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Effect of Thermal and Deposition Processes on Surface Morphology, Crystallinity, and Adhesion of Parylene-C

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Neural interface devices have been developed for neural science and neuroprosthetics applications to record and stimulate neural signals. Chemical-vapor-deposited Parylene-C films were studied as an encapsulation material for such an implantable device. The surface morphology of an implant affects its biocompatibility; thus, the Parylene-C surface morphology was investigated as a function of the precursor sublimation rate by atomic force microscopy. We found that high precursor sublimation rates resulted in slightly higher root-mean-square surface roughnesses (from 5.78 to 9.53 nm for deposition rates from 0.015 to 0.08 g/min). The crystallinity affects the physical properties of semicrystalline polymers, and various heat treatments were found to modify the crystallinity of Parylene-C films, as assessed by X-ray diffraction (XRD). The XRD peak at $2\theta = \sim 14.5°$ increased in intensity and decreased in full width at half maximum with increasing annealing temperature, indicating an increase in film crystallinity. Poor adhesion would compromise the protection offered by Parylene-C coatings. The adhesion between Parylene-C and silicon, amorphous silicon carbide, and boron silicate glass substrates were evaluated using the standard tape adhesion test from the American Society for Testing and Materials (ASTM) in an attempt to minimize the occurrence of delamination failures. The tape adhesion tests indicated strong adhesion for all the as-deposited Parylene films with the application of an adhesion promoter (Silquest A-174® silane). However, annealing the deposited films at temperatures from 85 to 150°C in air for 20 min reduced film adhesion, and also the adhesion testing procedure used significantly affects the results obtained. Supporting evidence suggested that the thermal stress generated in the films weakened the adhesive force. We concluded that the Parylene-C film properties (surface morphology, crystallinity, and adhesion) changed during deposition and thermal annealing, suggesting that the Parylene-C film properties can be tailored and that, with care, failure due to film delamination can be avoided.

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