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Low Temperature Deep Reactive Ion Etching: Design of Experiments

Kira Fishgrab, Travis Young, Michael Wiwi, Randy Shul, and Bridget Clevenger

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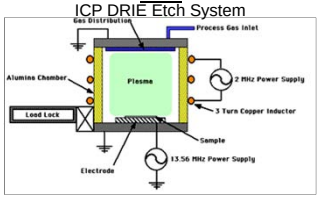
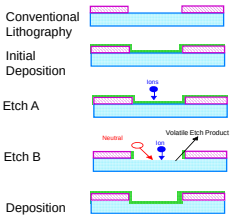
Deep Reactive Ion Etching (DRIE) of Si

ICP DRIE Etch System



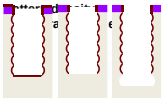
Basic DRIE Process

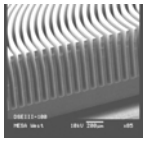


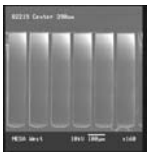
DRIE Etching

- Etch Rates 2.0 to 12.0 µm/min
- Selectivity 50 to 250:1
- Aspect ratios 30:1

Highly dependent on feature dimension,







Objective

Optimize 1) sidewall profile 2) morphology and 3) etch rate for deep reactive ion etching process as a function of electrode temperature (+20 to -20C).
Does low temperature improve sidewall profile by enhancing polymer deposition?

Experimental Procedure

7um AZ9260(photo resist) – approximately 17% open area
Target etch depth = 300um
SEM images used to calculate etch rate and evaluate sidewall profile and morphology

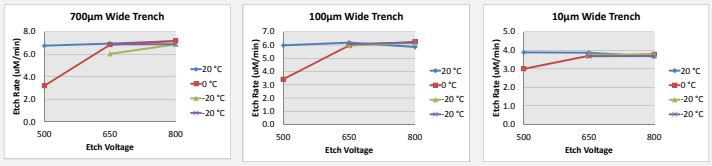
DOE 1

- Vary electrode Temperature (-20 to +20°C)
- Vary etch voltage (500 to 800V)
- Used 700um, 100um, and 10um trenches

DOE 2

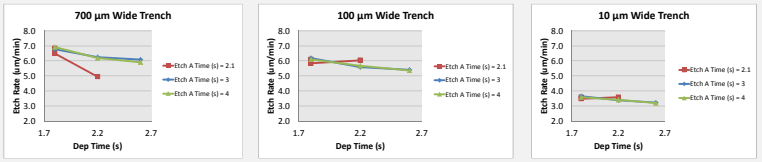
- Temperature at -20C and etch A voltage at 725V
- Vary etch A time (2.1 to 4 sec)
- Vary deposition time (1.8 to 2.6 sec)
- Used 700um, 100um, and 10um trenches

Etch Rate



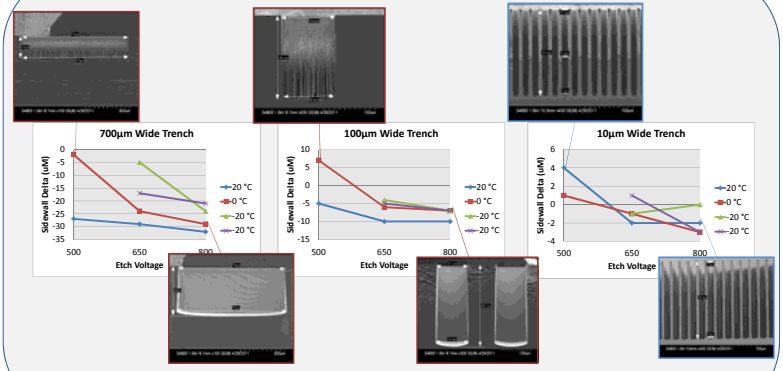
Etch rate did not vary significantly with electrode temperature or etch A voltage.
Note: The larger features (700um &100um) etch faster than the smaller feature (10uM) – this is the RIE lag effect.

