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Effect of Focused Helium-ion Beam on Surface Morphology of Polypropylene Thin-films for Power Capacitors

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Polypropylene (PP) films are one of the widely used dielectric materials for power capacitors in high-frequency and high-power applications due to their excellent dielectric strength, ease of processability, reliability, and low dissipation factor [1]. The rapid development of high-performance capacitors requires new methods of modification and advanced characterization of the PP films at the nanoscale level to enable their further miniaturization and to improve their performance. In this work, we investigated the effect of ion-beam irradiation on the surface morphology of PP films. Commercially available and deposited with spin-coating PP films were irradiated with a focused He^+-ion beam (He-FIB) in a Zeiss Orion NanoFab Helium Ion Microscope at landing energy of 25 keV with doses in a range of $5.4x10^{-5}$ nC/μm^2 to $8.07x10^{-3}$ nC/μm^2. Prior to irradiation, all samples were metalized with a very thin layer of a metal alloy. He-FIB was used to construct surface patterns similar to those fabricated in our previous studies [2,3] of polymer materials irradiated with FIBs. Atomic force microscopy (AFM) and optical microscopy were used to analyze the details of surface modification. The obtained results show that the irradiation of the PP films with He-FIB results in shrinkage of the polymer material and negligible surface sputtering effects. Surface ripples were observed at the borders between the irradiated and non-irradiated regions, which is attributed to the mechanical strain induced by the material modification. Among other things, our study shows that, alongside the known modification of dielectric and electric properties of PP material, the changes in the film shape in the irradiated regions should be taken into account as a geometrical factor that affects capacitance.

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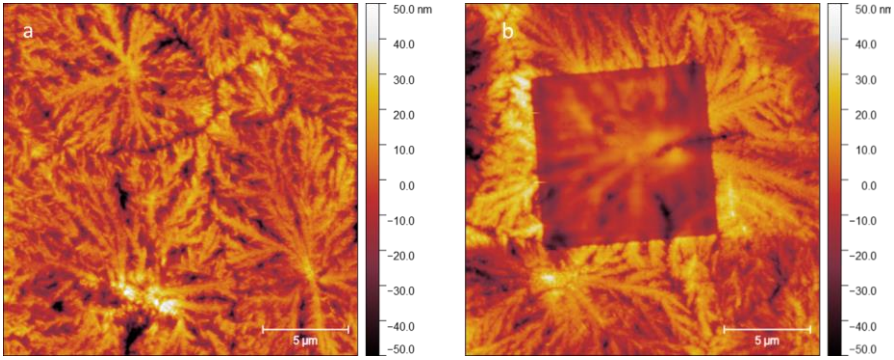

Figure 1: AFM images of the surface of spin-coated PP film, before (a) and after (b) FIB-He irradiation. The irradiated region is the dark square in b).