FIB/SEM Structural Analysis of Through-Silicon-Vias (TSV)

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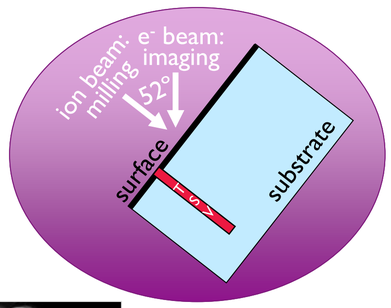
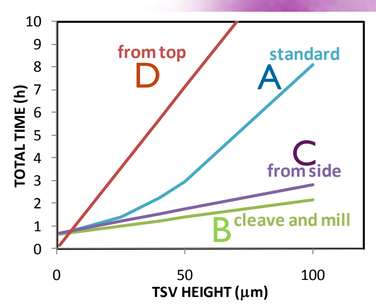
Introduction

- Structural analysis of TSV for control of: Cu filling (voids), grain size, barrier and oxide liner, for stacked dies also: bonding quality and alignment.
- FIB challenges: dimensions vs required resolution, SEM depth of focus, 3D analysis, curtaining, analysis time, no cleaving possible for stacked dies.

DB FIB/SEM





Results : milling configurations

A : Staircase + line milling

B : Cleave + line milling

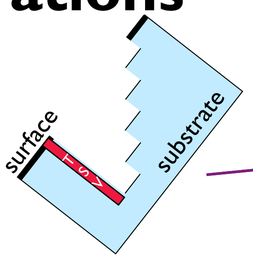
C : Cleave + mount on edge + mill parallel TSV axis

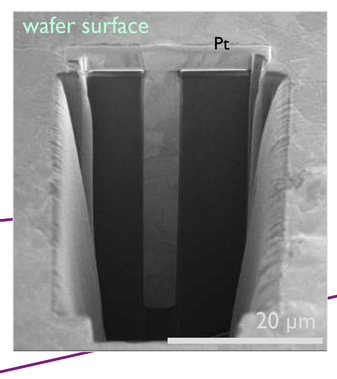
D : Cleave + mount on edge + mill from top TSV

