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Electrical Properties of Al/p-Si Structures with Colchicine Organic Thin Film

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In this study, we have fabricated an Al/Colchicine/p-Si structure and have investigated its current–voltage (I–V) and capacitance–voltage (C–V) characteristics at room temperature. The barrier height and ideality factor values of 0.68 eV and 3.22, respectively, have been obtained from the I-V plot. The value of the barrier height was compared with the barrier height value of 0.50 eV of a conventional Al/p-Si diode. This was attributed to the Colchicine organic film modifying the effective barrier height by affecting the space charge region of the inorganic Si semiconductor substrate. By using C^{-2}-V characteristics the diffusion potential value has been extracted as 1.32 V.

Keywords: Electronic Materials, Organic Films, Barrier Height, Ideality Factor, Surfaces and Interfaces.

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1. INTRODUCTION

Due to the technological importance of Schottky barrier diodes (SBDs), a full understanding of the nature of their electrical characteristics is of greater interest[1-2]. Metal–semiconductor (MS) contact is one of the most widely used rectifying contacts in the electronics industry[1-2]. It is well known that the interfacial properties of these contacts have a dominant influence on device performance, reliability and stability. There is a native thin insulating layer of oxide on the surface of the semiconductor in most practical MS contacts. This layer converts the MS structure into a metal/interfacial layer/semiconductor (MIS) diode[2]. Besides, it may be constructed as an organic thin film between metal and inorganic semiconductor intentionally. This film modifies some electrical parameters of the devices. For example, Schottky barrier heights of MS contacts can be manipulated by inserting a dipole layer between the semiconductor and the metal film. So far, many attempts have been made to realize a modification and the continuous control of the barrier height using an organic semiconducting layer or an insulating layer at certain metal/inorganic semiconductor interfaces[3-7]. Among the organic materials, Colchicine is considered to be a good candidate for organic semiconductor device fabrication such as Schottky device and solar cell, because it offers a possibility of low-cost and large-area devices. Colchicine with molecular formula $C_{22}H_{25}NO_6$ (N-[(7S)-1,2,3,10-tetramethoxy-9-oxo-5,6,7, 9-tetrahydro benzo[a]heptalen-7-yl] acetamide) is used in this study. Fig.1 shows chemical structure of colchicine organic compound. Colchicine is a highly toxic plant hormone that is used medically in the treatment of gout and in scientific researches [8].

2. EXPERIMENTAL DETAILS

MIS device was prepared by using one side polished (as received from the manufacturer) p-type Si substrate in this study. Chemical cleaning and metallization procedures were given in our previous work [7]. Colchicine organic layer was directly formed by adding 6 μL of the colchicine organic compound solution (wt 0.2 % in water) on the front surface of the p-Si substrate, and evaporated by itself for the drying of the solvent in N_2 atmosphere for four hours. Then, Al metal was evaporated on the colchicine organic film at 10^{-5} torr (diode area = 7.85×10^{-3} cm^2). In this way the Al/Colchicine/p-Si device structure was obtained as seen in Fig. 2. The current-voltage (I-V) and capacitance (C-V) measurements of this structure were performed by Keitley 487 Picoammeter/Voltage Source and HP 4192A analyzer, respectively.

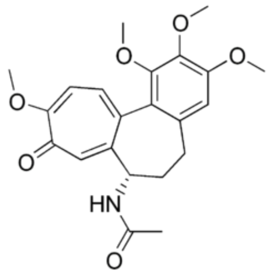

Fig. 1 – Chemical structure of Colchicine organic compound

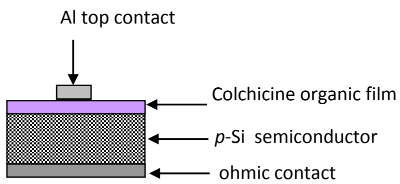

Fig. 2 – A cross-section of the Al/Colchicine/p-Si device

3. RESULTS AND DISCUSSION

Fig. 3 shows the I-V characteristic of the Al/Colchicine/p-Si diode. The values of the ideality factor n and barrier height(BH) obtained from I-V characteristic are 3.22 and 0.68 eV respectively. The

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high values at the ideality factor may be caused by some effects such as inhomogeneities of film thickness, non-uniformity of the interfacial charges and the effect of the series resistance. The BH value of 0.68 eV obtained for the Al/Colchicine/p-Si diode with organic layer is remarkably higher than that achieved with conventional MS contacts such as Al/p-Si diode, whose BH was 0.50 eV [9]. This may be ascribed to Colchicine interlayer modifying the effective barrier height by influencing the space charge region of the inorganic Si substrate[6]. Thereby, it is known that the Colchicine film forms a physical barrier between the metal and Si inorganic substrate, preventing the metal from a direct contact with the Si surface. The Colchicine organic layer appears to cause a significant modification of interface states even though the organic-inorganic interface becomes abrupt and unreactive[5, 6]. Thus, the change in barrier height can qualitatively be explained by an interface dipole induced by the organic layer passivation[5, 10]. Kampen et al.[10] have observed by photoemission spectroscopy investigations that the sulphur passivation reduces the surface band bending on n-type doped GaAs, and on the other hand, the band bending on the surfaces of p-type doped GaAs increases.

