ENHANCEMENT OF IC TRAY'S SURFACE CONDUCTIVITY USING ACCELERATOR TECHNOLOGY

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Abstract

We designed and manufactured a high current ion source for ion beam applications. As industrial application, we studied the relation between bombarded nitrogen fluence and surface resistivity on MPPO (Modified Polyphenylene Oxide) material, which are used for the IC tray, using the high current ion implantation technology. During the transportation, the electrical charge is induced on the tray surface and it generated the electrical shock into the IC chip. To prevent such damage, we developed the implantation process for the IC tray surface modification, which carried out at an accelerating energy of 50keV, ion beam current of 50mA. The surface resistivity of MPPO IC tray that is normally insulating was decreased in the range of 10^{12} to 10^{6} Ω/sq by increasing the total dose from 7×10^{14}ions/ c m ^{2} to 8×10^{16}ions/cm^{2}.

1 INTRODUCTION

Since the early 1970's, bombardment with charged particles employing heavy-ion accelerators has been used to obtain the information on changes induced in materials by radiation effects [1-3]. The ion beam processing of materials also has grown rapidly to fulfil needs for diverse technologies covering both electronics and mechanical applications [4-6].

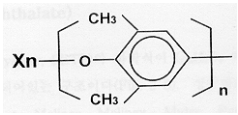
Electrically conductive polymers are very useful in a wide variety of industries [7,8]. Among the uses of these materials are EMI and rf shielding, antistatic surfaces, and battery electrodes.

Implantation of ions into the polymers generally leads to the radiation damages, which, in many cases, modified the electrical properties of the surface of materials. These modifications result from the changes of the chemical structure caused in their turn by changing the chemical bonding when the incident ion cuts the polymer chains, breaks covalent bonds, promote cross-linking and liberates certain volatile species[9,10]. The nature of these changes depends on the linear energy transformation, ion energy, incident ion mass and irradiation dose. According to current knowledge, high energy ions of the beam scatter on the target atoms and dissipating energy always causes some changes in polymer macromolecule structure. The dominating mechanism for energy transfer from ions to polymer is in elastic collision, referred to as electronic stopping, which affects the energy level of the electrons[11]. Electron exitations lead to the formation of free radicals and, consequently, chemical reaction in the polymer. Polymer chain rupture, crosslinks, unsaturated bond formation and gas liberation take place as a result of ion irradiation at low dose range[12]. Thus, various structures including regions of condensed aromatic structures are formed. Depending on the irradiation dose, the carbonization degree of polymer is increased.[13-15]

Despite of much research, our knowledge of chemical processes in ion implanted polymers is still incomplete. Here the structure and surface conductivity of MPPO implanted with N^{+} ions was studied at various ion doses. This study is intended to transfer KAERI's ion beam technologies to a domestic company so that it can commercialise MPPO modified material for antistatic, which are used for the IC tray.

2 EXPERIMENTAL

The MPPO used in this study is a sheet with the thickness of 1mm, the density of 1.06g cm^{-3} and its molecular structure of the repeating unit is



The sheets of MPPO were implanted with 50keV ions of nitrogen, xenon and argon in the range of ion dose from 10^{15} to 10^{17} ions/cm^{2}, using an ion current of approximately 10mA.

The chemical composition and structure of the surface of ion implanted MPPO were investigated with XPS (X-ray Photoelectron Spectroscopy). Depth profile and bonding structure of these samples were investigated with SIMS(Secondary Ion Mass Spectroscopy). XPS measurements were taken in a ESCALAB 200R system (manufactured by VG Scientific Co.) using MgKα radiation for excitation. SIMS measurements were carried out using a ϕ7200TOF-SISM/SALI system employing 8keV Cs beam. Surface resistivity were measured with Super Megohmmeter (SM-8215, TOA Co.).

