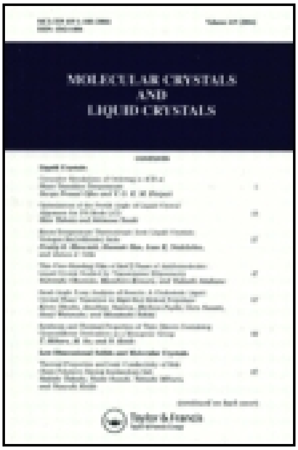

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Charge Storage Capability of Laser Ablated Poly(ethylene terephthalate) Film

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Poly(ethylene terephthalate) films were irradiated by ultraviolet laser with a subsequent electrification by corona discharging. Surface potential and surface morphology of samples were measured and analyzed. A significant increase of surface potential resulted from the samples irradiated of about 15 pulses. From SEM pictures, melted ripple tips were observed on the film surface and some of them were fused together. This surface layer may probably enhance the surface potential of the samples. This result suggests the possibility of enhancing the charge storage capability of polymeric electret by altering their surface morphology.

Keywords: corona discharge; laser irradiation; poly (ethylene terephthalate); polymeric electret; surface modification; UV laser

INTRODUCTION

Like other modern scientific disciplines, the field of electret research is in a steady transformation characterised by plenty of new developments over the past decades. These relates to materials used, measuring techniques, insights into charge storage, charge transport and retention, polarization phenomena, pseudo-piezoelectric properties, and applications of electrets [1]. For instance, in view of the pseudo-piezoelectric property, the sensitivity of an electret to mechanical stress depends on the charge density and its distribution in the

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surface layers of the electret material. In recent years, different types of materials like the non-polar porous polymer electret with quasi-permanent space charge, such as porous polytetrafluoroethylene (PTFE) film has been developed. Some experimental results have demonstrated that for PTFE film with higher porosity, the charge storage capability can be improved significantly [2,3]. Nevertheless, porous polymers are not easy to fabricate and they are not stiff enough for transducer applications. Therefore, there is an urge for effort in searching for high sensitivity electrets of reasonable stiffness.

For polymeric electret materials, such as poly(ethylene terephthalate) (PET) and PTFE, the electret properties have been well studied and classified [4]. Nevertheless, processes treatments like low-frequency glow discharge [5] and laser irradiation [6] can be applied to alter the surface morphology of these polymeric electrets. It will lead to some features that have not been studied before. For instance, submicron structures are induced on the polymer surface after laser irradiation [7,8], it will change the charge storage capability.

In the present study, laser irradiation was applied to ablate on PET films. The charge storage capability of the films after laser irradiation was studied. UV excimer laser was used as the radiation source, as a result, different submicron patterns on the PET films were observed. A considerable change in surface potential was found depending on the extent of surface modification.

EXPERIMENTAL

PET film of thickness 110 μm was cut into 19 × 19 mm samples. The samples were irradiated under atmospheric conditions directly by the pulsed KrF excimer laser (Lambda-Physik COMP EX205) with wavelength of 248 nm at a pulse rate of 1 Hz. The laser fluence was set nominally to 86 mJ/cm^2 without using any optical component. The irradiated area was controlled to 7 mm in diameter with a copper mask as shown in Figure 1. Three series of samples was prepared with different number of pulses varying from 0 to 40. After the laser surface treatment, the stiffness of the PET film still can be retained.

Corona discharge, unlike the γ-ray and glow-discharge, is an effective method to electrify the polymer without damaging the bulk properties [9]. Therefore, it was adopted to produce the electrets with the irradiated PET, at -5 kV for 10 minutes with the setup shown in Figure 2. The surface potentials of samples were measured by the electrostatic sensor (Keyence SK-030/200) before and after corona discharge treatment.

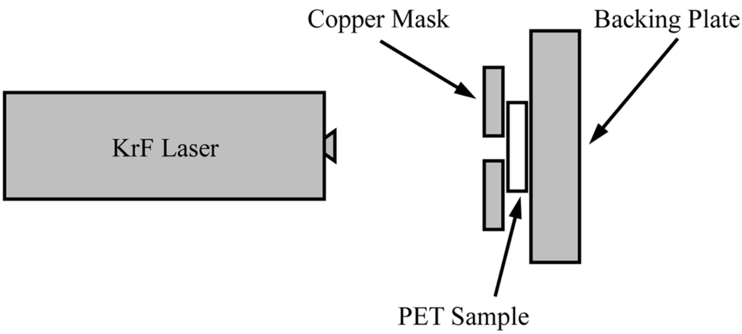

FIGURE 1 The schematic diagram of the laser irradiation set-up.

On the other hand, the surface morphology of the irradiated samples was inspected by a field-emission scanning electron microscope (SEM) (JEOL JSM-6335F) at a voltage of 3 kV.

