Block copolymer mediated healing of the LER of a patterned EUVL resist

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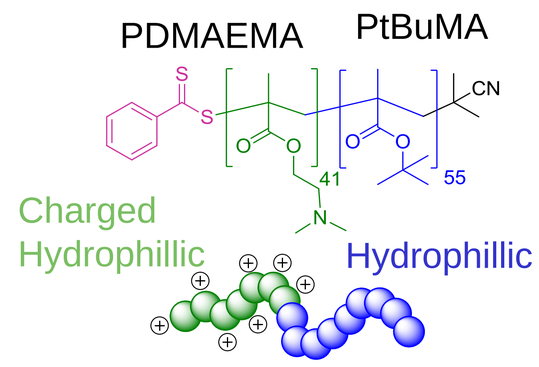
Introduction

- Nanoscale roughness can affect the performance of different devices, which include micro-/nano-electromechanical systems (M/NEMS) and microelectronics.
- The inherent roughness of printed features, commonly termed line-edge roughness(LER) or line-width roughness (LWR), is predicted to significantly degrade device performance.
- We proposes to **use the directed self assembly of a charged nanoparticles particles comprised of block copolymer** to coat surfaces and lithographically produced features. When this is followed by an **annealing** step, the nanoscale roughness can be healed.

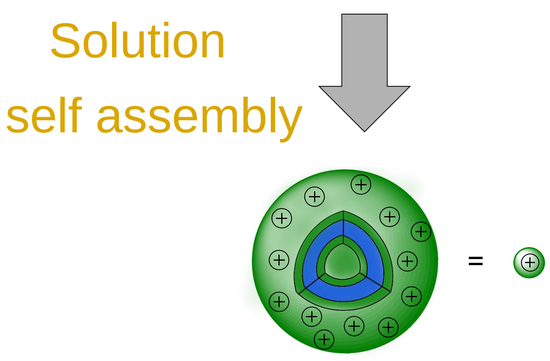
Polymer Synthesis and Solution Self Assembly

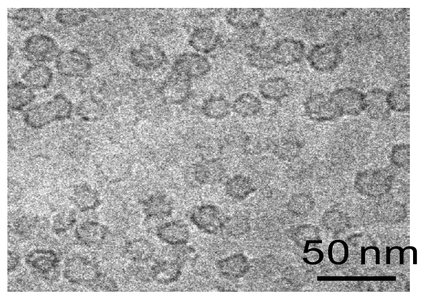
- **Synthesis:** Controlled polymerisation methods were used to synthesize PDMAEMA-*b*-PtBuMA
- Characterisation: Bulk characterisation by SEC (MW) and NMR (structure)



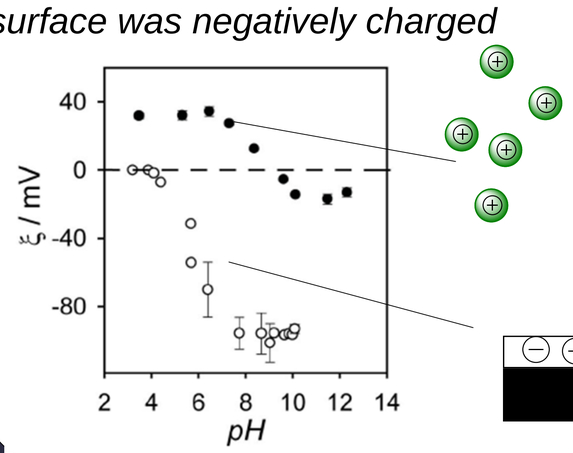
^{1}H NMR	SEC-MALLS	
(M_n)	(M_n)	$Đ_M$
14240	15280	1.14

- **Solution property:** Cryo-TEM show s that in pH 6.3 aqueous solutions, the BCP self assembles to form spherical nanoparticles, higher electron density at the shell (dark contrast)- which are consistent with formation of polymersomes.





