THE CHALLENGES OF 157nm NANO-LITHOGRAPHY

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Introduction

Lithography at 157 nm using F_2 laser is the next step after 193 nm for ULSI fabrication with dimensions below 50nm.

However there are problems related to the development of the 157 nm technology, the most important been:

- The design of photoresists suitable for this spectral region with proper absorption value at 157nm and low out gassing.
- Improving line edge roughness and resolution
- Possible self assembly of the polymer surface following laser illumination at 157nm.

The high value of the absorption coefficient of the polymeric materials in the VUV, with typical values between 0.1 to 20 μm^{-1}, imposes severe restrictions on the selection of the photoresist material for 157 nm lithography. On the other hand, at this wavelength there is high probability for breaking any chemical bond commonly encountered in the organic molecules and causing outgassing and ablation. Therefore the photodissociative processes could impose serious contamination problems on the optics of the projection system

In this communication we are reporting on the results of the European Research Effort for 157nm lithography regarding absorption, outgassing, self assembly, high resolution capabilities, and line edge roughness of resists.

Experimental Apparatus

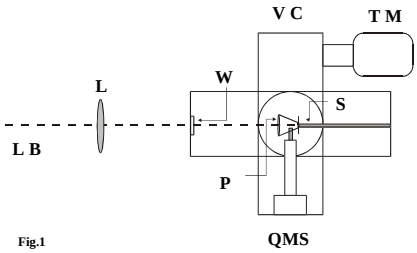
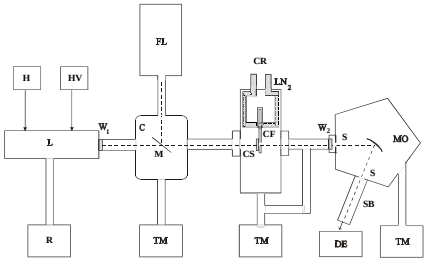


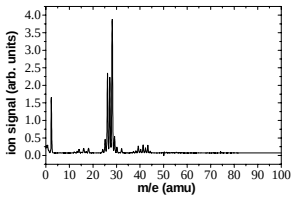
Fig.1

Experimental set-up for obtaining the mass spectrum of resists at 157nm. LB: laser beam, L: lens, VC: vacuum chamber, TM: turbo molecular pump, W: LiF: window, S: sample, P: photofragments, QMS: quadrupole mass spectrometer.



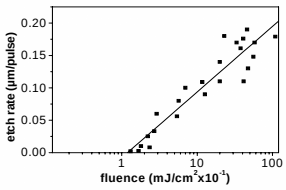
Vacuum ultraviolet absorption spectrometer coupled to the molecular fluorine laser and the hydrogen VUV light source; L: Hydrogen lamp; H: Hydrogen gas cylinder; HV: High voltage power supply; R: Rotary pump; $W_{1,2}$: LiF windows; C: Vacuum chamber; M: Mirror; FL: F_2 Laser; TM: Turbo molecular pump; CR: Cryostat; LN_2: Liquid nitrogen reservoir; CF: Cold finger; CS: Crystal sample; MO: Monochromator; S: Slit; SB: Solar blind photomultiplier or secondary electron multiplier; DE: Detection electronics

Results and Discussion

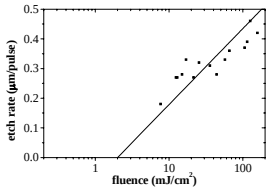


Mass spectrum of teflon at 157nm

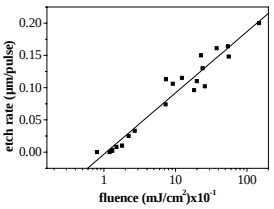
Etch rate of teflon at different fluences at 157nm. The absorption coefficient with this experimental method and with the specific material at 157nm was estimated to be closed to 2μm.



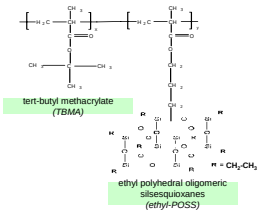
Etch rate of polyamide at different fluences at 193nm. The absorption coefficient was estimated to be 9μm^{-1}. Etching rate of 5nm per pulse was achieved at 2mJ/cm^2.



Etch rate of polyamide at different fluences. The absorption coefficient at 157nm was estimated to be 23μm^{-1}. Etching rate of 5nm per pulse was achieved at 0.6mJ/cm^2.



The random copolymers of this work comprising of two monomers (TBMA:x and ethyl-POSS:y) with different composition.



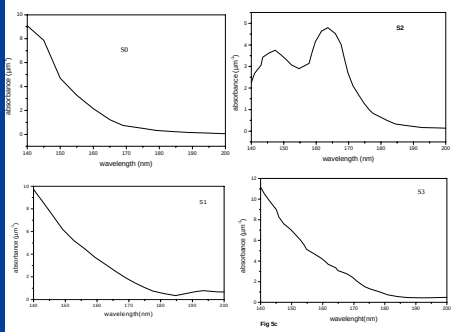
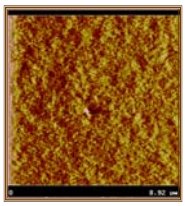


Fig 5c

•*Absorption of the S1, S2 and S3 copolymers taken with the VUV absorption spectrometer in the spectral range from 150 to 200nm.*

•*Absorption of the S0 homopolymer taken with the VUV absorption spectrometer in the spectral range from 150 to 200nm.*



7 Surface image of the S1 copolymer in the contact mode with the scan size of 30 x 30 μm . The surface seems to be flat with a RMS roughness of 0.4 nm.

Surface image of the S3 copolymer in contact mode. The image was taken with scan size of 8,92 x 8,92 μm. The surface RMS roughness was 0.3 nm.

Conclusion

✓Outgassing at 157nm cannot be avoided but it can be reduced since at 157nm extensive photochemical bond breaking takes place. For carbon based polymers each 157nm photon dissociates one monomer but the amount of outgassing depends on the degree of steepness of the dissociative excited electronic states

☯ The probability of cleavage of the side chain bonds is higher than of the main chain.

☯ For higher photon flux only photofragments of small masses were observed suggesting sub sequential bond breaking.

☯ The amount of out-gassing depends on the material's purity.

☯ The amount of outgassing of teflon, is of the same order of magnitude as for aliphatic carbonated polymers.

☯At 157 nm, the amount of out gassing seems to have a linear dependence on the laser fluence in the semi-log scale for small and large laser fluences. This response is not observed for longer laser wavelengths. This issue is under further investigation.

☯Resist surface nano-morphology depends on chemical composition.

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Acknowledgements

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