Plasma Directed Assembly and Organization: Effect of plasma processing conditions on order and nanodot dimensions

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Fabrication of periodic nanofeatures (dots, columns, pores etc) arrays on surfaces is widely used in science and technology (biology, hard disk drives, catalysis and photonics). Top-down nano-lithographic processes, as well as self-assembly processes [1] (block copolymer, colloidal lithography) are used for the fabrication of the nanofeatures, using plasma etching to transfer the nanopattern from the intermediate layer to the underlying substrate. However, not long ago lithography-less plasma nanofabrication was demonstrated for selected nanostructures [2-4]. In addition, ion beam sputtering has shown lithography-less nanofabrication capabilities, forming ordered nanodots on several substrates [5-7].

Recently [8-9], we demonstrated plasma directed assembly/organization by fabricating nanodots on PMMA substrates or films, using a simple, fast, low ion-energy oxygen plasma etching step in a helicon plasma source. Etching the polymer for a few tens of seconds to a few minutes, results in ordered nanodot formation: Fig. 1a shows the top-down 2D morphology and embedded 3D zoomed view of periodic nanodots which develop on a PMMA film. Fig. 1b shows the circularly averaged Power Spectral Density (PSD) of the surface in Fig. 1a demonstrating a strong peak. The peak in PSD is indicative of the periodicity of the surface, and corresponds to a period, λ, equal to ~62 nm. Fig. 2 shows the effect of temperature in the size and order of the nanodots for temperatures 40-80 ^{o}C.

In this work we will further study how changes in Bias Voltage and etching time affect the size and the order of the created nanodots. Also different materials will be studied as to their ability to create similar type of nanodots with the same process (polystyrene, pHEMA), followed by efforts for transferring the nanopattern on a Silicon substrate using the new material as a mask.

What is the mechanism causing this emergence of periodicity on the polymeric surfaces? X-ray photoelectron spectroscopy analysis of polymeric surfaces after plasma etching showed that Al_xO_y and $Al_xO_yF_z$ species (coming from the reactor wall) existed up to levels of even 10% [10]. Thus, we take into account this co-deposition of material coming from the reactor wall and implemented a mechanism of simultaneous ion driven etching and deposition with a stochastic modeling framework for topography evolution: We found out that simultaneous co-deposition of a small amount of depositing particles can induce periodicity on the etched surfaces [9].

References

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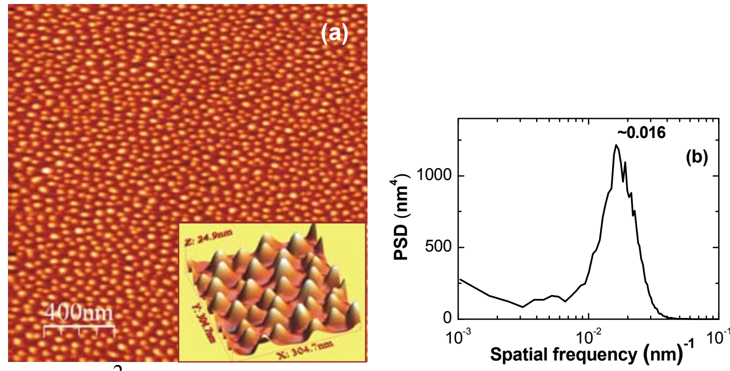

Figure 1. a) 2x2 um^2 (512x512 points) AFM image (CP-II AFM from Veeco) of a PMMA film surface after 46 s Oxygen plasma etching down to Si substrate. A 3D zoomed view of a part of the image is embedded. b) Circularly averaged PSD of the AFM image of Fig. 1a. The peak at 0.016 corresponds to a period of ~62 nm.

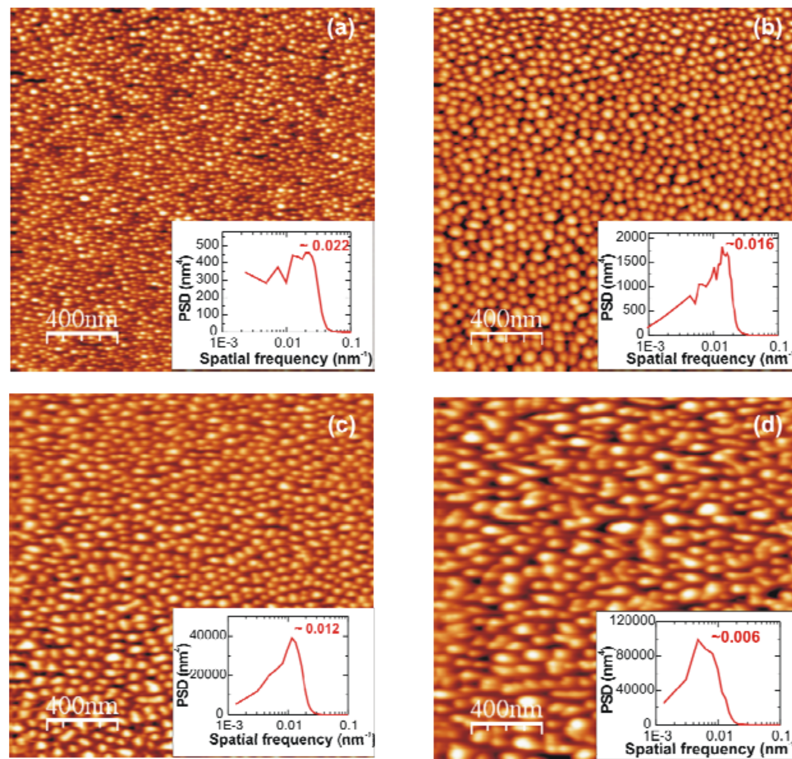

Figure 2. 2x2 um^2 AFM images (CP-II AFM from Veeco) of PMMA film surfaces after 40 s Oxygen plasma etching. The substrate temperature is a) 40 ^{o}C (1024x1024 points), b) 60 ^{o}C (512x512 points), c) 70 ^{o}C (1024x1024 points), and d) 80 ^{o}C (1024x1024 points). Circularly averaged PSDs of the AFM images are shown embedded.