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Temperature dependence of the current–voltage characteristics of the Al/Rhodamine-101/p-Si(1 0 0) contacts

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Abstract

The current–voltage (*I*–*V*) characteristics of Al/Rhodamine-101/p-Si/Al contacts have been measured at temperatures ranging from 280 to 400 K at 20 K intervals. A barrier height (BH) value of 0.817 eV for the Al/Rh101/p-Si/Al contact was obtained at the room temperature that is significantly larger than the value of 0.58 eV of the conventional Al/p-Si Schottky diode. While the barrier height Φ_{b0} decreases the ideality factors (n) become larger with lowering temperature. The high values of n depending on the sample temperature may be ascribed to decrease of the exponentially increase rate in current due to space-charge injection into Rh101 thin film at higher voltage. Therefore, at all temperatures, it has been seen that the *I*–*V* characteristics show three different regions, the ohmic behavior at low voltages, and the space charge limited current with an exponential distribution of traps at high voltages.

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1. Introduction

In recent years there has been growing interest in the field of thin organic semiconducting films due to their successful application in optical and electronic devices. In addition, organic semiconducting materials have now reached the early stages of commercialization with the technological success of thin film organic optoelectronic devices, particularly organic light-emitting devices and with improving their efficiency, manufacturing yield and long-term stability [1–5]. In spite of the recent technological success of these materials, relatively little is a detailed

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understanding of the charge injection and transport processes in organic semiconductor devices and therefore the analyzing these processes is crucial as mentioned in [4–9].

Some researchers [10,11] have studied the electronic structures of various metals/organic interfaces by using various surface-scientific methods and the formation of an electric double layer and chemical interaction at the interface. Schwieger et al. [12] and Tautz et al. [13], Hill et al. [14] and Peisert et al. [15] have presented a systematic study of the energy level alignment at the interfaces between metals and organic semiconductors, and have shown that there are contributions to the potential drop (dipole) across the metal/organic interface and a modification of the metal work function due to the adsorption of the organic molecules and a potential change in the organic semiconductor [10–15]. We can state more clearly that the surface-preparation methods serve some advantages because successive Schottky metallization generally causes an interfacial modification. However, the defective states originated from the deposition of Schottky metal and interfacial reaction during metallization can be passivated by the non-reactive organic materials onto the inorganic semiconductor substrates [16–21]. The organic/inorganic semiconductor diodes can be a sensitive probe useful in establishing processes for minimizing surface states, surface damage, and contamination which may ultimately increase the quality of devices fabricated using the semiconductor [16–21].

In general, the formation of high-quality Schottky barrier diodes (SBDs) with a low ideality factor using thin interfacial films is one of the essential prerequisites for devices. Moreover, as contacts to inorganic semiconductors such as Si, GaAs, InP, etc., polymeric and non-polymeric organic compounds can provide such a general route to the continuous control of the BH at certain semiconductor interface [20–26]. The first reports related to barrier height enhancement or modification using non-polymeric organic thin films (polycrystalline aromatic organic compound) deposited on inorganic semiconductor substrates have been published by Forrest et al. [24]. Furthermore, in some studies [25], it have reported how an alkyl monolayer can tune a resistor to a diode, and described how the electron transport correlates to the device performance in these ‘‘genuine’’ metal–molecular–semiconductor junctions, and has been explored the use of organic monolayers on oxide-free silicon to change the interfacial nature of metal–semiconductor junctions, i.e., effectively passivating the silicon surfaces and molecularly tuning the barrier heights (BH) of these junctions [25]. Kampen et al. [26] have fabricated Schottky contacts on chalcogen-passivated GaAs(1 0 0) surfaces to reduce the interaction between metals and GaAs, and they [26] qualitatively explained the change in barrier height by an interface dipole induced by the chalcogen passivation. Liang et al. [27] have fabricated polymer based Schottky diodes and studied their electrical characteristics. Recently, Temirci and Cakar [28] have published a paper about current–voltage characteristics of Cu/Rhodamine-101/p-Si/Al and they obtained a barrier height value of 0.78 eV and a better ideality factor value of 1.54 for the Cu/Rhodamine-101/p-Si/Al contact from the forward bias *I–V* characteristics, they attributed the possible reason for the deviation to $n = 1$ (ideal contact) to oxide layer between Si and the organic.

The purpose in the present study is to examine whether or not the Al/Rh101/p-Si/Al contact can be used as a rectifying contact and obtained a higher barrier height than that of conventional Al/p-Si Schottky contact for room temperature. Furthermore, the temperature dependence of the experimental forward bias current–voltage (*I–V*) characteristics of the device was investigated over the temperature range of 280–400 K. Molecular structure of the Rhodamine-101 is given in Fig. 1. The Rhodamine-101 (Rh101) is a xanthene type molecule and has a quantum yield in

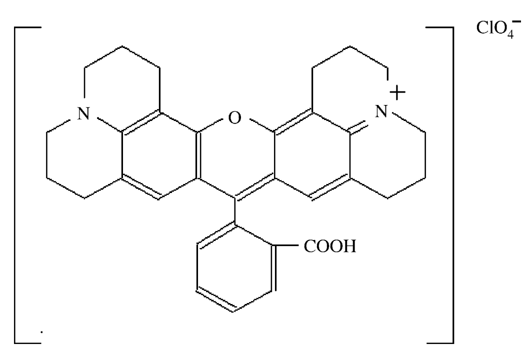

Fig. 1. Molecular structure of the Rhodamine-101 (molecular formula: $C_{32}H_{31}N_2O_7Cl$).