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Soft X-Ray Detection by Argon Implanted Poly Methyl Methacrylate

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Abstract: *Argon implanted methyl methacrylate sheets were subjected to Soft X-rays detection studies at room temperature. It is found that such sheets show high mobility lifetime product, low thermally generated charges at room temperature and high photelectric absorption of X-rays in the range 35KeV. X-ray switching studies conducted on these sheets show low rise and fall time making the material good for imaging applications.*

Keywords: *Atomic implantation, Detectors, Poly methyl methacrylate, Sensors, X-rays.*

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I. Introduction

In the field of material analysis, soft X-rays (wavelength of the order of Angstrom) have their plenty of applications including X-ray diffraction (XRD), X-ray microscopy and spectroscopy etc. [1-4]. X-ray detector is an important component of the instruments used in above mentioned applications. Large number of solid state materials are used to detect X-rays [5-6]. Choice of detector material is based on photoelectric conversion, mobility-life time product, stability, etc. With increasing applications of such detectors, another quality of the detector i.e. mechanical flexibility is now looked upon. For example, in dental radiography, if detector plate is flexible, it will be of great convenience. Similarly, for oscillation XRD plate there is requirement of cylindrical plate. In this connection, various polymer composite materials are being investigated [7].

II. Experimental

Poly methyl methacrylate [PMMA or $(C_5O_2H_8)_n$] plates (DELITE cast acrylic transparent clear) were procured from Amazon. India. Samples were prepared from the sheets with dimensions 1.2X1.2X0.3cm^3. Surfaces were cleaned using pure ethanol with soft paper tissue. Samples were mounted in vacuum chamber (pressure less than 10^{-6} torr). Argon ions (single positive charge state) were bombarded on the sample with fluence ranging from1.25X10^{15}/cm^2 to 14.0X10^{15}/cm^2. Accelerating voltage was kept 80KV and current was kept 5μA. Beam area was kept 1X1cm^2. Samples show slight etching on the surface and sample coloration changes from slight brownish to dark brownish.

Samples were then subjected to X-ray switching studies using X-rays at 35KV from copper target X-ray tube (Philips Holland). Continuous X-rays were obtained and beam was chopped at regular interval. It is done by using a switching rotor device using a stepper motor. Blocking of X-rays was done with thick semicircular lead ring. Rotation speed was controlled by a microprocessor P89C51RD2. Photocurrent was recorded by Keithley 6485 picometer. (Fig.1(a)).

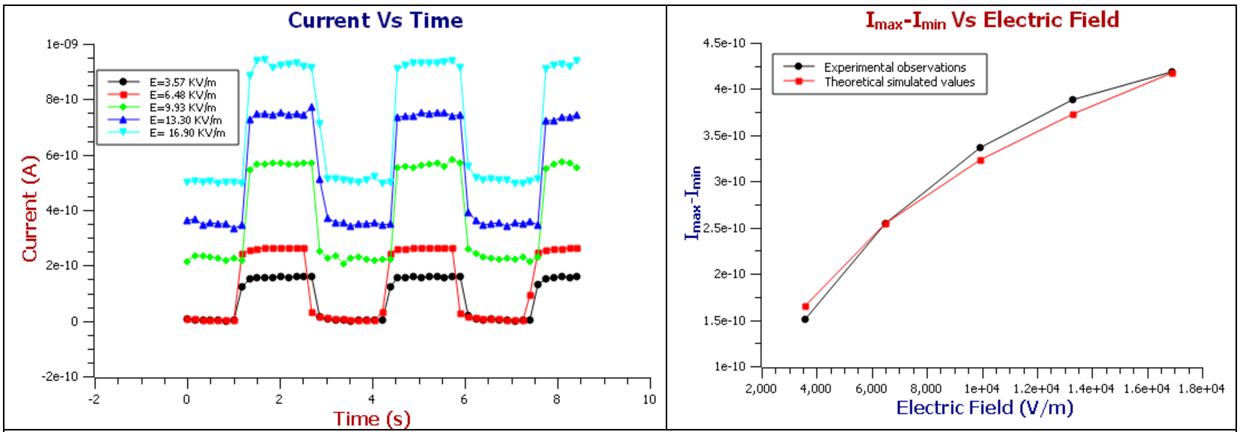

Fig.1(a) Photocurrent variation with time (b) Experimental and theoretical fitting of Photocurrent with electric field variation.

III. Results and Discussion

X-ray cross-section of PMMA with Argon concertation from 0.01%-0.3% were obtained using NIST XCOM software. It was observed that primarily, x-ray absorption in this material is due to photoelectric phenomenon. Elastic and inelastic scattering are comparably small. As energy is small, pair production phenomena are not expected. Presence of Argon in PMMA shows a peak at $3.202X10^{-3}$MeV. (Fig2). Peak intensity is found to increase linearly as the concentration of Argon is increased in PMMA. (Fig.4). X-ray absorption dominated by photoelectric absorption. It is a positive property for X-ray detector. This ensure high electron-hole pair production. For a good detector both quantum efficiency and spectral efficiency are to be high [8]. It is very important that charge generated, are to be collected with minimum loss to have high quantum efficiency.

