

ION IMPLANTATION INTO EVA POLYMER AND PERSPECTIVE APPLICATIONS IN ELECTRONIC DEVICES

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ABSTRACT

Experiences with ion implantation into EVAC (ethylene-vinyl-acetate copolymer) or EVA copolymer for biological-chemical applications suggested the use of this polymer as a promising material for "bipolar like" transistor architecture.

Recently in the literature various devices were proposed, using conducting or semiconducting polymer materials for FET or Permeable Base Transistor Polymer Grid Transistor, PGT.

Using a 90 keV energy Ar⁺ beam, we bombarded an EVA film on both faces and used this film in a cell potential of an ion selective electrode. The results show a sharp increase in ion selectivity [K⁺] almost reaching the theoretical value. Additional ion implantation experiences and subsequent electrical characterization envisaged that this polymer could have a potential semiconducting behavior like some others polymers mentioned in the literature.

This potential material behavior, motivated us to design some new transistor structures. Planar architecture of such device are suggested and open a new field of research and development in this area.

INTRODUCTION

The design of electronic devices with polymers have been a new field of research for microelectronics.

Recently published papers [1,2,3,7,8,10] show a set of new device architecture including LED (light emitting diodes) [3], FET (field effect transistors) [1,7], Tunnel Diodes [9], PGT (Polymer Grid Transistor) a NPN "Bipolar like" transistor [8].

In recent experiences with ion Implantation on EVA polymer (used for ion selective electrode in potentiometric cell) [11-15] motivated us to use ion implantation and that polymer to design electronic devices.

We show in this paper the results of ion implantation on EVA, the first electrical measurement and the ion selectivity in an ion selective electrode. Some proposed architecture to make electronic devices are presented using all polymer substrate and materials with ion implantation process.

EXPERIMENTS

Samples of EVA polymer was prepared using solid pellets, solvent and ionophore according to Moody method [11]. This preparation is intended for potentiometric cell application [11-15].

We placed the polymer film on the implanter sample holder (Ion Implanter Eaton GA 4204) and used the following parameters:

Sample N°	Energie (keV)	Ion	Fluence (ions/cm ²)	Current (μA)
# 0	90 keV	Ar ⁺	6.10 ¹²	6.24
# 1	90 keV	N ₂ ⁺	6.10 ¹²	4.80
# 2	90 keV	N ₂ ⁺	6.10 ¹³	7.00
# 3	90 keV	N ₂ ⁺	6.10 ¹⁴	12.00
# 4	150 keV	N ₂ ⁺	6.10 ¹²	2.50

Table 1 - Ion Implantation Parameters for EVA Polymer

The first values of fluence and energy was estimated based upon several reported ion implantation process in polymers [16-20].

Before ion implantation, all the samples were measured and exhibit very high electrical resistance. The ion selectivity as measured on a potentiometric cell show a slope of approximately 20 mV for potassium [K⁺] ion.

After implantation in both faces the films were applied to the construction of the potassium ion selective sensor. Slope around 48 mV, was measured well positioned between the limits of acceptable values [11].

The absolute resistivity of the implanted layer was difficult to measure because the film was very thick and the non-implanted high-resistivity bulk portion of the film dominated the overall value. But anyway, for potentiometric cell, ion selective sensor application the need is exactly full filled i.e., good ion selectivity is detected [21].

For [Ca²⁺] ion, the implanted layer shows no selectivity when applied to the potentiometric cell test [21].

SIMULATION

The experiments with ion implantation in EVA polymers were simulated using TRIM-94, a Monte Carlo method coded program for transport ions in matter, originally conceived in the Ziegler, Biersack and Littmark (ZBL) theory [22].

We used a monomer mass of 35.2 and a density of 0.925 g/cm^3 . The results shown in fig. 1, indicated by the R_p (projected range) and ΔR_p (standard deviation), confirm that the implanted ion concentration is placed a few tenths of micron deep in the film surface.

