Atmospheric plasma etching of polymers: A palette of applications in cleaning/ashing, pattern formation, nanotexturing and superhydrophobic surface fabrication

P. Dimitrakellis, E. Gogolides

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Atmospheric plasma etching of polymers: A palette of applications in cleaning / ashing, pattern formation, nanotexturing and superhydrophobic surface fabrication

P Dimitrakellis and E Gogolides

Institute of Nanoscience and Nanotechnology, NCSR "Demokritos", Aghia Paraskevi, Attiki, 15310, Greece

E-mails: e.gogolides@inn.demokritos.gr, p.dimitrakellis@inn.demokritos.gr

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Abstract. Atmospheric Pressure Plasmas (APPs) are promising alternatives to their low-pressure counterparts for material surface treatment due to their potential for cost-effective continuous processing. Here we present for the first time to our knowledge a palette of applications of polymer etching showing the potential of APPs for cleaning / ashing, nanopattern formation, nanotexturing, and hierarchical superhydrophobic surface fabrication using the same plasma source configuration. First, we used a dielectric barrier discharge (DBD) plasma source to study etching/cleaning/ashing of different polymers such as PMMA films and AZ photoresist with lithographic patterns using He/O_2 mixtures. We achieved high-rate, uniform etching, indicating the source potential for cleaning/ashing even in ambient air conditions. We have noticed that thick photoresist films are damaged after prolonged etching in air plasmas, a phenomenon resembling photoresist damage observed during low-pressure plasma etching. Second, we applied colloidal lithography with polystyrene (PS) nanoparticles followed by isotropic APP etching in order to form nanopatterns on both Silicon and Polymers. We observed that APP induces "cauliflower-like" nanotexturing of the PS spheres. This nanotexturing in combination with plasma etching of the underlying polymer and the spheres allow the fabrication of hierarchical surfaces. Optimization of plasma etching duration (i.e. hierarchical topography) followed by low-pressure plasma deposition of a low surface energy fluorocarbon (hydrophobic) coating led to the preparation of superhydrophobic surfaces with water contact angle 158° and hysteresis 9° (roll-off behavior).

1. Introduction

Plasma etching, since its first introduction in integrated circuit (IC) fabrication [1], has become the key top-down technology for micro- and nanofabrication for a wide variety of applications such as photovoltaics, MEMS and microfluidics [2-6]. Low-pressure plasma etching requires costly vacuum equipment with limited processing capability of complex size materials. In this context, APPs are attracting interest as a promising alternative to low pressure plasmas as they are more cost-effective, more suitable for larger area treatment in a continuous mode and easier to install in an already existing industrial line. [7-9].

A plethora of APP sources have been proposed in the literature such as corona discharges [10,11], APP jets [12-15] and dielectric barrier discharges [16-18]. Most of such APPs have been successfully applied for the etching of different materials during the last decades. APP sources such as coronas or DBDs have already been applied successfully in industry, mostly for surface activation processes. Atmospheric plasma etching and especially ashing apparatus for use in semiconductor or other industries have been reported in the literature as well.