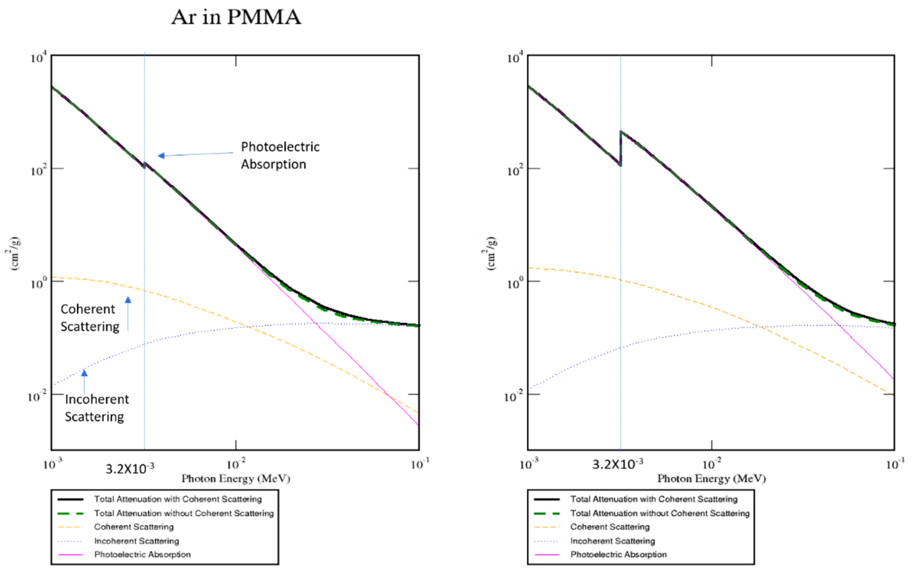

Fig.2. X-ray cross-section for 0.01(left) and 0.3% (right) Argon implantation. Increment of peak at $3.2X10^{-3}$MeV (NIST XCOM)

Further using 2D implant from Axcelis.com (Monte Carlo program), depth profiling of Argon implant was carried out. Results are shown in Figure. 3, for the fluence used in experimental work i.e. from $1.25X10^{15}/cm^2$-$14.0X10^{15}/cm^2$ in six steps. It was revealed that majority of Argon ions implanted within 150 Angstrom depths in the PMMA sheets. Moreover, with increasing fluence, collection of Argon ions are towards the surface (within 30 Angstrom). This large collection of Argon near the surface causes surface etching. Similar etching is also observed in Ar/O_2 plasma. [9]. This is primarily due chain scission done by high energy ions [10].

Mobility-life time product is an important parameter of a detector material. This parameter is obtained by using modified Hecht equation:

$$Q = Q_O\left(\frac{\mu\tau E}{d}\right)[1-\exp^{(-d/\mu\tau E)}] + kE$$

Here Q is charge collection by photogeneration, μ is charge mobility, τ is life time, E is electric field, d is sample thickness and k is correction coefficient. Term kE is added for the charge collection by the base material for sample holding. In our case it is PMMA sheet. Although PMMA has very high resistivity, yet a small contribution is made by the base material. Correction coefficient ‘k’ will depend on the intensity of the radiation reaching at the base material as well as charge generation by the medium due to highly ionizing radiation. Using iterative method mobility-life time product was found to be $6.4X10^{-3}$ cm^2V^{-1}(Fig.1b). Value is sufficiently high for a good detector material.

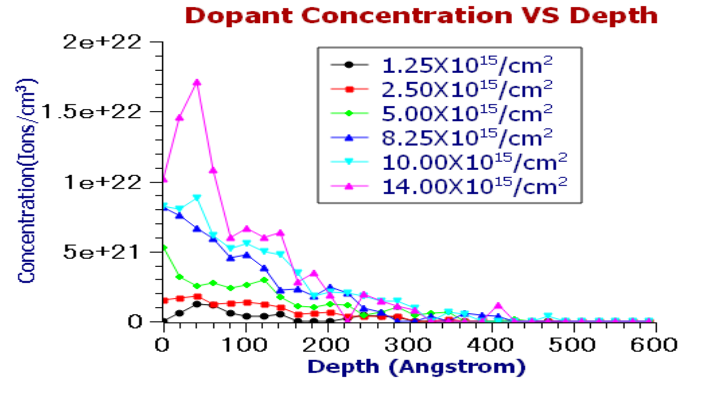

Fig. 3. Depth profiling of Argon implantation

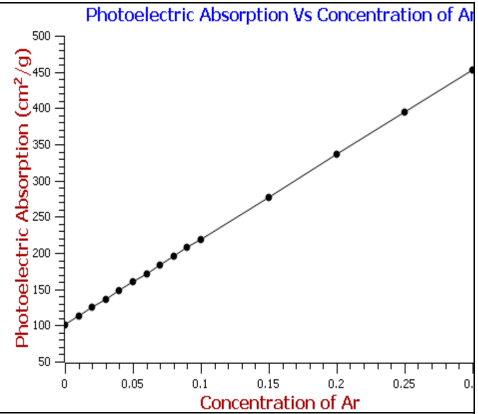

Fig.4 Photoelectric absorption variation with Argon concentration variation.

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IV. Conclusion

Soft X-ray detection studies conducted on Argon implanted PMMA reveled that it is a promising material. PMMA sheets can be casted in any shape. It is most advantageous characteristic of this material. However, controlling etching during implantation is a challenge.

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