Development of Polyaniline/n-Si hetero-junction detector: Construction and Preliminary Studies

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Introduction

Polyaniline (PANI) is a polymer material, having an outstanding thermal and chemical stability. It also has electrical features ranging from an insulator to a metallic state based on oxidation state and dopant [1]. Lot of studies have been carried out by various researchers in pursuit of electrical properties, optical properties, radiation induced morphology and Schottky junction effect utilizing PANI films/blend composites [1 – 6]. Few studies have shown that PANI can be used a radiation dose sensitive material based on the change in their electrical properties observed after exposure to radiation such as γ, x-ray, β, α etc. [7 – 9]. Based on all these studies, it was intended to tap the properties of PANI film to develop PANI/n-Si hetero-junction detector. In this device, the precious gold film (used in conventional surface barrier detector) on n-Si can be replaced by Al-film on PANI/n-Si hetero-junction. Another application could be use of PANI film as a standalone detector. In this paper, we describe the fabrication of PANI/n-Si hetero-junction radiation detector and its characterization.

Fabrication Process

Si-samples (n-type, <111> orientation) of 1 kΩ-cm resistivity, ~12 mm diameter and ~200 micron thickness were taken as starting material. They were lapped by various grain-size lapping powders. After lapping, they were thoroughly cleaned by ultra-sonicating them first in Methanol, followed by in Trichloroethylene and finally in de-ionized water. Subsequently, the samples were dried up by keeping them under infra-red lamp. Then these samples were chemically polished by etching them in an etchant comprising of 6:1:1 volumetric composition of HNO_3:HF:CH_3COOH. Electro-deposition technique has been used to deposit PANI film, on chemically polished Si-samples with their one side coated with Al. Deposition was done on n-Si substrates using 100 potentio-dynamic cycles (Cyclic voltammetry). For the deposition of PANI, the electrochemical cell consisted of Si working electrode, platinum wire as pseudo reference and platinum loop as counter electrode with electrolyte consisting of 0.5 M aniline solution (prepared in 0.5 M HCl) and 0.5 M HCl in 1:1 ratio. Thicknesses of PANI films can be varied by depositing the films with different number of potentiodynamic cycles or amperometry pulses. In the present samples, 50 potentiodynamic cycles (range -1.2 to 1 V) and 100 repetitions of pulsed amperometry (at 1.5 V) were used. The wafer was then fixed on a ceramic mount. Al-layer of 200 nm thickness was deposited onto the side having the PANI layer deposited on n-Si. On the back side, an ohmic contact was prepared by depositing 200 nm thick Al again (as the earlier deposited Al-layer was partly damaged while carrying out PANI deposition on n-Si sample) using vacuum evaporation at 10^{-6} Torr. Finally, the ceramic mount was hooked up in SS transmission assembly having the microdot connector as it is done in conventional transmission type detectors.

Results and Discussions

The performance of the fabricated detector was tested. The detector showed forward (Fig.1) and reverse (Fig.2) *I-V* characteristics expected for a Schottky junction. *I-t* characteristic (Fig. 3) was also measured for a fixed reverse bias of 40 V and a stable value of the reverse current (~ 40 μA) was observed. Detector was tested for alpha particle response (Fig. 4) using ^{241}Am – ^{239}Pu dual source. Clear Am and Pu peaks were found with an energy resolution of 110 keV for an applied reverse bias of 950 V, applied through a preamplifier having a load resistance ~ 110 MΩ.

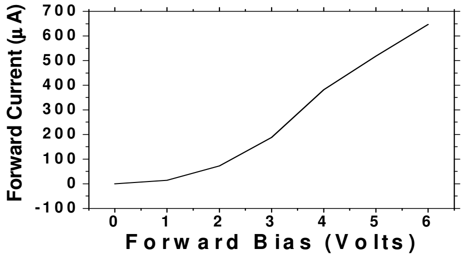

Fig. 1 Forward I-V Characteristics

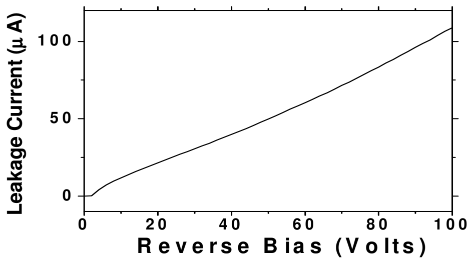

Fig. 2 Reverse I-V Characteristics

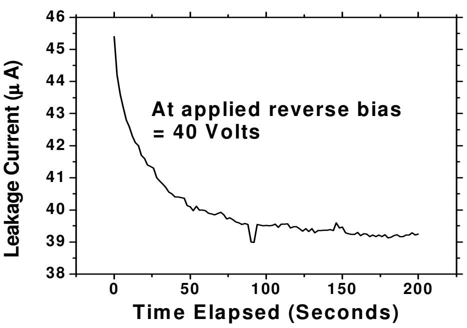

Fig. 3 *I-t* characteristics

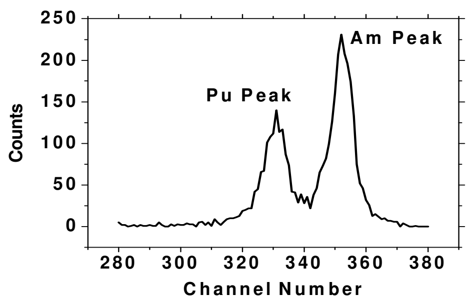

Fig. 4 Typical alpha spectrum of fabricated detector

Since PANI is known to be a p-type semiconductor, p-n junction is formed with PANI/n-Si hetero-junction. The electron-hole pairs created due to the absorbed radiation at the junction gets separated easily to the respective terminals due to the electric field at the junction.

Conclusion

Response of PANI/n-Si hetero-junction towards alpha radiation has shown promising results for using the hetero-junction as a radiation detector. Deposition of PANI by electrochemical methods on silicon substrate make the process cheaper and cost effective compared to the precious Au which is otherwise used for such detectors. However, long term effects of radiation need to be further studied to confirm the long term stability of the detector.

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