The Improvement of mechanical and gloss property by dual ion beam irradiation

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1. Introduction

Ion beam irradiation provides a unique way to modify the mechanical, optical, and the electrical properties of polymers by depositing the energy of ions in the material on an atomic scale [1]. Beam irradiation of ions into polymers generally leads to radiation damage, which, in many cases, modifies the properties of the surface and the bulk of the material [2]. These modifications result from changes in the chemical structure caused in their turn by changes in the chemical bonding when the incident ions cut the polymer chains, break covalent bonds, promote cross-linking, and liberate certain volatile species [3]. The nature of these changes depends on the properties of the polymer, such as the composition and molecular weight [4]. In this study, we measured the mechanical property changes of polymer surface such as hardness and strength. Also, we observed the change of gloss property before and after ion beam irradiation.

2. Experimental

Each polymers (Polycarbonate & Polyethylene) irradiated with N^+, He^+, C^+ at the irradiation energy of 50~100keV and the dose range of $1x10^{14}$~$1x10^{17}$ ion/cm^2. The ion current density maintained under 7 ㎂/cm^2 to prevent overheating leading to melt-down at the polymer surface. Surface hardness changes caused by the ion beam irradiation were characterized using a nano-indentation technique [5]. Besides we also simply identified hardness with pencil scratch hardness test which is a simple and effective technique to evaluate the hardness. And we observed the improvement of surface gloss using the gloss meter.

3. Results

The hardness depth profiles of dual gaseous ion beam irradiation (Nitrogen + Helium, Nitrogen + Carbon) are shown in Figure 1. In all cases, significant hardening effects were observed. The hardness of the ions implanted sample with N^+ 70keV $5x10^{15}$ions/cm^2 and C^+ 70keV $5x10^{15}$ions/cm^2 were measured to be approximately 6GPa. Experimental results showed that surface hardening can be achieved for the polymer (PET) concerned when dual ions implanted. The hardening effects were generally proportional to the dose and beam energy. Moreover, while the chain scission generally degrades the polymer's mechanical strength, the cross-linking increases its hardness and improves wear and scratch resistance of the polymer surface layer and decreases the friction coefficient.

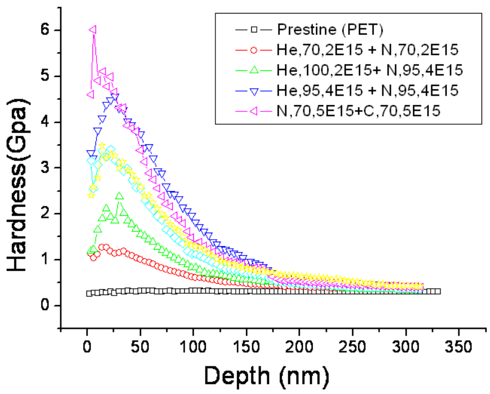


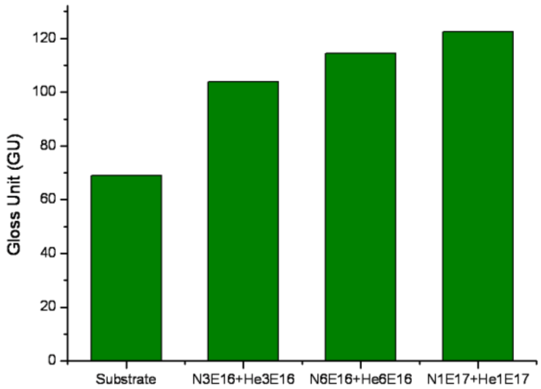
Fig. 1. The hardness depth profiles obtained with nano-indentation.

The polymer samples were irradiated with N^+ ion having energies from 50 to 90 keV at dose up to $1x10^{15}$ions/cm^2 and were irradiated with dual ions(N^+ + He^+, N^+ + C^+) at 70 and 95 keV , $1x10^{15}$ions/cm^2. The hardness pencil tests of polymers are shown in table 1. Pencil strength of polymer increased up to 4H by dual ion beam irradiation. It was revealed that for the both PC (Polycarbonate) and PET(Polyethylene), the scratch strength was much greater the N^+ + C^+ and He^+ + N^+ dual ion irradiated surfaces than N^+ ion irradiated surfaces of polymer.

Table 1. Pencil scratch hardness test

Ion	Ion energy (keV)	Ion dose (ions/cm^2)	Pencil strength
Pristine			HB-B
N^+	50	1E14	2H-3H
N^+	50	1E15	3H
N^+	90	1E15	2H
He^++N^+	70	1E15	3H-4H
N^++C^+	95	1E15	4H

In this study also provides a polymer with improved gloss properties using ion beam surface treatment. Many types of plastics are widely used in manufacturing a variety of parts due to qualities such as excellent mold-ability, lightweight, and relatively low price. However, many types of plastics also have low surface hardness and undesirable external appearance and are vulnerable to scratch. The polymer samples were irradiated with dual ion which have dose to $3x10^{16}$ ions/cm^2, $6x10^{16}$ ions/cm^2, $1x10^{17}$ ions/cm^2 at 90keV. Figure 2 shows the surface gloss was improved about 2 times by dual ion beam irradiation. And the general trend was that for increasing ion doses the surfaces gloss increases.



● Surface gloss measurement

- ✓ Material: PC/ABS
- ✓ Instrument: Haxe-Gloss Meter 4601 [BYK Gadner, Germany]
- ✓ Method : ASTM D523, D2457
- ✓ Angle : 20°[High gloss], **60°[Middle gloss]**, 85°[Low gloss]

Fig. 2. The improvement of Gloss unit by dual ion beam treatment

4. Conclusions

The hardness of the samples with dual gaseous ion irradiation was measured to be approximately 6GPa. Also, the pencil scratch hardness test which is another hardness measurement method shows the enhancement of strength up to 4H.

Moreover, the results of this study show the improvement of surface gloss property as well as hardness by dual ion beam irradiation which is used two different irradiated ions. From some measurements, it was found that the improvement in surface properties after ion beam treatment was related to graphite carbon or cross-linked carbon-double-bonding formed on the surface. The technology related to this study is applicable in automobile interior parts.

ACKNOWLEDGMENTS

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