



Short Communication

Structure and optical characteristics of 200 keV Argon implanted High Density Polyethylene (HDPE)

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Abstract

Present study aims at studying the optical properties of High Density polyethylene (HDPE) specimens as a result of 200 keV Ar⁺ ion implantation. The samples were implanted in the fluence range from 1×10^{14} Ar⁺ cm⁻² to 1×10^{16} Ar⁺ cm⁻² using ambient pressure of $\sim 10^{-6}$ Torr. Due to ion implantation, structural modification of target material has been recorded. These structural alterations lead to changes in its chemical, structural, optical and electrical properties. UV-Visible and FTIR-ATR spectroscopy were utilized to study the changes in optical and structural properties. Ar⁺ ion implantation resulted in a decrease in the optical energy gap from a value of 2.42 eV for virgin specimen to a value of 0.69 eV at the highest ion fluence. A correlation between optical properties and structural modification of implanted HDPE has been discussed. These results were also supported by FTIR-ATR spectroscopy.

Keywords: Ion implantation, Optical property, UV-Visible spectroscopy, FTIR-ATR, Polyethylene.

Introduction

Polymers are widely used engineering materials due to their unique properties. These properties include light weight, availability in wide variety of compositions, low cost, ease of processing, fabrication into a complex shape and structure etc. Ion implantation is very useful method for transformation of bonding characteristics leading to changes in optical, structural, chemical and electronic properties of the target material without modification in their structure¹⁻³.

In the present endeavour, the modification in the optical properties of HDPE as a result of Ar⁺ ions implantation has been studied. For carrying out these studies, argon ions were chosen for implantation. This process leads to modification in the surface structure of the HDPE polymer. The basic monomer structure of HDPE polymer is as presented in Figure-1.

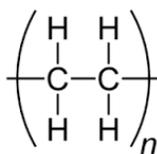


Figure-1
Monomer structure of HDPE

HDPE due to its unique properties has many applications in making containers and films for packaging, food cutting boards, corrosion resistant wall coverings, inspection covers in chemical plants, radiation shielding etc.

Materials and Methods

The investigated specimens were of size 1.5×1.5 cm² of High density Polyethylene (HDPE) having thickness about 1mm. These samples were implanted with argon ions of energy 200keV. The fluence range used in present study was varied from 1×10^{14} to 1×10^{16} ions/cm². The values of electronic and nuclear energy losses as per SRIM calculations were found to be 39.76 eV/Å and 24.67 eV/Å respectively for this ion- target combination.

The average range of implanted ions was ~ 310 nm⁴. The alterations in optical properties arising as a result of implantation in HDPE specimens were studied using UV-Visible spectroscopy. These studies were performed utilizing a Shimadzu Double Beam Double monochromator Spectrophotometer (UV-2550), equipped with Integrating Sphere Assembly ISR-240A in the wavelength range of 190 nm to 900 nm with a resolution of 0.5 nm. The structural transformations observed as an effect of ion implantation have been further correlated using the FTIR-ATR spectroscopy.

Results and Discussion

Figure-2 depicts the UV-Visible absorption spectra of virgin as well as implanted HDPE specimens in the fluence range from 1×10^{14} – 1×10^{16} Ar⁺ cm⁻². The presence of two absorption bands at 235 nm and 270 nm in the case of virgin HDPE specimen clearly indicates towards π - π^* transitions.

Further, after ion implantation significant shift in the absorption edge has been observed towards higher wavelength region, which clearly indicates a decline in value of optical energy gap^{5,6}.

Using Tauc's relation, the optical energy gap from the UV-Visible absorption spectra has been calculated¹⁻³:

$$(\alpha h\nu)^{1/2} \propto (h\nu - E_{opt})$$

Here $h\nu$ represents the incident photon energy corresponding to the fundamental absorption edge and E_{opt} is the optical energy gap. Taking into account the linear portion of the fundamental absorption edge of the UV-VIS spectra (curves a-d in Figure-2), $(\alpha h\nu)^{1/2}$ was plotted as a function of photon energy ($h\nu$) for determining the optical energy gap. The energy gap plots of virgin and implanted (at different fluences) HDPE polymer are shown in Figure-3. The energy gap shows a decrease from a value of 2.42 eV for virgin specimen to a value of 0.69 eV at the highest ion fluence.