RESULTS AND DISCUSSION

In general, the laser irradiated PET samples showed a smeared pattern at the ablated area, although in the first few pulses of irradiation, the surface of the film is not altered considerably. It has no pattern formation when PET samples are irradiated for only a very few pulses. When the PET sample is irradiated for 5 pulses, as shown in Figure 3, a shallow pattern with peaks and troughs begins to occur,

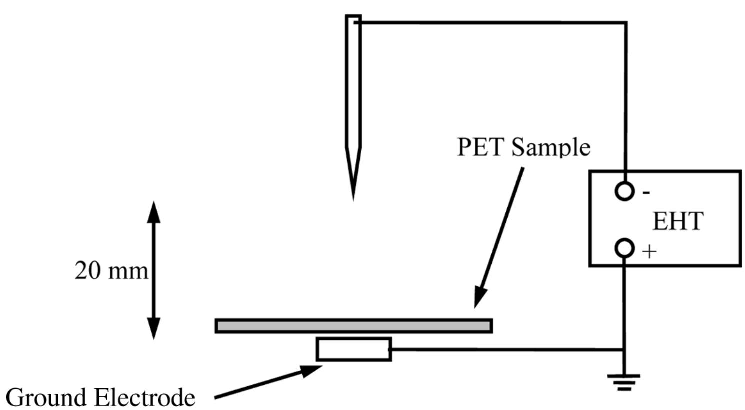

FIGURE 2 The schematic diagram of corona discharging set-up.

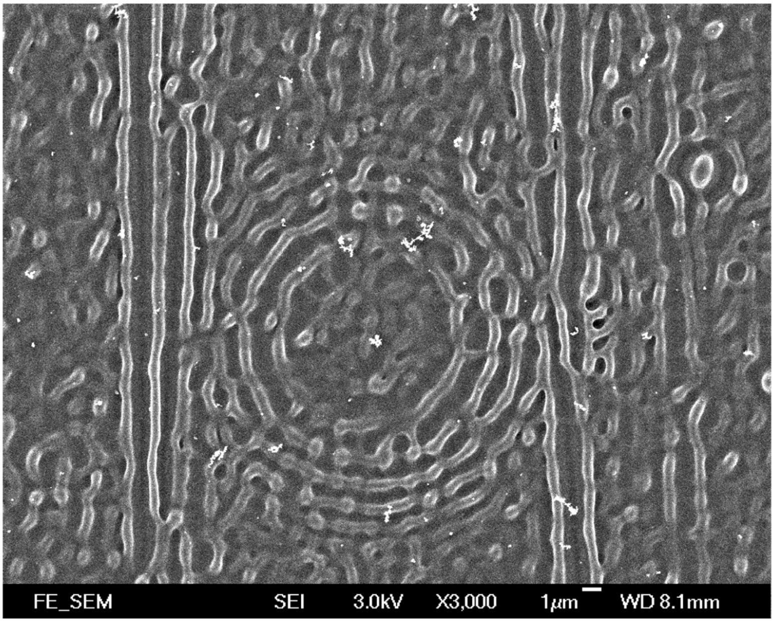

FIGURE 3 SEM picture of PET surface irradiated by laser for 5 pulses.

it also consisted of some long thin structures. For the PET samples irradiated for almost 15 pulses, rod-like structures are observed as shown in Figure 4, which are broken from the long thin structures found in samples irradiated with less pulses. Obviously, increasing the number of pulses produces a finer ripple structure. Figure 5 shows the feature obtained by 18 pulses irradiation, the fine ripple structure is still observed, but some of the ripple tips become narrower and fuse together with their neighbours. A layer of polymer material is formed on the fused ripple tips. This phenomenon can be explained in the following. Figure 6 is a schematic diagram to show the cross-section of an ablated surface. The ablated film surface comprises of three layers, i.e., the ablation layer, the fusion layer and the heat-affected layer. The inner depth of the film is not affected by the laser. The ablation layer is the part removed by the laser from the surface. The temperature at the fusion layer immediately below the ablation layer would be raised above the melting point of the PET film (about 300°C) because of the absorption of laser energy and the PET melts instantaneously. As it solidifies, shrinkage takes place, and the mode of stabilisation is different at each point