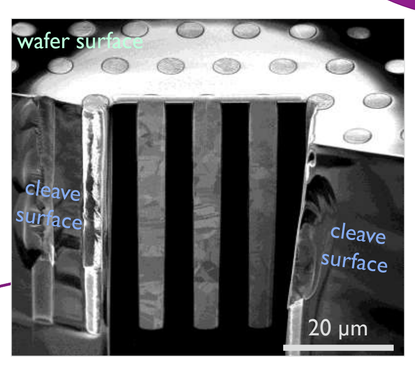
E : Inclined milling from surface

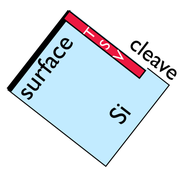
F : Staircase + inclined milling

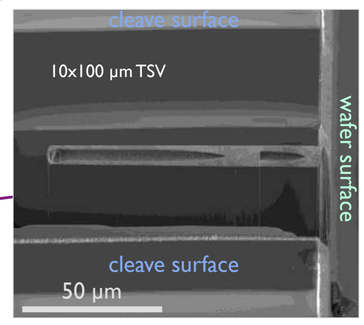
G : Inclined milling in cleaved face

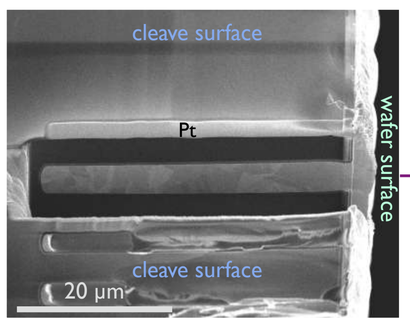


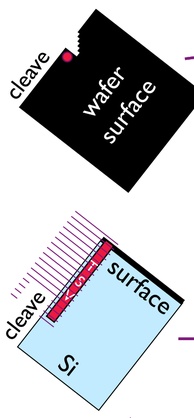


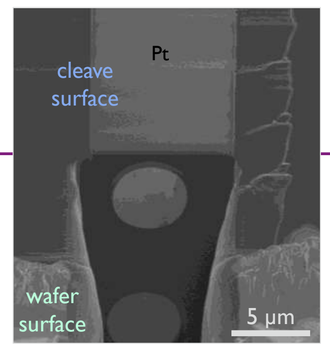


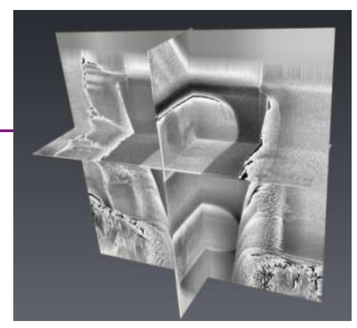


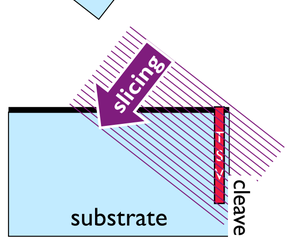


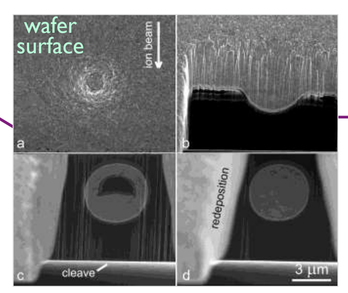


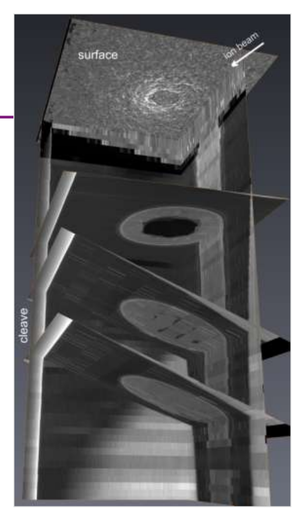


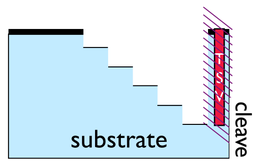


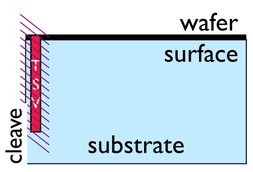


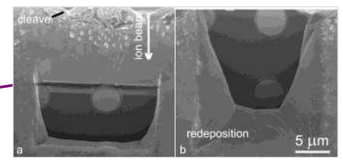




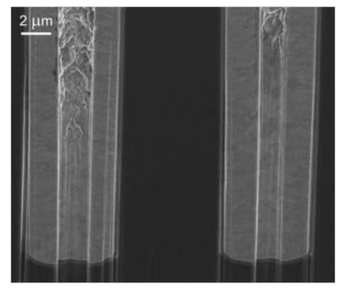




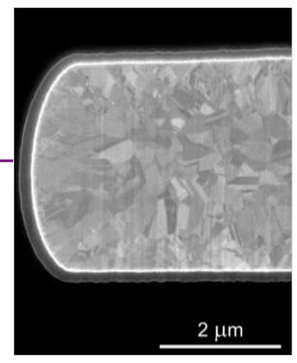




Curtaining

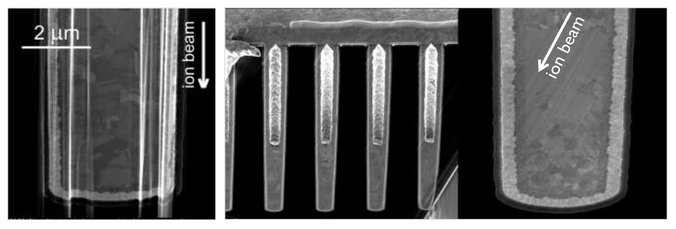


A, B : strong curtaining under oxide liner and voids

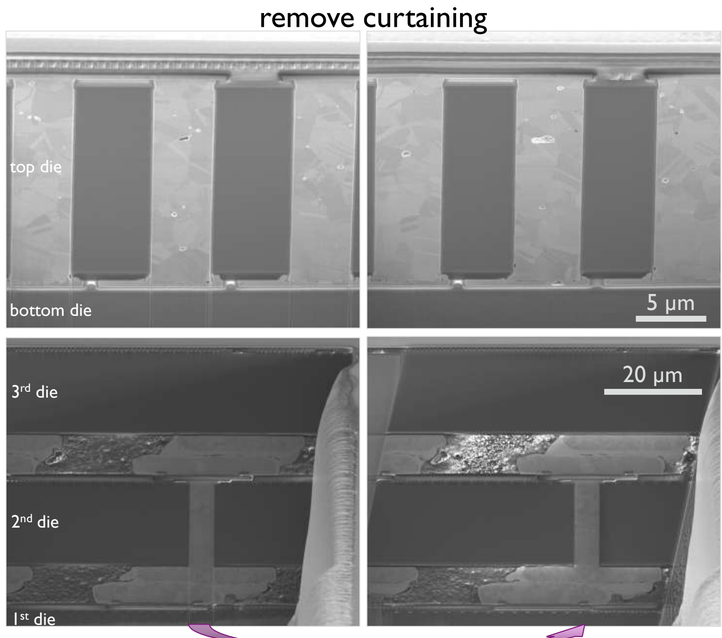


C : weak, non-harmful curtaining

A, B : tilted milling reduces curtaining



A : tilted milling applied to stacked dies to remove curtaining



Comparison FIB/SEM techniques

		Dual beam FIB/SEM									
	Embed & polish	**A Staircase + line milling**	**B Cleave & line milling**	**C On edge, mill parallel axis**	**D On edge, mill from top**	**E Inclined milling from surface**	**F Staircase + inclined milling**	**G Inclined milling from cleaved face**	**XeF_2 enhanced Ga-FIB**	**Xe plasma-FIB**	**Laser ablation + Ga-FIB**