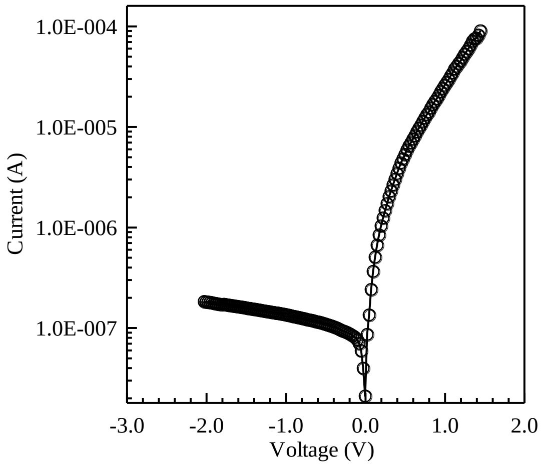

Fig. 3 – I-V characteristic of the Al/Colchicine/p-Si diode

Similarly, Zahn et al. [11, 12] have indicated that the initial increase or decrease in effective barrier height for the organic interlayer is correlated with the energy level alignment of the lowest unoccupied molecular orbital with respect to the conduction band minimum of the inorganic semiconductor at the organic-inorganic semiconductor interface.

Capacitance measurement is one of the most important nondestructive methods for obtaining information on rectifying contact interfaces[7]. Fig. 4 shows the forward and reverse bias C-V and C^{-2}-V characteristics of the diode measured at f = 500 kHz frequency, at room temperature. From linear section of C^{-2}-V plot, assuming dielectric constant $\varepsilon_s = 11.9\varepsilon_0$, the carrier concentration of p-Si was obtained as 8.72×10^{14} cm^{-3}. The voltage axis intercept of the C^{-2}–V plot gives a value of 1.32 V for diffusion voltage. Also, Schottky barrier has been calculated as 1.56 eV.

As seen from the obtained values, the difference between Φb(I–V) and Φb(C–V) for the Al/Colchicine/p-Si MIS diode originates from the different nature of the I–V and C–V measurements. Due to the different nature of the C–V and I–V measurement techniques, barrier heights deduced from them are not always the same. The capacitance C is insensitive to potential fluctuations on a length scale of less than the space charge region and C–V method averages over the whole area and measures to describe BH as seen Fig. 5. The DC current I across the interface depends exponentially on barrier height and thus sensitively on the detailed distribution at the interface [2, 13]. Additionally, the discrepancy between the barrier height values of the devices may also be explained by the existence of an interfacial layer and trap states in semiconductor [14, 15].

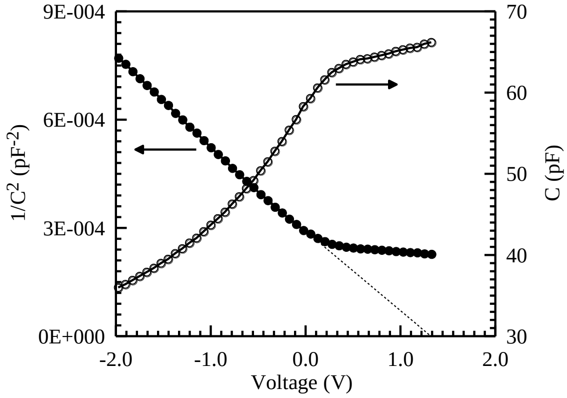

Fig. 4 – C-V and C^{-2}-V characteristics of the Al/Colchicine/p-Si diode

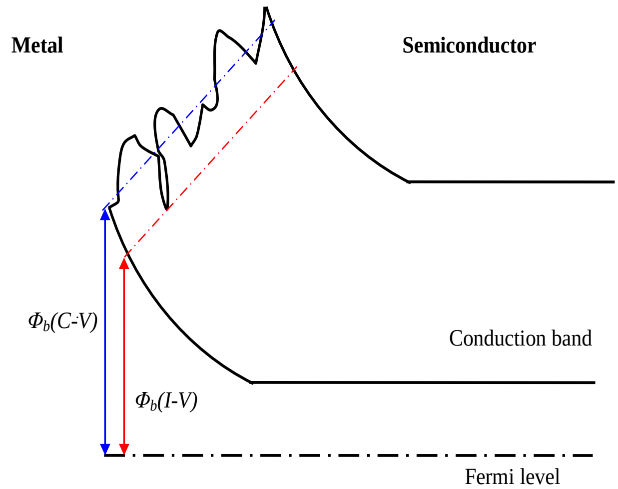

Fig. 5 – Potential fluctuations for I-V and C-V measurements at MS structures

Consequently, the rectifying junction characteristics of Colchicine organic film on p-type Si substrate have been studied. It has been observed that the Colchicine - based structure shows a rectifying behavior and that the Colchicine film increases the effective barrier height by influencing the space charge region of p-type Si.

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