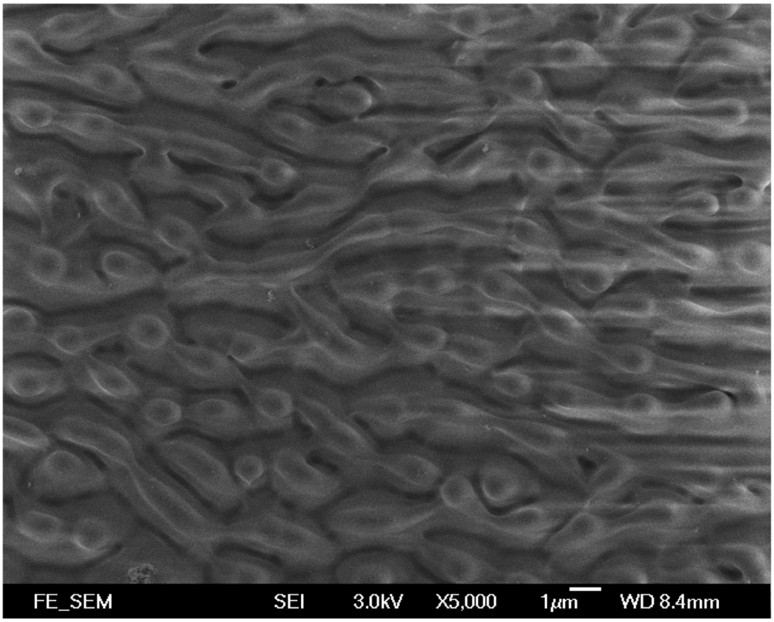

FIGURE 4 SEM picture of PET surface ablated for 15 pulses, fine ripple structure is observed.

depending on the molecular orientation and thermal properties of the materials. The peaks- and-troughs structure on the PET ablated area is produced by this difference.

A further irradiation for more than 20 pulses, the ripple pattern is probably destroyed by the excess laser energy. The tips of the structure are cut down and an island-like pattern is formed. The surface of the ablated area becomes relatively flatten compared with the sample of 15 pulses. This feature can be clearly seen in Figure 7. In order to study the effect of these surface patterns on the electret property of the PET, surface potential of three series of treated films were measured after electrified by corona discharge method. From Figure 8, it can be seen that, the average surface potential of the charged films is about 1.2 kV. It varies between 1.2 kV to 1.4 kV for samples irradiated for a very few pulses to about 15 pulses. For samples ablated for more than 15 pulses, a significant increase in surface potential is observed. It increases to more than 1.5 kV. The surface potentials of samples pulsed for more than 20 times then decrease to an average of 1.3 kV and even lower if the samples had been irradiated more.

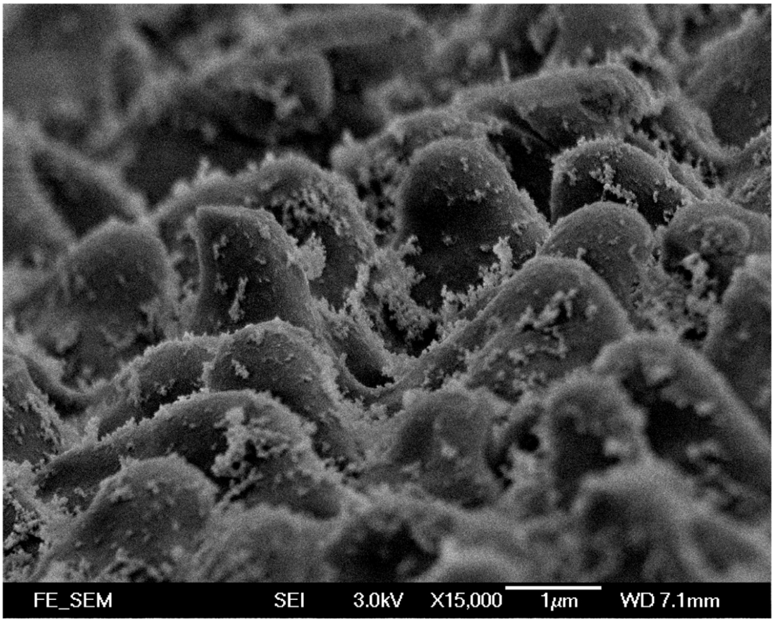

FIGURE 5 SEM pictures of laser ablated PET surface for 18 pulses, the fine ripple structure is still observed, some of the ripple tips fused together with their neighbours.

It is most likely that the surface potentials are correlated to the ripple pattern obtained by laser ablation. We have noted earlier that at about 15 pulses, a layer of melted ripple tips (Fig. 5) are formed, some of

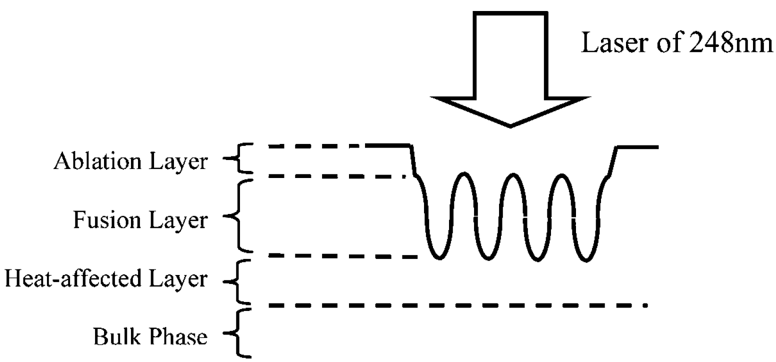

FIGURE 6 Model of PET film surface modified by irradiation of pulsed UV excimer laser.

