Low Level of –OH Analysis in SiOx and SiCOH Dielectric Films by FTIR using Multiple Internal Reflection Technique

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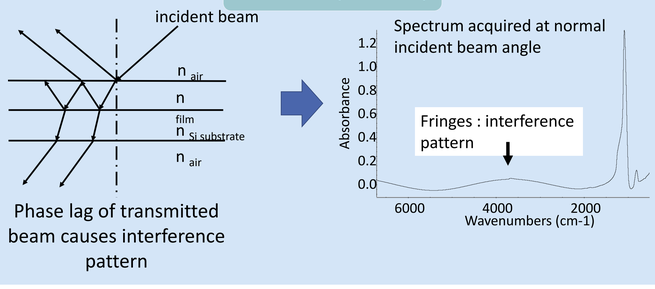
Introduction

- RC target is very challenging to meet as technology node scales down
- Dielectric material requirements become stringent:
  - Low k constant
  - Environment stability
  - Good thermal stability and mechanical proprieties
- Oxide / low k films are sensitive to Process Induced Damage (PID) , cause by plasma as well as chemicals.
  - C depletion increases k value
  - Moisture uptick increases leakage
- Film property changes are reflected as chemical bonding variations

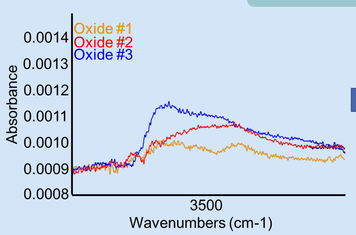
Challenges in FTIR Film Characterization

Thick film (>100nm)



Phase lag of transmitted beam causes interference pattern

Thin film (<10nm)

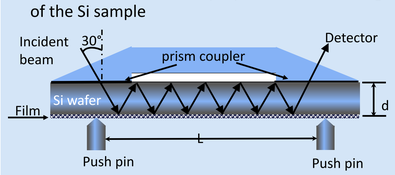


- Spectra are very noisy
- Peak integration is not reliable
- Difficult to differentiate –OH species

Overcoming the Challenges

Multiple Internal Reflection (MIR): 4000cm-1 ~ 1500cm-1

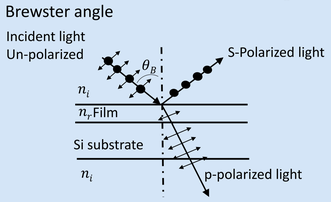
- Si wafer sample is used as part of the ATR prism
- IR light tunneling through the Si wafer multiple times thus enhances signal
- Number of reflections is proportional to the length of the Si sample



Schematic of Multiple Internal Reflection Optical Configuration

Brewster Angle Set up 4000cm-1 ~ 450cm-1

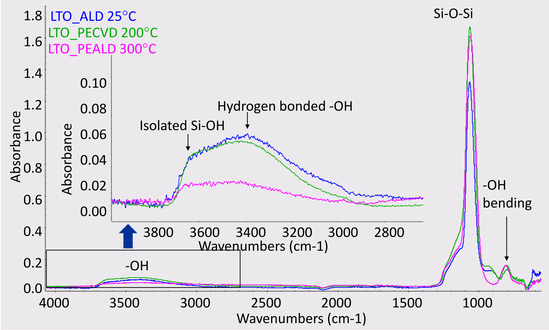
- Parallel polarized incident light at such an angle is completely transmitted , free of reflection
- Sample is set at off normal incident angle = Brewster angle



Quantifying Low Levels of –OH in LTO Film

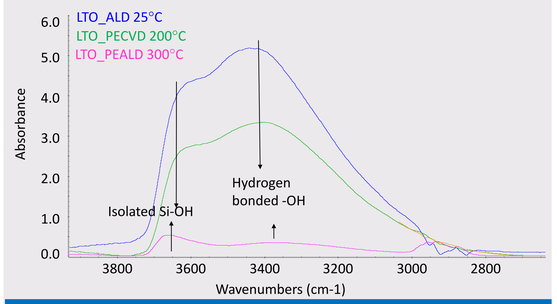
- Low temperature deposited silicon oxides (LTO) used as hard masks are difficult to pattern by EUV
- HMDS (Hexamethyldisilazane) primer improves the surface property of LTO by forming surface hydroxyl (-OH) with Si surface
- -OH level becomes a useful parameter in evaluating and understanding the surface property

