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Large area roll-to-roll processing of flexible polymers by atmospheric pressure hydrogen plasma

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Flexible polymeric substrates were treated by atmospheric pressure plasma generated in pure hydrogen and the mixtures of hydrogen and nitrogen. A novel curved plasma system based on diffuse coplanar surface barrier discharge (DCSBD) in the roll-to-roll arrangement was used to mimic continual in-line processing. Flexible transparent conductive substrates with conductive connection sites were used to etch thin (~ 10-100 nm) film from the surface of the composite polymer substrate with embedded Ag-coated Cu-wires. In contrast to etching in ambient air, pure N_2, and N_2 /H_2 mixtures resulting in a strong degradation both the polymer and metal parts of the substrate, the etching in pure hydrogen plasma let to the fast (~ 1s) selective etching of the thin surface polymer film without any destruction of the coated wires. The effect of processing parameters (treatment time, plasma-to-sample distance) on the etching mechanism was studied using SEM/EDX and laser confocal microscopy. Dry etching with hydrogen plasma at longer treatment times (~ 1-10 min) was used for creating a nanoscale roughness on thin (50 um), flexible poly(methyl methacrylate) (PMMA) substrate. Using scanning electron microscopy, X-ray photoelectron spectroscopy, atomic force microscopy, contact angle analysis and the transmittance measurement, it was found that a hydrogen plasma treatment produced nanoscale pillar structures on the PMMA surface resulting in an increase of contact angle of water to ~ 140° after etching from the original contact angle of 75° measured on the untreated surface. The PMMA substrate with initial wetting behaviour thus achieved the superhydrophobic surface properties which can expand the application of thin PMMA foil to many new applications.

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