Enhancing Reactive Ion Etching Control with Real-Time Laser Interferometry

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Introduction

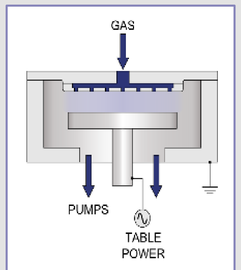


Figure 1: Reactive Ion Etching Diagram inside the process chamber

What is Reactive Ion Etching?

- Microfabrication technique used to remove material with chemically reactive plasma
- Direction dependent anisotropic etching process
- Ionizes gas mixture with radio frequency (RF) power source to create plasma that chemically reacts with material on substrate
- Control gas composition, pressure, temperature, RF power for precise etching process

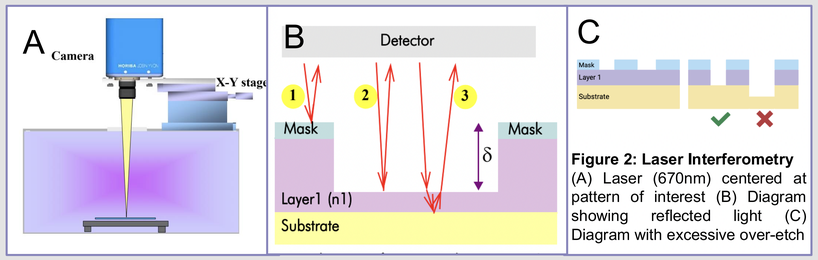


Figure 2: Laser Interferometry (A) Laser (670nm) centered at pattern of interest (B) Diagram showing reflected light (C) Diagram with excessive over-etch

Introducing Laser Interferometry

- Monitors etching/deposition processes by measuring interference patterns created by a laser
- Laser detects changes in optical path as material is removed, resulting in variations in reflected light intensity that correspond to constructive and destructive interferences
- Variations of light intensity provide real-time information on etch rate and material thickness

Objective

- Establish baseline operating parameters for laser interferometry as an etch-stop method for transparent thin film plasma etch processing
- Optimize endpoint detection parameters to etch the layer of interest

Methodology

1 Create Samples

- Tool: Plasma Enhanced Chemical Vapor Deposition (PECVD), Spin Coat
- Material: SiO_2, S1813 Photoresist

2 Etch Without Using Endpoint Detection

- Tool: Oxford PlasmaPro 100
- Material: SiO_2

3 Etch Using Endpoint Detection

- Tool: Oxford PlasmaPro 100
- Material: S1813 Photoresist

Results

Etch Rate With Different Times

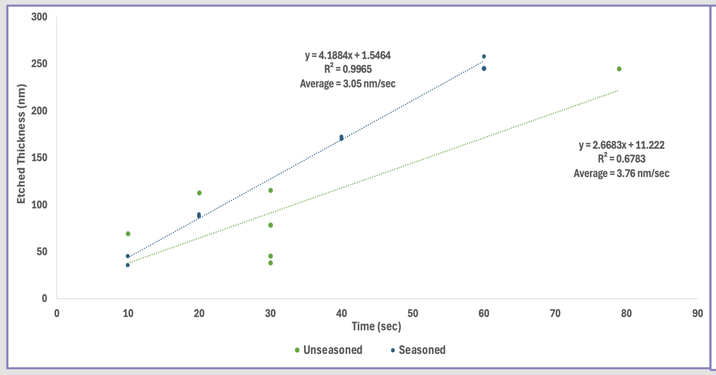
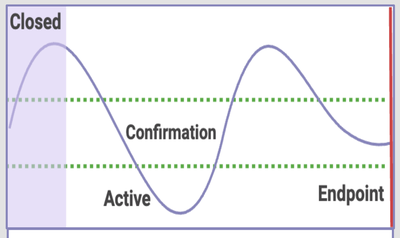


Figure 3: Reactive Ion Etch Rates Comparison of Unseasoned and Seasoned Chamber

SiO_2 samples were etched using the Oxford Instrument. Seasoned chambers showed more consistent etch rates compared to unseasoned chambers. The average etch rate for all samples was 3.83 nm/sec.