- Transmission at normal incident beam angle
- Low sensitivity , quantification of –OH is NOT reliable



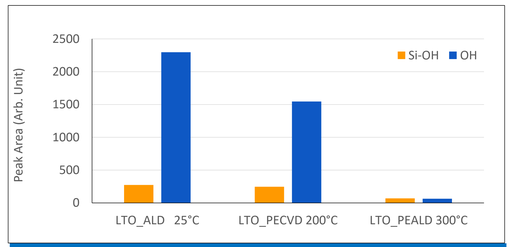
Transmission FTIR spectra of various LTO films

- MIR set up improves signal sensitivity significantly
- Deconvolution and integration of H-bonded –OH vs isolated Si-OH is more reliable



MIR spectra of various LTO films

- Relative amount of H-bonded –OH and isolated Si-OH reveals the surface differences between three films processed with different conditions
- At higher process temperatures –OH levels are significantly lower

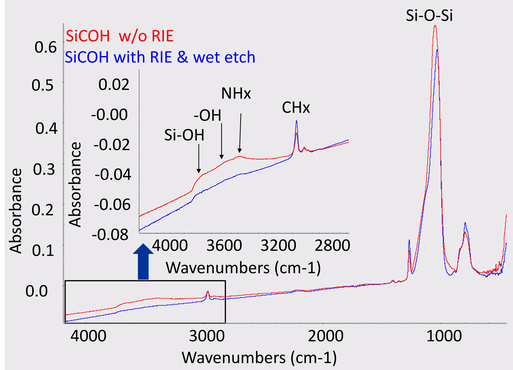


Relative levels of isolated Si-OH and hydrogen bonded -OH

Determine Low Level of N in SiCOH Film

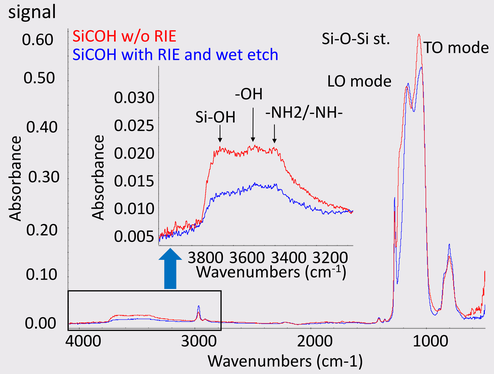
- Incorporation of N in SiCOH film suppresses film degradation and improves film quality
- High sensitivity signal at 4000cm-1 to 2800cm-1 range: -NHx stretching band is clearly presence

- Thicker film at normal incident beam angle
- Unable to identify –NHx peak due to severe base line tilt



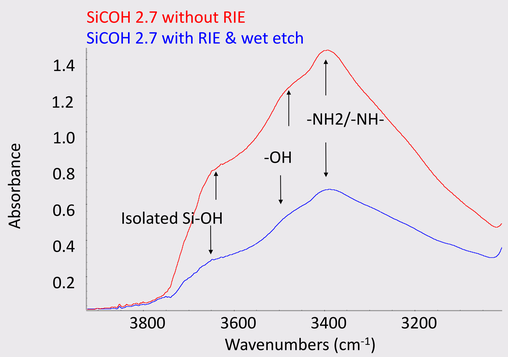
Nitrogen doped SiCOH low k films: Transmission spectra

- At Brewster angle spectra are fringe free
- Relative amount of –OH in these 2 samples showed PID increased moisture level in the film
- Unable to identify -NHx in PID film sample due to weak signal



Nitrogen doped SiCOH low k films Brewster angle set up spectra

- 10x sensitivity Improvement: MIR
- NHx absorption band clearly identifiable in PID damaged film indicating N maintained inside film after multiple processes.



Nitrogen doped SiCOH low K film: MIR set up spectra

Conclusion

- Benefits of using MIR in high wavenumber range from 4000cm-1 to 1500cm-1:
  - Significant improvement of sensitivity at high wavenumber range
  - Reliable deconvolution absorption bands of –OH species and –NHx, as well as semi-quantification of absorption bands
- Brewster angle set up provides fringe free spectra for thick film samples in full mid IR range, from 4000cm-1 to 450cm-1 , it increases sensitivity for low absorption bands such as -OH , -NHx

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