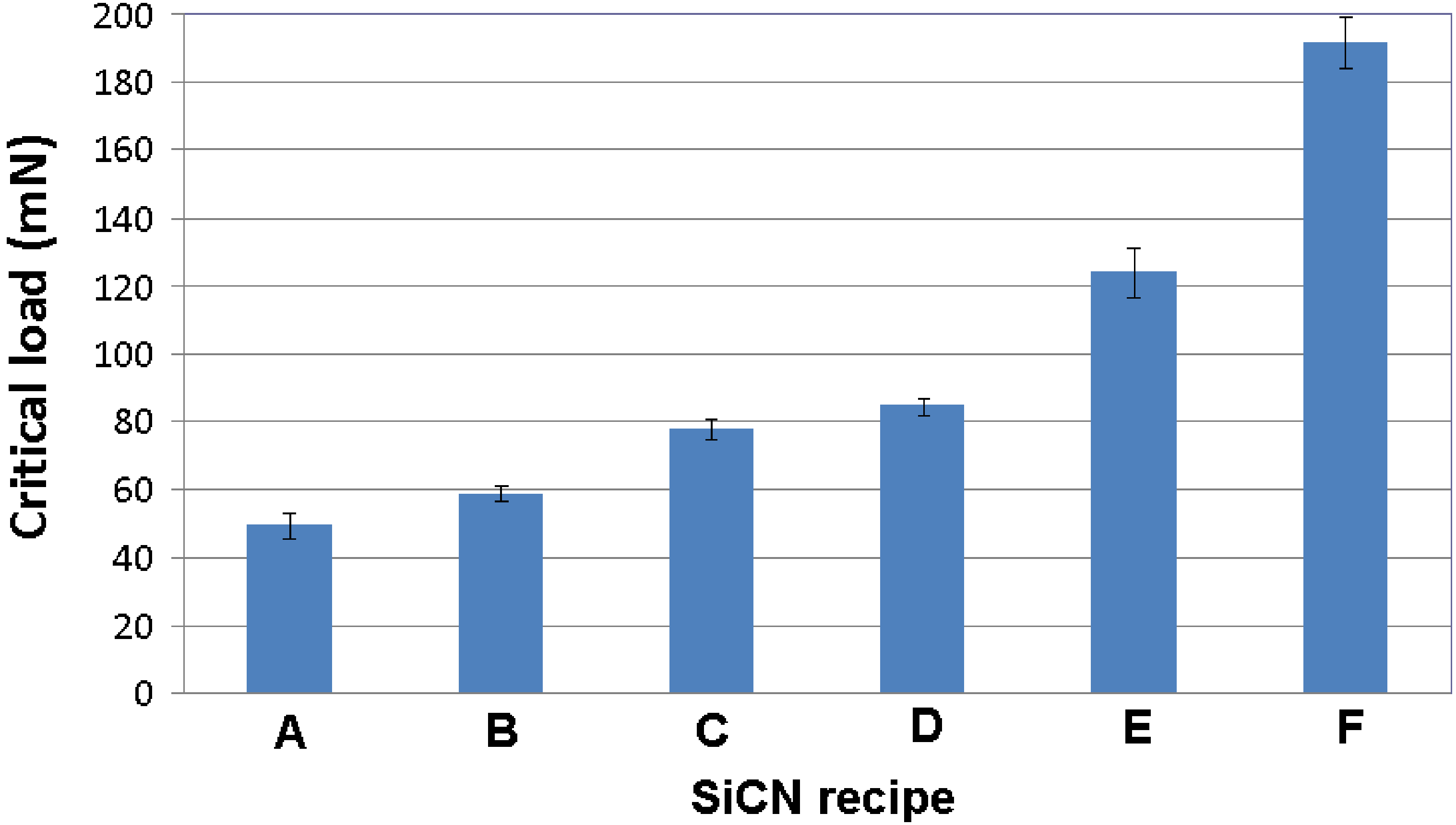
Adhesion of SiCN/SiO_2 by Nanoscratch





- AES detected Si, C and N signal at the delaminated area, confirming the SiCN/SiO_2 delamination.
- The shining regions in the optical images indicate the exposed SiCN.

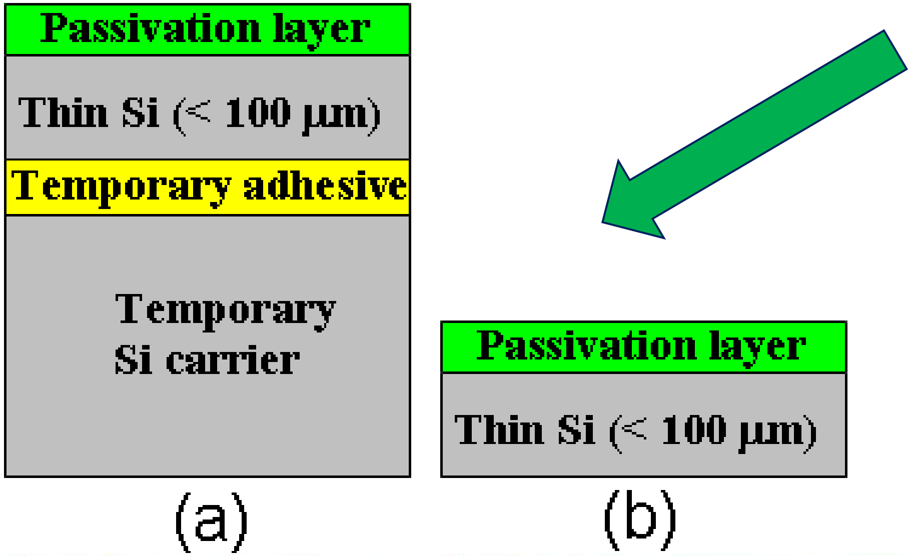
Adhesion of $SiCN/SiO_2$ by Nanoscratch



➢ By changing the SiCN deposition process, the $SiCN/SiO_2$ adhesion was significantly improved from sample A to F, as shown in both the optical images and critical loads.