Endpoint Status from Light Intensity



- **Closed**: Endpoint processing ignored
- **Confirmation**: Cross threshold and capture timer starts
- **Active**: Does not cross threshold
- **Endpoint**: Threshold satisfy capture time

Endpoint Parameters

Parameters	Definition	Set Parameters
Normalization Level	Percentage of maximum signal value used for normalization	50%
Endpoint Closed Time	Time from start of process before endpoint processing starts	10 seconds
Threshold Value	Percentage from normalization value	5%
Endpoint Capture Time	Time period which condition must be satisfied for endpoint confirmation	10 seconds
Overetch Time	Time to continue process after endpoint confirmed	10 seconds

Derivative Endpoint Type

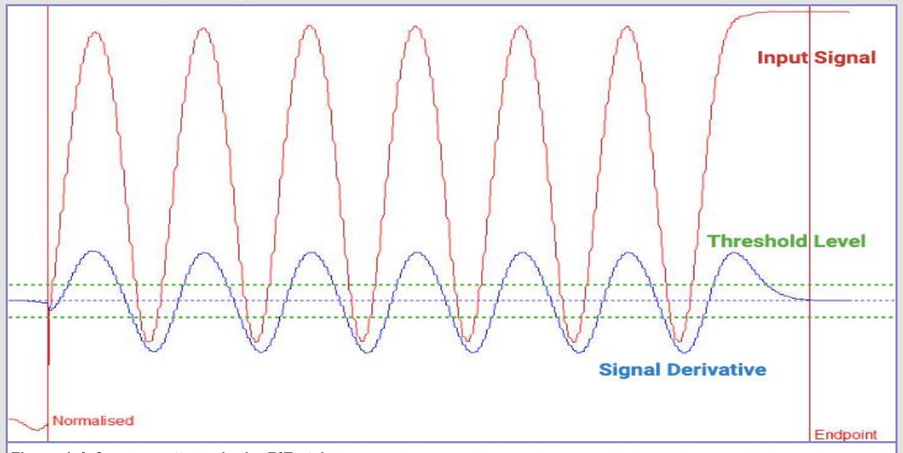


Figure 4: Inference patterns in the RIE etch process
Etch process was done on a 1300nm thick S1813 photoresist 3 inch silicon wafer. The process stops as the absolute value of the reflected light intensity (signal) derivative falls less than the threshold value during the endpoint capture time duration. This suggests the photoresist layer has been completely etched.

Discussion & Conclusion

- Laser interferometry effective in enhancing reactive ion etch control through real time monitoring
- For transparent materials with different refractive indices, interference pattern would change and trigger endpoint

Things to Consider

- Material and substrate need noticeably different refractive index
- Camera used to ensure laser on pattern of interest

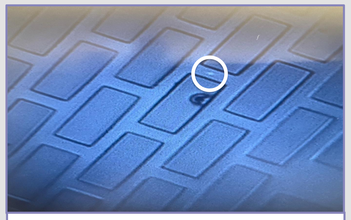


Figure 5: Laser on Pattern of Interest

Future Directions

Optical Emission Spectroscopy (OES)

- Plasma emits light at characteristic wavelengths
- Measure intensity for all wavelengths of emitted light
- Analyze changes in light intensity that correspond to different materials to determine when a material is present

Other Directions

- Find optimal parameters to etch certain thickness within a layer
- Explore other materials (SiO_2, SiN_x)
- Test different endpoint types (DeltaZ, Signal)

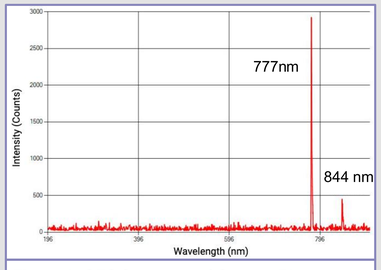


Figure 6: OES Spectrum of Oxygen Plasma

References

HORIBA Jobin Yvon. '*LEM Camera User Manual.*' 2006. PDF (Figure 1)

PlasmaPro 100 Cobra ICP RIE Etch, Oxford Instruments, 2024. (Figure 2)

Acknowledgments

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