- **Surface charge:** Zeta potential of the BCP solutions *in* 10 mM NaCl (aq) *indicate that the particles are positively charged at pH 8 and below; streaming potential of a crosslinked model for a resist surface was negatively charged*



Results indicate that self assembly of particles at resist surfaces should occur through electrostatic interactions

Method of treatment

- **Polymersomes solution:** dissolved PDMAEMA-*b*-PtBuMA in THF and dropwise into 10mM NaCl to make a 0.6mg/mL solution
- **Coating** : a wafer that is coated with $PtBMA_{0.42}$ - *stat* -$PMMA_{0.56}$ - *stat* -$PGMA_{0.02}$ or a commercial resist TER60 was dipped coated in the polymer solution, followed by immersing in water.
- **Annealed** at 100 °C (above T_g of the BCP (56 °C)

Healing Study on a Flat Model Surface

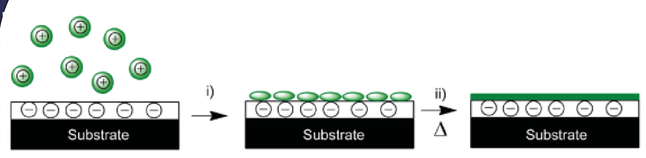


Fig 1. i) Modification of model, flat, negatively charged surfaces with positively charged polymersomes; ii) Annealing of surfaces to tune roughness.

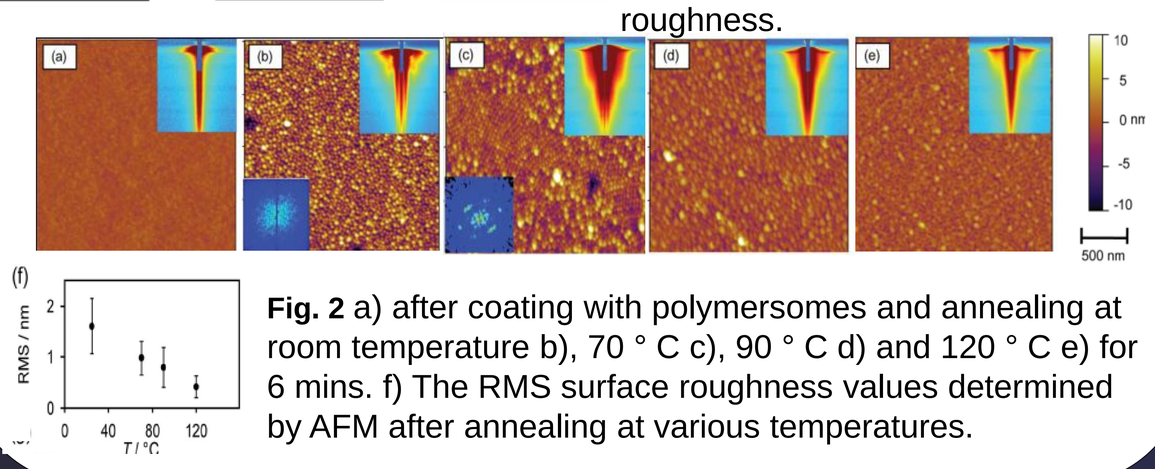


Fig. 2 a) after coating with polymersomes and annealing at room temperature b), 70 ° C c), 90 ° C d) and 120 ° C e) for 6 mins. f) The RMS surface roughness values determined by AFM after annealing at various temperatures.

Process Diagram for Healing

- PHOST based EUV resist was patterned by EBL.
- Patterns were treated with aqueous solutions of BCP polymersomes.

