Deposition and Characterization of The Composite Material P-Si/Polymer-Cu for Photovoltaic Applications

A. Zouaoui[1], B. Khaniche[1], I. Chikouche[1], A. Sahari[2], A. Zegadi[1]

[1]Laboratoire: Croissance et Caractérisation de Nouveaux Semi conducteurs,

[2]Laboratoire de chimie, d'ingénierie moléculaire et des nanostructures,

Université Ferhat Abbas – Sétif, Route de Bejaïa, 19000 Sétif, Algeria.

*Corresponding author: E-mail : a_zouaoui_dz@yahoo.fr

Abstract

The aim of this paper is to report on the results obtained on the deposition of the composite material p-Si/Poly[4-pyrrol benzoic acid]-Cu (p-Si/poly (PBA-Cu) thin films for photovoltaic applications. The deposition of the polymer film was made by electrochemical oxidation of the monomer in organic medium. The incorporation of copper in the polymer film was performed by complexing and electroreduction of copper ions II. We analyze the influence of the semiconductor substrate in the deposition of the polymer thin film. In the characterization, we have used cyclic voltammetry (CV) and electrochemical (EIS) and Atomic force microscopy (AFM). Preliminary results obtained using impedance spectroscopy is finally presented. The new structure Si/Polymer-Cu offers many possibilities of application in various fields, in particular for microelectronic and photovoltaic application.

Keywords: Polymer, Modified electrodes, Silicon, Copper

Introduction

In the search to replace silicon and other semiconductor thin film technologies, and in order to develop a long term technology bearing in mind that this should be environmentally friendly, low cost and abundant an increasing research interest is nowadays given to organic materials [1].

The incorporation of small metal particles in organic matrices, in particular polymers, has resulted in numerous published works [2]. Studies on the incorporation by electrochemical reduction of metal particles with catalytic properties in polymer films have been mainly devoted to the incorporation of noble metals (Pt, Pd, Rh) [3]. However, only a few examples are found in the literature concerning the inclusion in polymer films of particles of transition metals such as nickel, copper or cobalt [4]. Recently, new electrode materials composite (carbon / polymer-metal) have been developed [5-6].

The aim of this paper is to report on the results obtained on the deposition of the composite material p-Si/Poly[4-pyrrol benzoic acid]-Cu (p-Si/poly (PBA-Cu) thin films for photovoltaic applications. The deposition of the polymer film was made by electrochemical oxidation of

the monomer in organic medium. The incorporation of copper in the polymer film was performed by complexing and electroreduction of copper ions II.

Experimental

Silicon substrates, p-type conducting, <100> oriented, of resistivity in the range 0.01 – 0.08 Ω.cm, and of active area of 0.32 cm^2 have been used as electrodes. Each electrode is cleaned with acetone and then ethanol, respectively, for 10 min and then washed thoroughly with distilled water. Thereafter, these were treated in a solution of 10% HF [7] for a short period of time in order to remove the oxide layer (SiO_2) and other contaminants and finally activated in a hydrochloric acid solution (1M) for one minute.

The electrodeposition process of the polymer Poly[4-(pyrrol-1-yl-methyl) benzoic acid] (PAB) was carried out in a Pyrex glass cell which has a double wall and a capacity of 5 ml with a glass lid in which there exist four holes that allows the easy passage of three electrodes. The counter electrode was a platinum wire and the reference electrode is an electrode Ag/Ag^+ (10^{-2} M) which is a silver wire immersed in a solution of silver nitrate 10^{-2} M in the acetonitrile with supporting electrolyte.

All of our electrochemical experiments was carried out with a Voltalab PGZ 301 that consists of a potentiostat-galvanostat, running under the software VOLTALAB Master 4.

Results and Discussion

Electropolymerization of 4 - (pyrrol-1-yl-methyl) Benzoic Acid

The deposition of Poly[4-(pyrrol-1-yl-methyl) benzoic acid] (PAB) on a p-silicon electrode is obtained in an organic solution of CH_3CN which contains 4.10^{-3} M of 4 - (pyrrol-1-yl-methyl) benzoic acid and 10^{-1}M $LiClO_4$ by electrochemical oxidation of monomer . Figure 1 shows the recording of successive voltamperograms (20 cycles)

The voltammogram show the appearance of two waves, one cathodic to 0.05 V corresponding to the reduction of the polymer previously obtained and another anodic towards 0.7 V corresponding to its oxidation[9]. These processes increase in a regular manner, this translates into the growth of the polymer film deposited on the surface of the electrode.

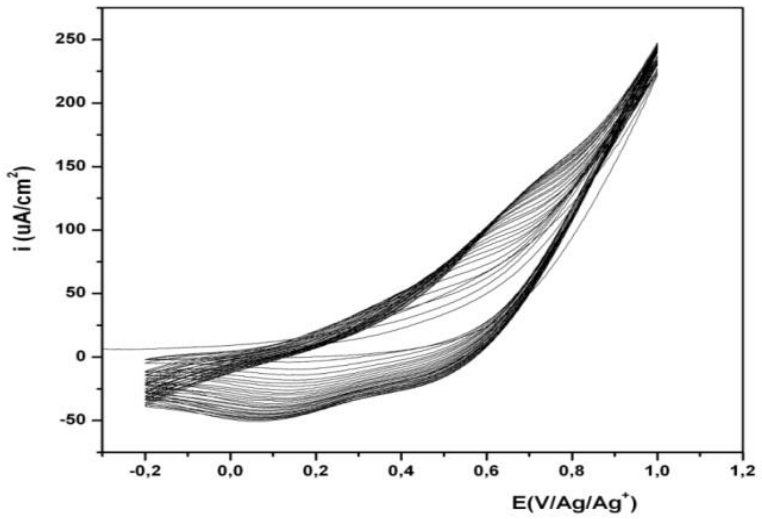

Figure 1 : Cyclic voltammetry curve of 4 - (pyrrol-1-yl-methyl) benzoic acid recorded at Si in CH_3CN + 0.1 mol L^{-1} TBAP scan rate = 0.1 V s^{-1}.