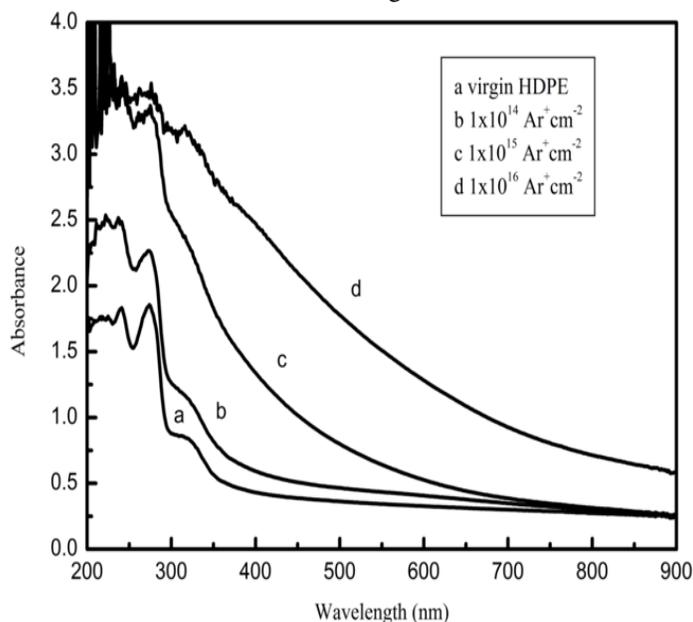


Figure-2

Absorption spectrum of 200 keV Ar⁺ implanted HDPE polymer obtained using UV-Visible spectroscopy; (a) Unimplanted (b) with 1x10¹⁴ ions/cm², (c) 1x10¹⁵ ions/cm² and (d) 1x10¹⁶ ions/cm²

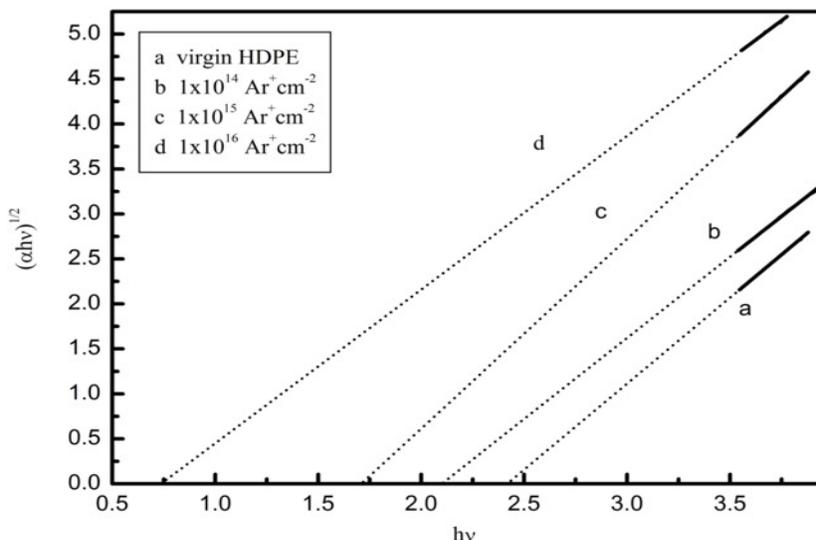


Figure-3

Optical energy gap plots of 200 keV Ar⁺ implanted HDPE polymer; (a) Unimplanted (b) with 1x10¹⁴ ions/cm², (c) 1x10¹⁵ ions/cm² and (d) 1x10¹⁶ ions/cm²