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3. RESULTS AND DISCUSSION

The R_p(projected ion range) of N, Ar and Xe with 50 kV acceleration voltage are calculated by using the TRIM code, shareware software, on the MPPO material. The calculation result is shown in Fig. 1, in which nitrogen ion species were considered as mixed with nitrogen atom and molecule. Calculated R_p of 50keV N^++N_2^+ ions in MPPO is approximately 1900 Å . With increasing the ion mass, the projected range is decreased due to the elastic collision[1].

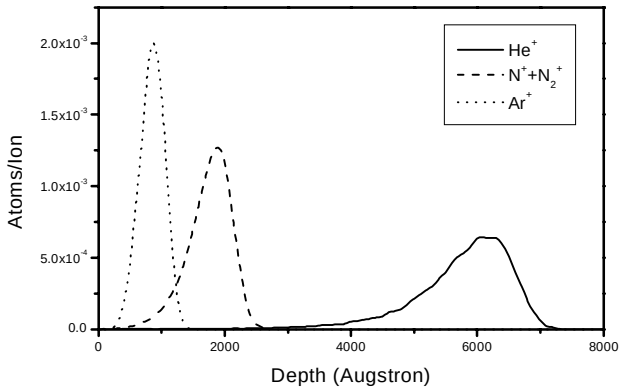

Figure 1. Various projected ion ranges for MPPO at 50kV Energy

We have implanted nitrogen ions onto the surface of MPPO, and found out that the surface resistivities are changed from 10^6 to $10^{12}\Omega$/sq with increasing ion fluence 5×10^{15} up to 7.6×10^{16} ions/ cm^2, which is enough to antistatic. Fig. 2 is the result of the surface resistivity dependency as a function of irradiated ion fluence.

We observed that the surface resistivity is rapidly decreased in the range of 1×10^{16} ions/cm^2 fluence and saturated over 7.6×10^{16} ions/cm^2 fluence. The phenomenon of the decreasing surface resistivity with increasing ion fluence is considered that the CH_3 bonds in polymer are broken by ion irradiation, and then result in making carbon layer by unsaturated bond, chain scission and cross-linking effects[16,17]. The saturation of the surface resistivity over 7.6×10^{16} ions/cm^2 ion fluence means that almost amount of CH_3 bonding are broken, and made a carbon bondings(carbonization), but it is still open question.

We compared other data of a previous study of polyimide polymer, which performed with nitrogen ion at 50 keV energy[12]. It shows similar tendency with MPPO case, since they are considered as a governed same physical modification mechanism.

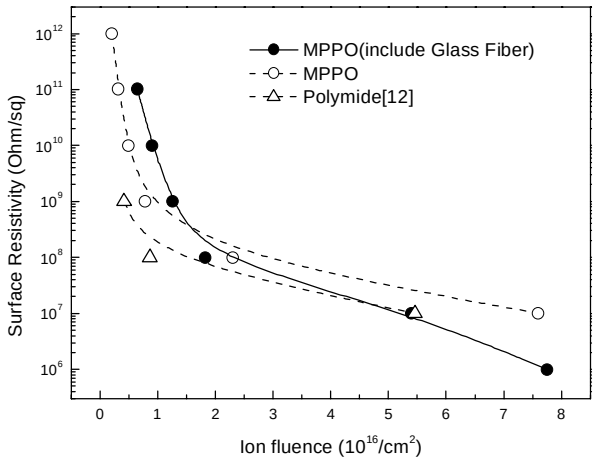

Figure 2. MPPO surface resistivity result as a function of ion fluence

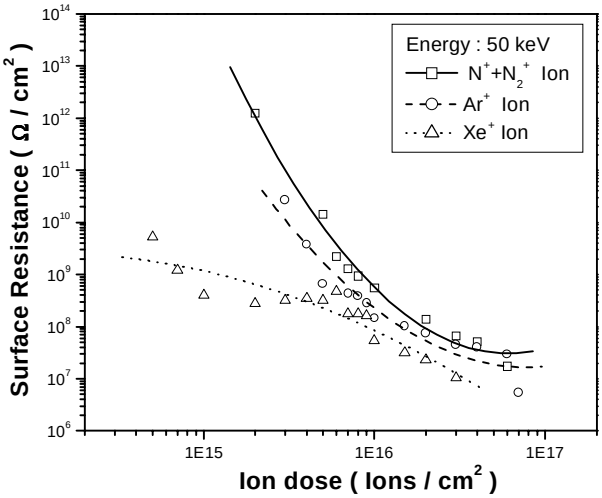

Figure 3. Surface resistivities of Ar, N and Xe ion fluence.