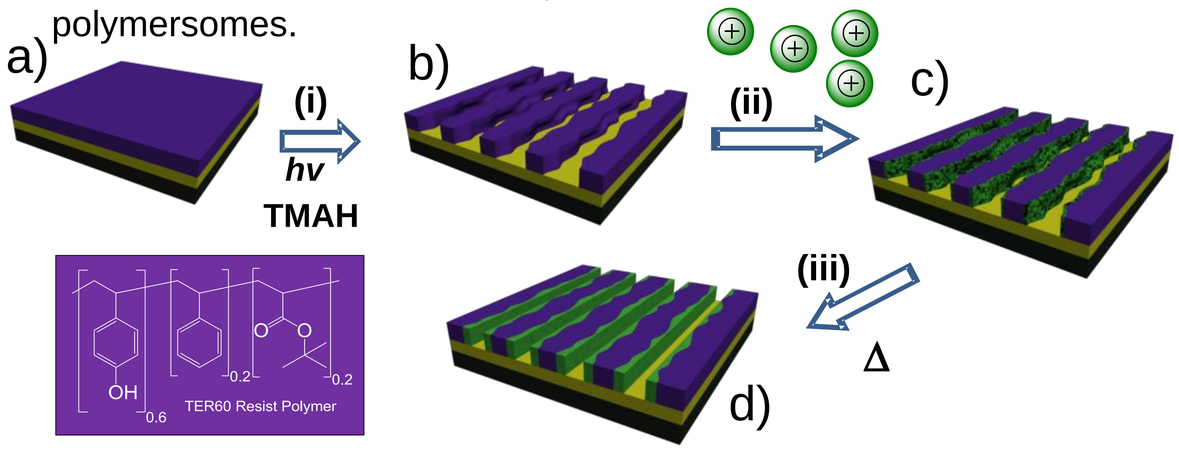


Fig. 3 a) wafers coated TER60 EUV resist based on PHOST chemistry; i) irradiation with EBL and development, b) patterned resist; ii) dip coating of BCP; c) patterned resist coated with BCP; iii) annealing; d) healed patterns.

Healing Study on SEM pattern features

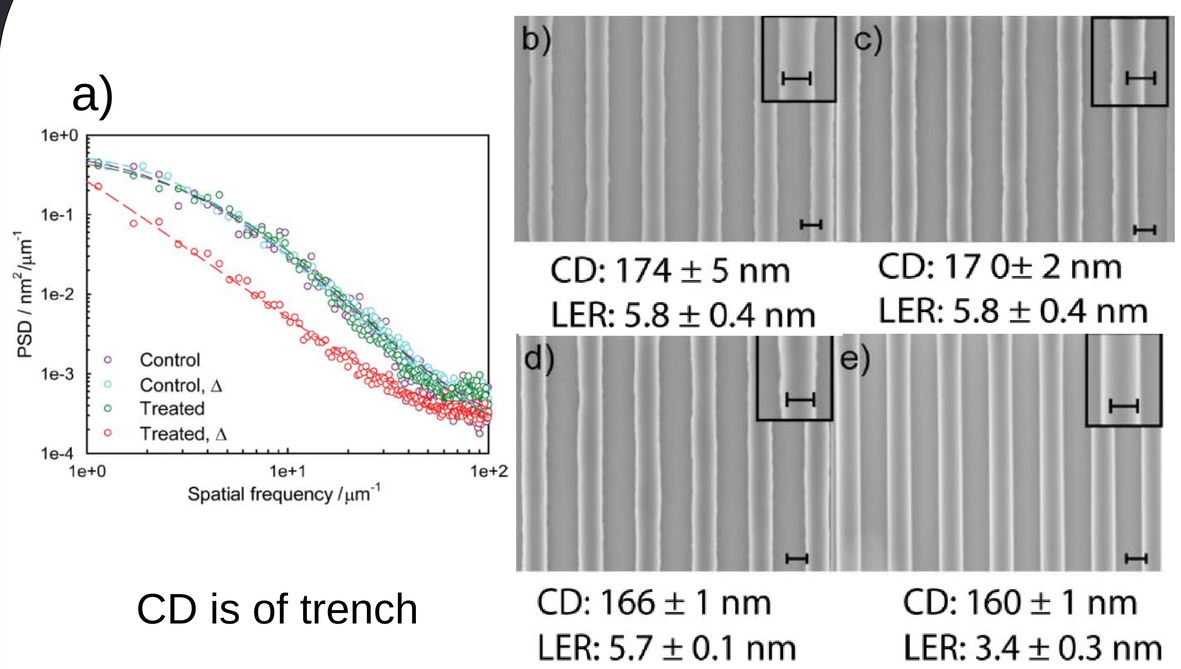


Fig 4 a) The change in PSD function patterns before treatment, after treatment and after annealing. b) Top-down SEM patterned resist c) Patterned resist annealed at 100 °C as a negative control (i.e., the pattern has not been treated with polymersomes). d) Patterns after being treated with positively charged polymersomes without annealing. e) Patterns after being treated with positively charged polymersomes and annealing at 100 ° C, where the roughness was found to decrease significantly.

Summary/Conclusions

- Block copolymers with well defined composition and molecular-weight distribution were prepared
- They were able to self assemble into positively charged polymersomes at pH 6.3.
- Annealing temperatures were less than T_g of common resists.
- E-beam patterned surface lead to a reduction in the LER value from 5.8 nm to 3.4 nm
- Estimates of LER improvement as high as 58%
- a novel process for modulating the nanoscale roughness of pattern features has been presented

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