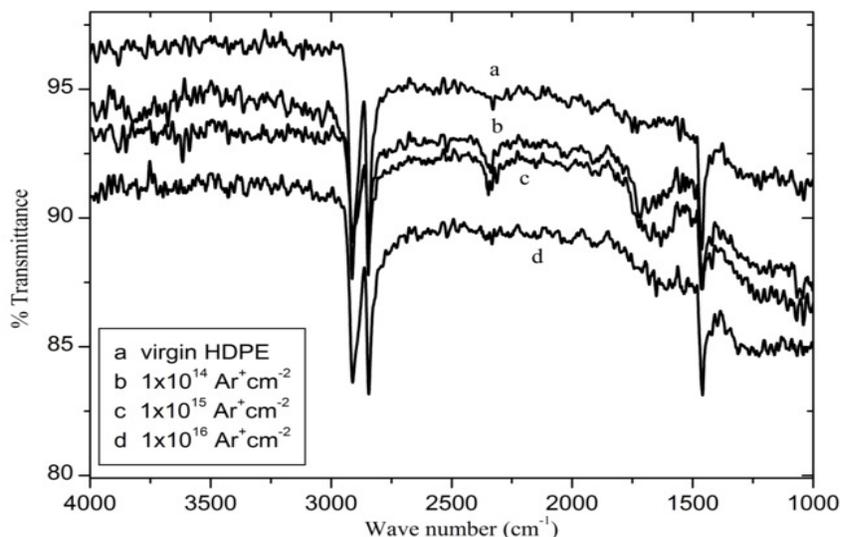


Figure-4
Transmission spectrum of 200 keV Ar⁺ implanted HDPE polymer obtained using FTIR-ATR spectroscopy;
(a) Unimplanted (b) with 1x10¹⁴ ions/cm², (c) 1x10¹⁵ ions/cm² and (d) 1x10¹⁶ ions/cm²

The observed trend in optical energy gap may be attributed to the creation of unsaturated dangling bonds in the implanted layers of the specimens⁶. This modified structure of implanted HDPE as seen using UV-Vis spectroscopy has also been studied with the help of FTIR-ATR spectroscopy. The transmission spectra of unimplanted and implanted specimens obtained using FTIR-ATR spectroscopy are depicted in Figure-4.

In the FTIR-ATR spectrum of virgin HDPE polymer (curve a Figure-4), two C-H stretching vibrations near 2950 cm⁻¹ have been observed. Further the presence of C-H scissoring vibration near 1460 cm⁻¹ was observed. The occurrence of these vibrational bands confirms the fundamental monomer structure of HDPE polymer⁶⁻⁸. Moreover the presence of a weak intensity band at 1894 cm⁻¹ and a high intensity band at 1303 cm⁻¹ clearly provides an indication towards crystalline nature of specimen⁹. The transmission intensity of all the characteristic bands diminishes due to ion induced changes in the polymeric matrix. This behaviour is due to structural changes induced by argon implantation.

Conclusion

In the present work, main results have come due to modification of the microstructure of HDPE polymer when implanted with 1X10¹⁶ Ar⁺/cm² at 200 keV. At these parameters, optical energy gap is reduced from 2.42 eV (in unimplanted HDPE) to 0.69 eV after implantation. The change in energy gap is closely related to the structural modification induced in HDPE polymer as a result of ion implantation.

References

1. Shekhawat N., Aggarwal S., Sharma A., Sharma S.K., Deshpande S.K. and Nair K.G.M. (2011). #Surface disordering and its correlations with properties in argon implanted CR-39 polymer.# *J. Appl. Phys*, 109, 083513.
2. Pavia D.L., Lampman G.M., Kriz G.S. and Vyvyan J.R. (2007). #Spectroscopy.# Cengage Learning India Private Limited, New Delhi.
3. Fink D. (2004). #Fundamentals of Ion-Irradiated Polymers.# Berlin, Heidelberg: Springer-Verlag Publishers.
4. Ziegler J.F., Biersack J.P. and Littmark U. (1985). #The Stopping power and Range of Ions in Solids.# Pergamon Press, New York.
5. Dong H. and Bell T. (1999). #State of the art overview: ion beam surface modification of polymers towards improving tribological properties.# *Surf Coat Technol*, 111, 29-40.
6. Gowariker V.R., Viswanathan N.V. and Sreedhar J. (2003). #Polymer Science.# New Age International (P) Ltd., Publishers, New Delhi.
7. Bahadur P. and Sastry N.V. (2002). #Principles of Polymer Science.# Narosa publishing House.
8. Shekhawat N., Aggarwal S., Sharma A. and Nair K.G.M. (2015). #Surface hardening in N⁺ implanted polycarbonate.# *J. Mater. Sci.*, 50, 8.
9. Mayo D.W., Miller F.A. and Hannah R.W. (2003). #Course Notes on Interpretation of Infrared and Raman Spectra.# John Wiley & Sons, Inc., Hoboken, New Jersey.