Incorporation of Cooper in Poly[4-(pyrrol-1-yl-methyl) Benzoic Acid]

The electrochemical behavior of copper was investigated on an electrode of silicon in an aqueous solution less acidic containing 0.1 M Na_2SO_4 as a supporting electrolyte and the salt concentration of 0.01 M of $CuSO_4$. The cyclic voltammogram recorded at a scan rate of 0.1V/s in a potential range between 0 to -1.6 V, see figure 2.

We note that the electrochemical reduction of copper on the new substrate is difficult compared to n-type substrates because the field of electroplating copper becomes large and the appearance of a reduction peak has reduced the potential to the value of -1.3V during the first cycle then we notice a shift of these peaks towards positive potentials with a steady increase in the intensity of the current showing the film formation of a metal deposit.

Electrochemical impedance spectroscopy (EIS)

The impedance measurements were performed on films of poly Poly[4-(pyrrol-1-yl-methyl) benzoic acid] (PAB) synthesized by galvanostatic coulometry at an imposed current of 0.2 mA during the elaboration of the polymer on the silicon electrode. The study is performed in the frequency range between 100 mHz to 100 kHz at the equilibrium potential. Figure 3 illustrates the results obtained.

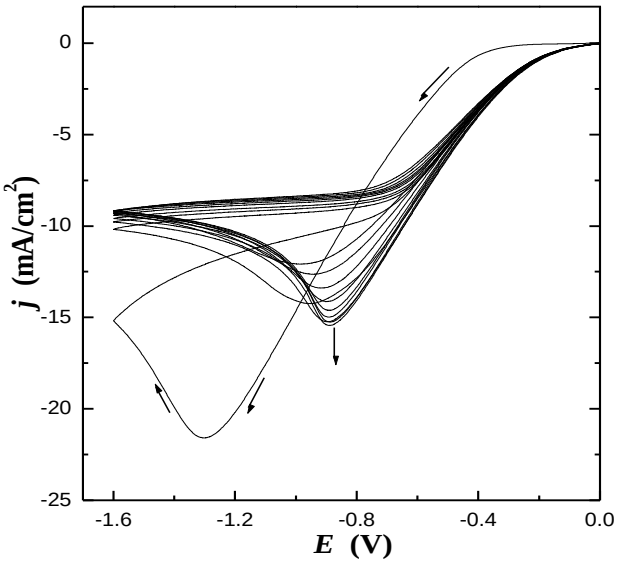

Figure 2: Electrochemical reduction of copper on the p-Si electrode carried out at the scan rate of 0.1V/s.

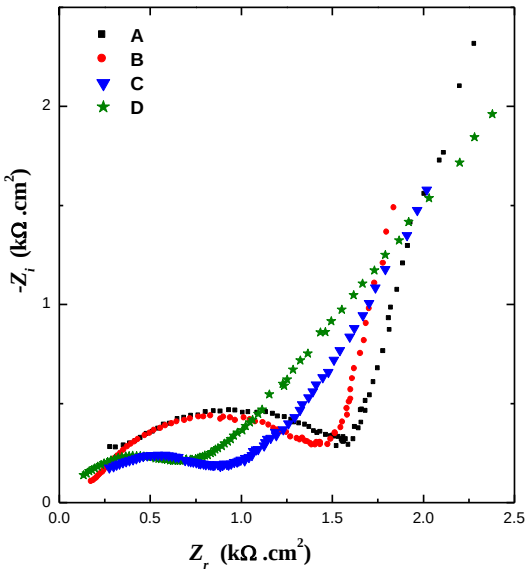

Figure 3: Nyquist diagrams for : A) p-Si, B) p-Si/poly (PBA), C) p-Si/poly (PBA)/Cu (1st incorporation) and D) p-Si/poly (PBA)/Cu (2nd incorporation).

Nyquist diagrams obtained after the 1st and 2nd electrochemical reductions of copper on poly (PBA) show some differences in appearances, suggesting that the number of reduction affects the electrochemical behavior of the modified electrode p-Si/poly (PBA) [12]. Also, all the diagrams obtained do not start at the same value on the real axis indicating

that the resistance of the electrolyte has changed. According to these diagrams, it is worth noting that when the copper incorporation number is increased our composite thin film becomes more conductive.

Conclusion

We have presented an electrosynthesis process that produces homogeneous and strongly adherent poly Poly[4-(pyrrol-1-yl-methyl) benzoic acid] (PAB) films on semi conductors electrodes in acitonitrile solutions. Consequently, the electrodeposition of poly (PBA) was successfully achieved under different electrochemical techniques, such as potentiodynamic (i.e. cyclic voltammetry), and galvanostatic (constant current). The electrochemical incorporation of copper particles into Si/Poly (PBA) was considered with the aim of obtaining new electric properties. The new structure Si/Poly (PBA)-Cu offers many possibilities of application in various fields, in particular for microelectronic and photovoltaic applications.

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