Speed	Slow	Slow	Medium	Medium	Slow	Slow	Slow	Slow	Fast (+ Slow slicing)	Fast (+ Slower slicing)	Fast (+ Slow slicing)
Typical for 5x50 µm TSV	8 h	6-8 h	3-4 h	3-4 h	> 8h	> 8h	> 8h	> 8h		1 h	(3-4 h)
Area	Large	>30x50 µm²	>30x50 µm²	>50x10 µm²	>10x10 µm²	>100x10 µm²	>100x10 µm²	>20x20 µm²	>30x50 µm²	>100x100 µm²	>100x100 µm²
3D	~	Slice and view	Slice and view	Slice and view	Slice and view High SEM magnification but moves out of view	Slice and view High SEM magnification but projected ellipse	Slice and view High SEM magnification but projected ellipse	Slice and view High SEM magnification but projected ellipse	Standard FIB slice and view	Slice and tilt Slice and Ga-image	Standard FIB slice and view
Curtaining	Polishing artefacts	Strong	Strong	Weak	Weak	Weak	Weak	Weak	As normal FIB	Strong	As normal FIB
Redeposition during line milling	-	Important	Weak	Less important (wide crater)		Weak on cleaved sample	Weak on cleaved sample	Important	As normal FIB		As normal FIB
Bonded dies	(Yes)	Yes	No	No	No	Yes (uncleaved)	Yes (uncleaved)	No	Yes	Yes	Yes
	Patient operator	Mature Best for bonded dies	Mature Best for cleavable samples	Mature Best for >50 µm TSV						System development No dual SEM	System development

Conclusion

- Standard FIB/SEM can yield very detailed information on TSV quality and stacking but is too slow.
- Configuration C or milling under an angle (pretilted holder) are most efficient to reduce curtaining.
- Fast alternatives with larger field of view needed (Xe plasma, laser ablation, nano-XRT).