

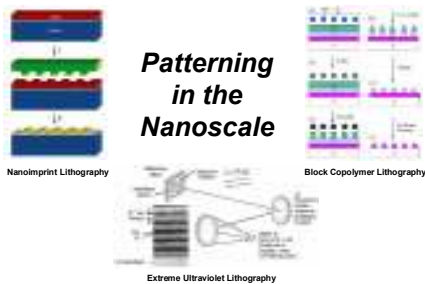
Investigation of Plasma-Polymer Interactions for Plasma/Energetic Beam Templating of Materials

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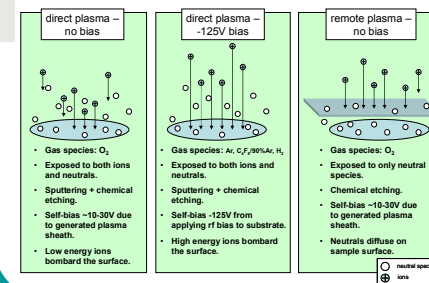
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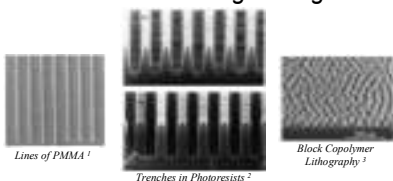
All techniques require plasma etching!

1. Nakajima, et al. *Thin Solid Films* 453:441 (2005)
2. Levenson, *IEEE Circuits & Devices Magazine* 16:58 (July 2002)
3. Hamby *Nanotechnology* 14:R304-R314 (2003)

Etching Experiments: Direct and Remote Plasmas



Sidewall and Line Edge Roughness

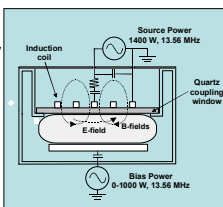


- Patterned structures inherit roughening caused by organic mask degradation in the plasma processing step
- Fundamental understanding of plasma-polymer interaction required to tailor polymers for optimal properties under plasma conditions

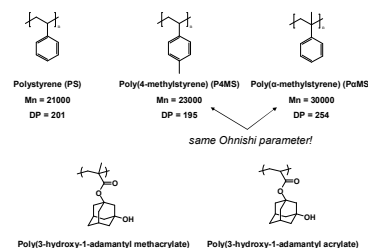
1. Hu, et al. *J. Vac. Sci. Technol.* A21(20): 3124-3130 (2003)
2. Hu, et al. *J. Appl. Phys.* 94(4): 1981-1987 (2004)
3. Hamby *Nanotechnology* 14:R304-R314 (2003)

Experimental

- Typical conditions**
- Source Power: 100-1000 W
 - RF Bias: 100- 600 W (0-125V Self bias, 13.56 MHz)
 - Pressure: 10 mTorr
 - Gas chemistry: C₂F₄/90% Ar, Ar, O₂
 - Total gas flow rate: 50 sccm
 - Moving shutter
- Diagnostics**
- Single Wavelength Ellipsometry
 - X-ray Photoelectron Spectroscopy (XPS)
 - Atomic Force Microscopy (AFM)
 - Fourier-Transform Infrared Spectroscopy (FTIR)



Model Polymers



Empirical Modeling of Etch Rate

$$ER \propto \frac{N}{N_c - N_o}$$

RING PARAMETER

Etch rate is proportional to molecular weight of carbon atoms contained in a ring structure in a monomeric unit over total molecular weight of monomeric unit

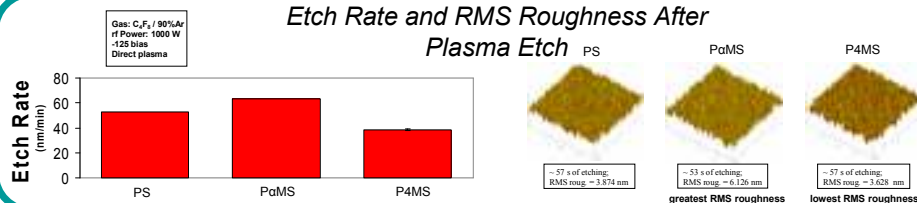
OHNISHI PARAMETER

Etch rate is proportional to number of atoms in a monomeric unit over number of carbons minus number of oxygens in a monomeric unit

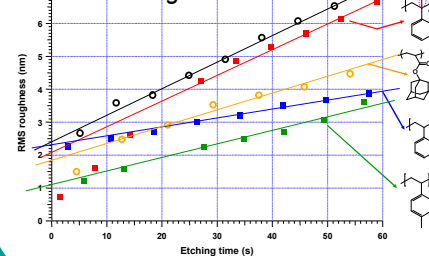
$$ER \propto \frac{M_{CR}}{M_{TOT}}$$

- Many polymers deviate from these relationships.
- Gives us no understanding of plasma-polymer interactions.

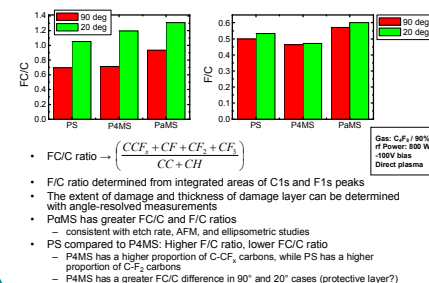
Etch Rate and RMS Roughness After Plasma Etch



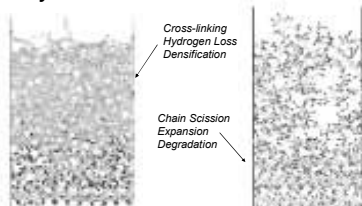
RMS Roughness Evolution vs. Etching Time



XPS Determination of FC/C and F/C Ratios



Polymer Modification Mechanisms



- Methyl group on polymer backbone increases rate of chain scission under plasma etch
- Pendant aromatic rings increase rate of cross-linking under plasma etch

Adapted from Hamada et al. International Conference on Simulation of Semiconductor Processes and Devices 07-10 (2005)



Ellipsometry Analysis

Ar/C₄F₈ Plasma in ICP Chamber

Dissolution Studies in Fume Hood

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Conclusions

- Similar polymers can have significantly different modifications under same plasma conditions
- Greater etch rate and rms roughness in PoMS corresponds to methyl group attached to polymer backbone
- Enhanced roughening and etch rate in PoMS and HAMA points to a different mechanism of plasma interaction compared to polymers lacking methyl group on backbone
- PoMS shows greater fluorocarbon damage compared to PS and P4MS
- P4MS shows the largest change in FC/C ratio between 20° and 90° cases (possible protective layer)