We also investigated the mass dependency effect of an implanted ions as showed in Fig. 3. In the same ion energy and fluence, the surface resistivity decreases with increasing the ion mass.

It is considered that the function of implanted ion is to destroy molecular bonding and help the carbon recombination process producing new carbon layer on MPPO surface.

Fig. 4 is the result of depth profile for 50 keV nitrogen irradiated MPPO. The abundance of a C-N bonding in MPPO changed drastically as a function of depth up to 3000 Augstron(Standard SiO_2 sputtering ratio), which was not observed at a pristine material. The other bondings, OH, C-C, are just showed small fluctuation as a function of depth.

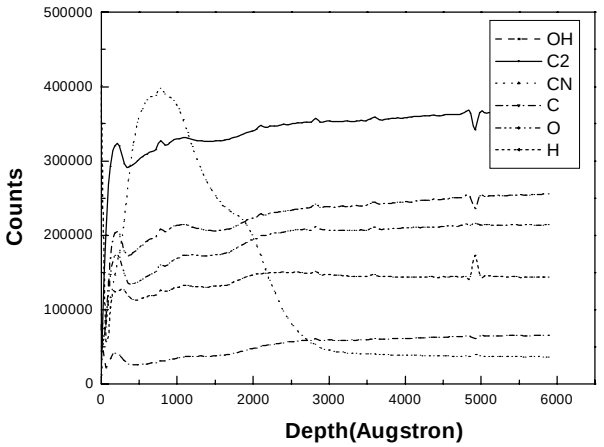

Figure 4. SIMS analysis result for irradiated MPPO with a 50 keV nitrogen

The increase of C-N bonding is also observed at the XPS analysis. Fig. 5 is the XPS analysis result on MPPO surface as a function of binding energy. The C-N bonding showed at binding energy 287eV which mixed together with C-O-C(286.4eV), C-C(284.9eV) and C=O(288.3eV) bonding within energy resolution. Nitrogen atoms substitutionally bound to sp^3 type and sp^2 type C cluster. More studies are need for investigation of the surface resistivity mechanism.

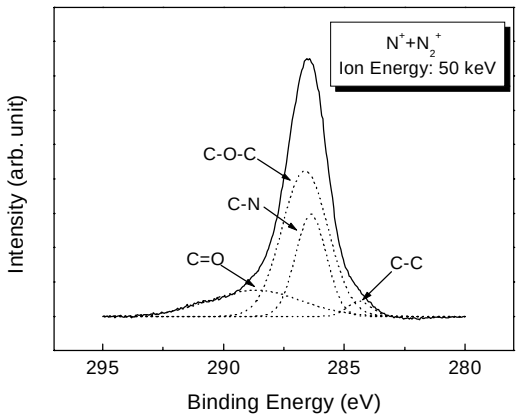

Figure 5. XPS analysis result for MPPO with nitrogen implantation

5 CONCLUSION

We have designed and manufactured a high current ion source for antistatic of polymer material employing heavy-ion accelerator technology.

Irradiating a low energy ion beam(50keV) to polymer, specially MPPO, as an electric insulator can change drastically its surface resistivity in the range of 10^{12} to 10^{6} Ω/sq. It is assumed that the origin of the conductive surface layer has concerned with chain scission and a formation of C-N bonding in polymer. The SIMS and XPS analysis proposed that a C-N bonding on the MPPO surface is deeply related with surface resistivity, but need more study.

The decrease of surface resistivity on MPPO using IC tray is very important situation to prevent electrical shock due to the electrostatic generation for IC chip transportation.

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