Etch Rate



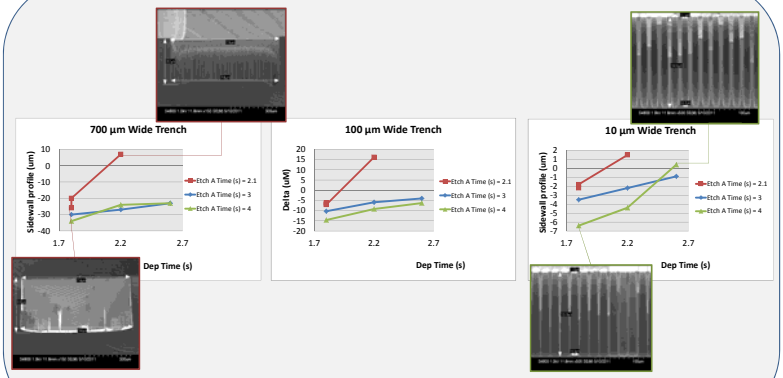
Etch rate decreases slightly with increased deposition time. Etch rate shows little correlation with etch A time.

Sidewall Profile



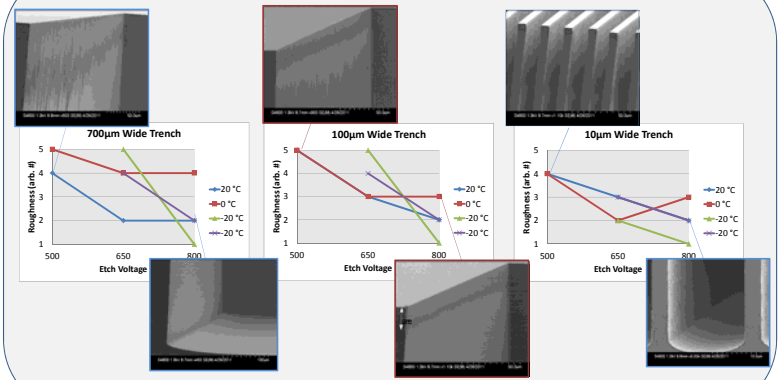
Sidewall profile becomes increasingly negative or undercut as etch A voltage increases. This is due to increased polymer removal efficiency at higher ion energy.

Sidewall Profile



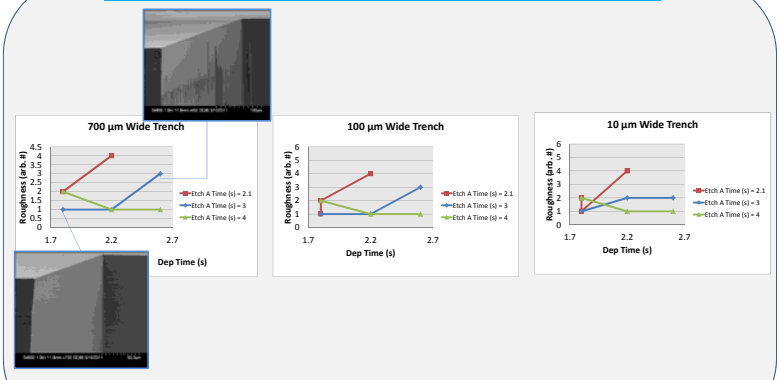
Sidewall profile becomes more anisotropic as deposition time increases and etch A time decreases. Thus, increased polymer deposition combined with shorter etch time lends itself to better sidewall control.

Roughness



Sidewall roughness and micro-masking decrease as etch A voltage increases. No clear correlation in roughness versus temperature.

Roughness



Sidewall roughness and micro-masking showed varying results with changes in Etch A time. At 2 and 3 seconds of etch A time, the roughness increased, however at 4 seconds, the roughness decreased. This indicates that more etch time is needed to sufficiently remove the polymer.

Conclusions

- **Profile control is dependent on feature size/aspect ratio – Large features (700um) undercut more while smaller features (100um & 10 um) are more anisotropic under a wider range of these DOE conditions.**
- **Etch A time, deposition time, and etch A voltage are highly interrelated and need careful balancing to optimize profile control and sidewall morphology. These parameters must be optimized based on the aspect ratio of the structure to be etched.**
- **In general, low temperature DRIE appears to improve profile control, polymer deposition and etch A sputter conditions must be optimized to realize these improvements.**
- **Further testing is needed to determine optimal settings at low temperature.**