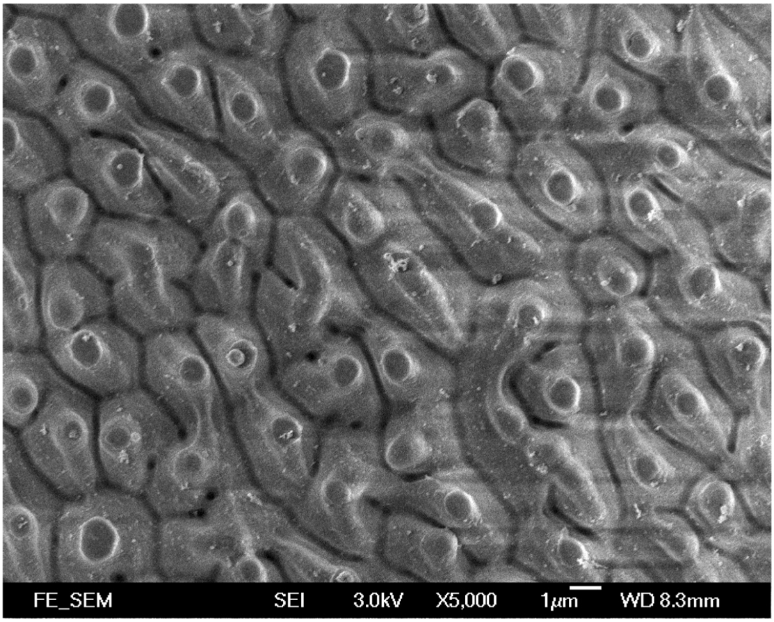

FIGURE 7 SEM picture of PET surface irradiated for 20 pulses, tips of the structure were cut down and island-like pattern was found.

them will even fused together. The surface potential of these samples is significantly higher than that of other samples. This higher surface potential can be attributed to the formation of this layer. Nevertheless, when the PET samples were ablated for 20 pulses or more, the ripple tips have been cut down and the film surface becomes flattened. It is not surprising that the charge storage property of these samples become worse.

CONCLUSION

Pulsed UV laser irradiation on polymer films can be used to alter the surface morphology of this material. Some special ripple patterns are formed on the surface and change gradually with the increase of laser irradiation numbers. The different surface potentials of PET film appear to stem from the surface pattern of the polymer. The most pronounce pattern is the formation of tips at the surface with a slightly fused together between neighbouring tips. Samples with this feature also exhibit the highest surface potential which implies as well

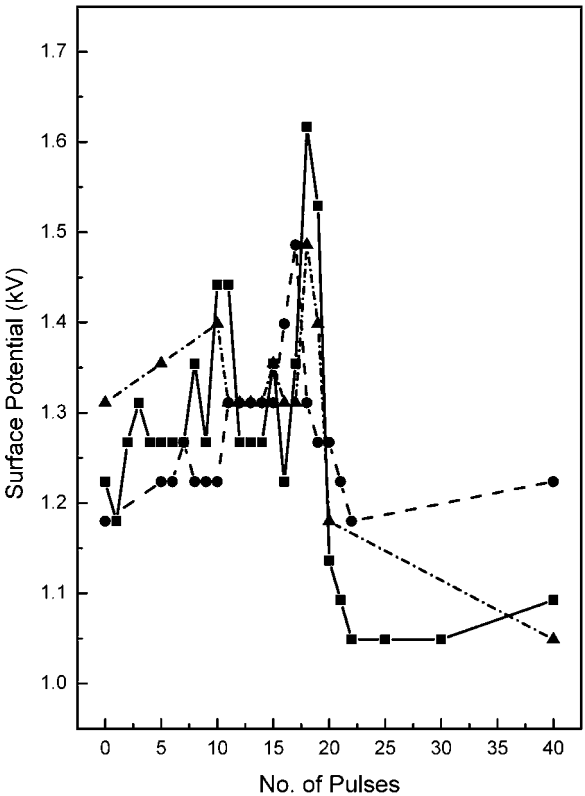

FIGURE 8 The surface potential of laser ablated PET films varying with different number of pulses.

a highest charge storage capability. By suitably controlling the laser fluence and pulse number, the surface potential can be enhanced by this new surface layer.

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