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The Effect of Interface States Density Distribution and Series Resistance on Electrical Behaviour of Schottky Diode

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Abstract

The forward and reverse bias current-voltage characteristics of the In/p-Si Schottky barrier diode (SBD) have been investigated in the temperature range of 360K to 120K. The current-voltage measurements have been used to extract the electrical parameters such as series resistance, barrier height, ideality factor and interface states density distribution. The higher values of series resistance, ideality factor and interface states energy distribution at low temperature was attributed to the presence of an interfacial insulated layer, popularly known as metal-insulator-semiconductor (MIS) devices. The temperature dependence energy distribution profile of interface states was obtained from the forward bias I-V-T measurements by taking into account the bias dependence of the effective barrier height and ideality factor. The interface states density (N_{SS}) decreased with increasing temperature was explained by the result of atomic restructuring and reordering at the metal semiconductor interface.

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Keywords: Series resistance; barrier height; interface states; insulating layer

1. Introduction

It is well known that rectifying metal-semiconductor contacts are one of the most widely used junction in electronics industries. The fabrication of such type of structures plays an important role in the realization of some useful devices [1- 4]. The electrical transport across Schottky barrier diode has been of considerable interest in the

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recent years for the well known applications such as microwave field effect transistors, radio frequency detectors, photo transistors and solar cells [5-6]. It is also a valuable tool to study electrical and physical properties of the new and smart semiconducting materials. The popularity of such studies comes from their important to semiconductor industries. For past several years, the interface properties and carrier transport mechanism have been studied both experimentally and theoretically, however there is a lacking of information about Schottky barrier formation and electronic structure at the metal semiconductor interface. Detail information of the charge carrier transport at metal semiconductor and metal insulator semiconductor contacts is still a challenging problem [7]. Now a days investigation on insertion of thin layers of different kind of organic and semiconducting material between metal and semiconductor have also been applied to change the barrier height in semiconductors [8-9]. The thickness of the interface oxide layer also referred as the interface controlled layer [10]. For ideal behaviour of Schottky diode approaching an ideality factor to unity, low series resistance and low reverse leakage current. The electrical characteristics of Schottky diode are often influenced by various non-idealities such as interface states, interfacial oxide layer and series resistance. The current-voltage measurement of Schottky diode at room temperature does not give sufficient information about conduction mechanism and nature of barrier formation at the metal semiconductor interface.

The current–voltage characteristics behaviour analysis over a wide temperature range give some satisfactory information for consideration of various aspects of conduction mechanism, inhomogenity and interfacial properties of Schottky barrier diode features. In general, the performance, stability and reliability of Schottky barrier diodes are significantly influenced by the interface states between deposited metal and the semiconductor surface [11]. The ideality factor of real Schottky barrier diode is strongly temperature dependence. The ideality factor increases with decreased in temperature, this is known as T0 effect and due to that, the apparent barrier height obtained from forward bias current-voltage characteristic using thermionic emission theory also shows strong temperature dependence. T0 effect is either related with inhomogenity of barrier height or with the function of recombination and tunneling current component [7]. The apparent increased in ideality factor and decreased in barrier height at low temperature due to inhomogeneous of metal thickness and composition of the layer, non-uniformity of interfacial charges or presence of charges and the thin insulating interfacial layer between metal and semiconductor [12]. It is well known that unless using ultra-high vacuum system, the fabricated Schottky barrier diodes possesses a thin interfacial native oxide layer between the metal and the semiconductor. The interface states and interfacial oxide layer at the metal semiconductor rectifying contact play an important role in the determination of the Schottky barrier diode and other characteristic parameters of the device and also affect the device performance.

In this context, investigations of the non-idealities electrical behaviour of soft metal Indium fabricated on chemical etched passivated smooth surface of moderately doped p-type silicon. The performance of electrical characterizing parameters barrier height, ideality factor, series resistance, interface states density distribution curve evaluated for wide temperature range 360K to 120K with equal intervals of 20K. Before the evaluating current-voltage normally affected by parasitic resistance such as series resistance and shunt conductance corrected by finding out approximate value of each temperature. However, ideality factor is more than unity and derived by proposing Cheung and Cheung formula are much higher than common thermionic emission theory. It indicates directly that Schottky diode has a presence of thin interfacial layer and interface states located at the metal semiconductor interface. Due to that the ideality factor larger than unity at higher temperature also indicates the existence of thin native oxide layer between metal and semiconductor interface [13].

2. Experimental

In this study,p-type silicon crystal was used to fabricate In/p-Si Schottky diode. The density of crystal is around 10^{16} cm $^{-3}$and it is acceptor type. The polished surface of crystal was etched in 1:3:3 mixtures of electronic grade hydrofluoric acid, nitric acid and acetic acid. It was kept in saidmixture till brown vapour appeared (around 30 seconds). Later on, it was immersed for a minute in a dilute solution of HF: H_2O (1:9) [27]. Now, p-type silicone crystal was kept inside the vacuum coating unit (HIND HIVAC: 15F6D). The system was evacuated to a pressure of 10^{-6}torr. An aluminum coating was made on the rough side of the crystal to make ohmic back contact.The thickness