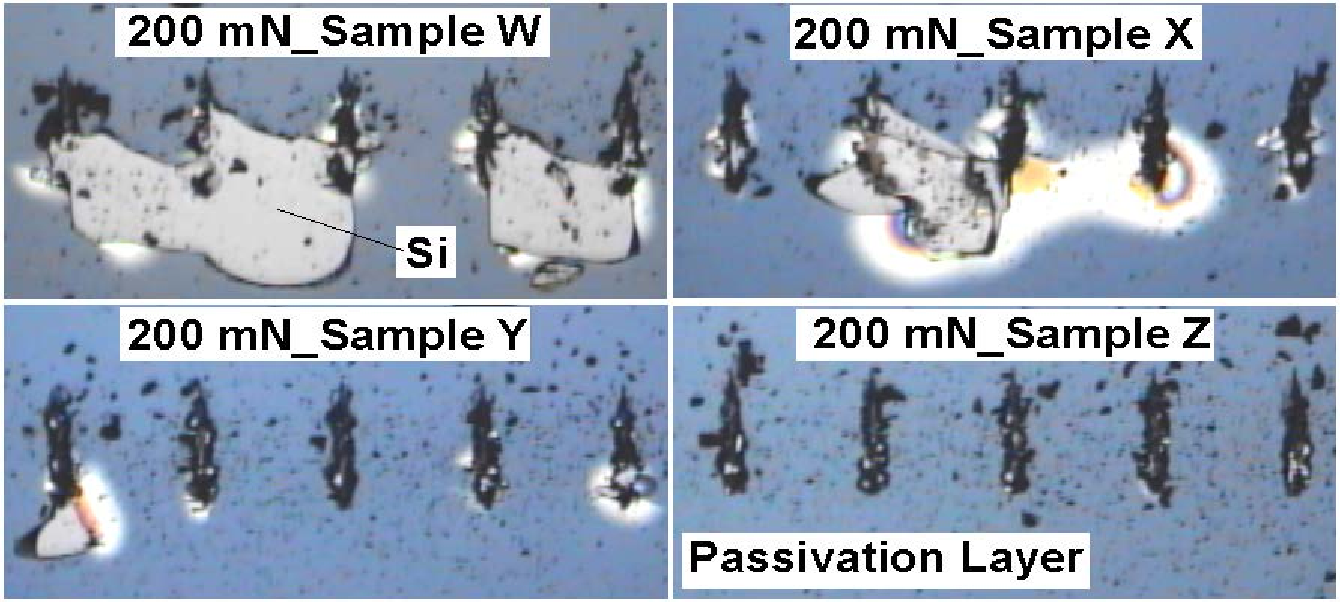
Adhesion of Thin Si / Passivation

- During the 4PB test, the samples with adhesive (a) were delaminated at the Si/adhesive interface; the samples without adhesive (b) broke.



Wafer stack seen during the TSV integration process

- Nanoscratch test was able to induce Si/passivation delamination and clearly detect the adhesion difference among four wafers with adhesive (a).



Conclusions

- The nanoscratch technique is able to characterize the adhesion of SiCN/SiO_2 interface used in BEOL, a “brittle/brittle” interface with strong adhesion, which is challenging for 4PB to measure.

- By controlling the normal load, thus the penetration depth, the nanoscratch-induced stress was controlled to be high enough to delaminate the SiCN/SiO_2 interface, but not sufficient to initiate crack in the underlying SiCN layer.

- The capability of nanoscratch technique as a member of the adhesion characterization metrology family is further demonstrated by its successful characterization of the thin Si/passivation adhesion for TSV integration.

References

1. R. H. Dauskardt, M. Lane, Q. Ma and N. Krishna, *Eng. Fract. Mech*. **61**, 141-162 (1998).
2. R. P. Birringer, P. J. Chidester and R. H. Dauskardt, *Eng. Fract. Mech*. **78**. 2390-2398 (2011).
3. W. J. Liu, J. N. Zhou, A. Rar and J. A. Barnard, *Appl. Phys. Lett.* **78**, 1427-1429 (2001).
4. G. Wei and J. A. Barnard, *J. Appl. Phys.* **91**, 7565-7567 (2002).
5. G. Wei, J. Liu, D. Fillmore, M. Violette and S. Lu, *Mater. Res. Soc. Symp. Proc*. **997**, I10-09 (2007).
6. A. R. Akisanya, N. A. Fleck, *Int. J. Fract.* **55**, 29 (1992).

Micron®

Focused on Memory | Engineered for Innovation