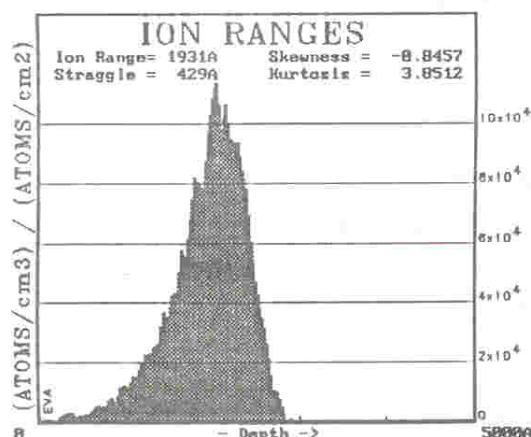


Fig. 1 - TRIM-94 simulation for ion distribution (5000 N^+ ions, 45keV, into $\text{H}_{12}\text{C}_7\text{O}_2$) in EVA polymer. The maximum concentration is only $20 \mu\text{m}$ deep from the polymer surface

EVA AS A PROMISING MATERIAL FOR ELECTRONIC DEVICES FABRICATION

The electronic structure, energy band models and precise description of polymer devices are somewhat controversial [9]. There are evidences that EVA polymer could present a N-type behavior. Normally the undoped polymer (chemically doping process) exhibit a P-type behavior [23]. But, with implanted process the polymer could assume a N-type characteristic.

This assumption was made based on the electrical tests we did with this polymer. We use low work function metals like Al and Mg to make contacts with the samples. We compare this measurements with that made by conducting polymer ink (ELECTRODAG 423SS). The system (two contacts on surface) shows a high resistance behavior, in all cases, even with Mg contacts one of the lowest work function metal ($\phi = 3.66 \text{ eV}$) [23].

This measured characteristic indicate (like in inorganic semiconductors) that EVA could present a N-type behavior. In general, inorganic semiconductor like silicon or gallium arsenide exhibit a high potential barrier height with metals due to the nature of the N-type energy bands.

These first tests were made in the same material used for potentiometric cell applications, i.e., we have two implanted surface with a high bulk resistivity part between them. For electronic devices such as suggested below we need a totally implanted material. So, more experiences and measurement efforts must be done to clearly identify the electrical polymer behavior [23, 24].

Based upon this assumption, we can design the basic vertical structure shown in fig. 2.

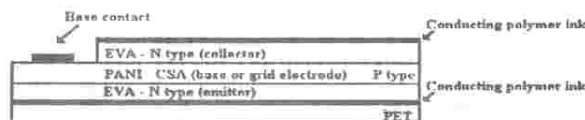


Fig. 2: An all polymer based "NPN Bipolar like" transistor

The "Grid" electrode proposed in this structure could be synthesized according to ref [8] with polyaniline protonated with camphor sulphonic acid (PANI-CSA).

This basic idea shows an all polymer based transistor. The polymer film used for "mechanical" substrate is poly (ethylene-terephthalate), PET.

Besides the vertical structure sketched in fig. 2 we envisage the "quasi-planar" architecture for "bipolar like" transistor (fig. 3).

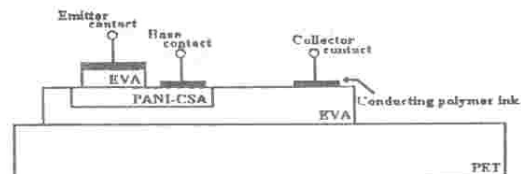


Fig. 3 - A proposed "quasi-planar" architecture for "bipolar like" transistor

The base region "diffused" into the EVA "collector" area can be made by the same process of the "permeable" grid transistor [8]. Because PANI-CSA could be used as hole injector [3].

These structures can be made possible using the basic technologies for inorganic semiconductor electronic devices.

CONCLUSIONS

In this paper, we show that with different kinds of polymers and using basic printing techniques used in microelectronics, it is possible to design some device architecture such like all-polymer "bipolar like" transistor.

The materials used for these devices could be synthesized or obtained by polymer suppliers. We avoid the use of metallic connections in these structures but it can be done without loss of flexibility property of such components. The planar or "quasi-planar" architecture open the possibility of device integration. Aging phenomenon due to air exposure must be studied searching for stable components.

Additional implantations and characterization to determine more precisely the polymer and device behavior are envisaged.

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