

EVALUATION OF POSSIBLE STANDARDS FOR X-RAY REFLECTOMETRY

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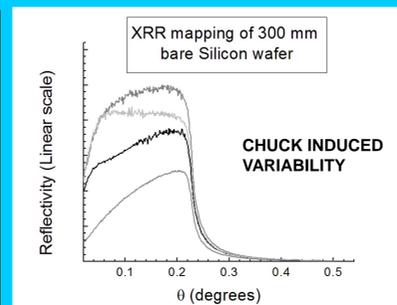
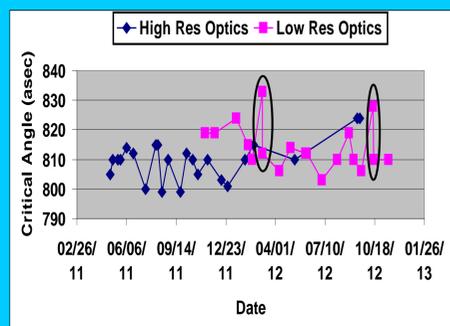
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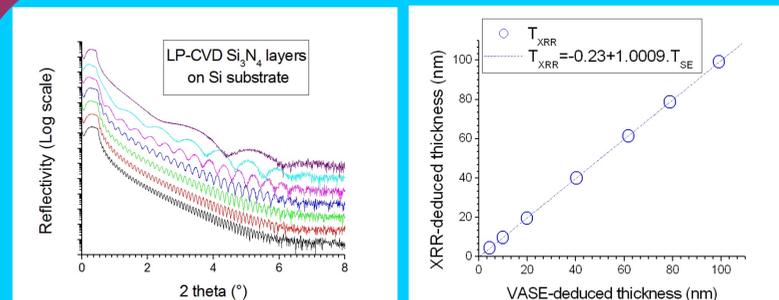
Introduction

- Increasing importance of XRR in semiconductor development and fabrication
- Need for Calibration Standard for both In-line metrology tools as well as new generation of analytical XRD/XRR tools
- Wish to obtain a suitable material to use as a calibration standard until NIST standard becomes available.
- Desire material that can be readily fabricated in semiconductor FAB.



Silicon Critical Angle

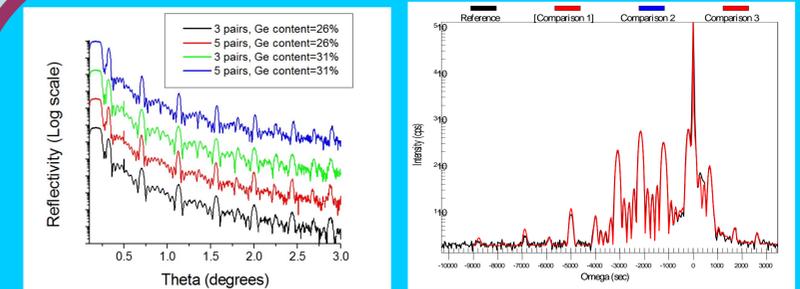
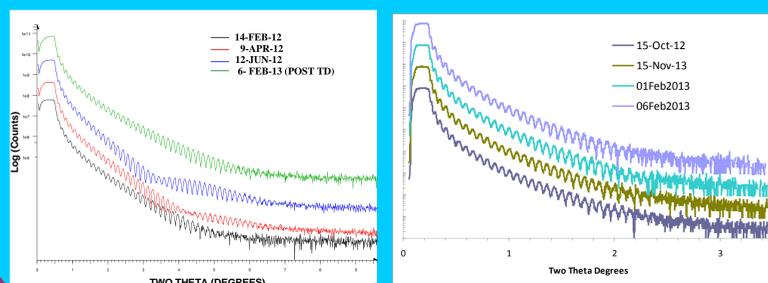
- Measurement of the critical angle of single crystal silicon was found to be more sensitive to instrument misalignment compared to other potential standards evaluated.
- On freshly prepared silicon (HF etch), observe growth of oxide on surface over two week period. No further growth observed after two weeks (cleanroom environment).
- Simulation studies suggest that surface oxide does not affect critical angle measurement.



Si3N4 Thickness (nm)	XRR Average Thickness (nm)	XRR Average Density (g/cm3)
20	19.6 (0.2)	2.77 (0.05)
40	40.0 (0.2)	2.77 (0.07)
60	61.4 (0.2)	2.77 (0.06)
80	78.6 (0.3)	2.85 (0.06)
100	99.2 (0.3)	2.83 (0.06)

Silicon Nitride

- Nitride ellipsometry standards found to be unsuitable due to variations in density with thickness (thickness spec from vendor requires that nitride be considered single homogenous layer on silicon).
- Si3N4 produced by LPCVD @950C found to have uniform density desired. Excellent agreement in thickness values between XRR and Variable Angle Spectroscopic Ellipsometry (VASE), as well as good correlation in data collected on different tools at different sites.
- Si3N4 films stable when stored in cleanroom environment, but problems with Airborne Molecular Contaminants (AMC) when stored in lab environment.



Si / SiGe Superlattice

- Si/SiGe superlattice structures fabricated by epitaxy on Si(001) substrates.
 - Si capping layer used to eliminate effect of surface oxide.
 - HRXRD: Structures characteristic of pseudomorphic stacks
- Fitted values of thickness found to be independent of Ge (fixed vs floating)

			T-Si-Top	T-2-SiGe	T-3-Si	T-4-SiGe	T-5-Si	T-6-SiGe
S02	Floated %Ge n=30	Average	20.08	10.15	9.80	10.11	9.77	10.23
		Sigma (nm)	0.07	0.05	0.04	0.06	0.06	0.05
	Fixed %Ge n=30	Average	20.09	10.18	9.78	10.11	9.78	10.26
		Sigma (%)	0.33	0.53	0.43	0.59	0.61	0.52
S10	Floated %Ge n=50	Average	20.15	10.22	9.92	10.10	9.89	10.09
		Sigma (nm)	0.10	0.09	0.07	0.07	0.06	0.05
	Fixed %Ge n=30	Average	20.06	10.34	9.85	10.17	9.86	10.14
		Sigma (%)	0.39	0.62	0.64	0.70	0.52	0.51

Conclusions

- Critical angle measurement of single crystal silicon provides a sensitive measure of instrument (mis)alignment.
- Silicon Nitride on silicon has potential to serve as an interim XRR reference standard. Uniform density critical.
- Issue of airborne contaminants will be challenge for any XRR standard stored outside a cleanroom.
- Si / Si-Ge superlattice structures have potential to serve a XRR reference standard for thickness.