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Electrical and structural properties of rapidly annealed rare-earth metal Er Schottky contacts on p-type InP

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ABSTRACT

We investigate the effect of annealing temperature on the electrical and structural properties of Er/p-InP Schottky contacts. The barrier height of as-deposited Er Schottky contacts is found to be 0.89 eV (*I–V*) and 0.98 eV (*C–V*). After annealing at 200 °C, a maximum barrier height is obtained for the Er Schottky contact and the corresponding values are 0.93 eV (*I–V*) and 1.11 eV (*C–V*). However, both *I–V* and *C–V* measurements show that the barrier height slightly decreases for the contacts annealed at 300 °C and 400 °C. Norde and Cheung's methods are used to extract the barrier height, ideality factor, and series resistance of Er/p-InP Schottky contact. The barrier heights obtained from the Norde and Cheung's methods are closely matched with those obtained from the *I–V* method. Further, the discrepancy between Schottky barrier heights calculated from *I–V* and *C–V* methods is also discussed. Based on the AES and XRD results, the increase or decrease in Schottky barrier heights upon annealing at elevated temperatures could be attributed to the formation of interfacial phases at the Er/p-InP interface vicinity.

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1. Introduction

Owing to applications in various optoelectronic and electronic devices, metal–semiconductor (MS) structures have a significant role in the fabrication of semiconductor devices [1,2]. Group II *I–V* compound semiconductors, particularly indium phosphide (InP) is an attractive semiconductor due to its advantages for solar cells, laser diodes, photo-detectors and high speed metal–insulator–semiconductor field effect transistors (MISFETs), microwave sources and amplifiers operating at high power and high frequencies with low noise [3–5]. It is well known that the electrical characteristics of the Schottky barrier diode (SBD) strongly depend on the MS interface [6–16]. Unless specially fabricated, an SBD possesses a thin interface native oxide layer between the metal and the semiconductor which may convert the device to metal–insulator–semiconductor (MIS) diode [1–11]. This may have a strong influence on the diode characteristics as well as a change of the interface state charge with bias which will give rise to an additional field in the interfacial layer [1–15]. Besides, in order to design contracts with improved thermal and electrical stability, as well as desirable morphologies, it is important to have a thorough understanding of the reactions of the contact metals with InP. Therefore, the development of thermally stable Schottky contacts to InP with high barrier height and low-reverse leakage current is still a challenge.

The electrical characteristics Schottky barrier diodes (SBDs) have been extensively investigated both experimentally and theoretically due to their technological importance of the performance and reliability in the electronic industry [16–19]. Earlier, attempts have been made to investigate the electrical properties of p-InP Schottky diodes using various metallization schemes [20–27]. For example, Singh et al. [20] fabricated metal–insulator–semiconductor (MIS) and metal–semiconductor (MS) diodes on the Yb/p-InP system and investigated their electrical properties as a function of temperature. They reported a high value of ideality factor (n) for MS diode than the MIS diode. Asubay et al. [21] reported the barrier height for the as-deposited Au/p-InP/Zn–Au Schottky barrier diodes (SBDs) varied from 0.58 to 0.72 eV and ideality factor n from 1.14 to 1.47, and for the annealed at 400 °C SBDs varied from 0.76 to 0.82 eV and ideality factor n from 1.17 to 1.39 from the current–voltage (I–V) characteristics. Asubayet al. [22] prepared metal/p-InP SBDs using different metals and reported that the laterally homogeneous barrier heights obtained for Schottky diodes. Varenne al. [23] studied the electrical parameters of Pd and Au pseudo-Schottky contact on p-InP as a function of metal species and thickness by current–voltage (I–V) measurements. They showed that the pseudo-Schottky junctions exhibited a significant barrier height enhancement. Ejderha et al. [24] studied the I–V–T characteristics of the sputtered Ni/p-InP Schottky diodes in the temperature range of 60–400 K. They reported that the series resistance (R_s) and the interface state density (N_{ss}) values increase with a decrease in temperature. Janardhanam et al. [25] fabricated Ti/p-InP Schottky diode, and reported that the barrier height of 0.73 and 0.77 eV at 300 K by I–V and C–V measurements. Also, they observed that the interface was homogeneous. Asubay [26] investigated the electrical characteristics of identically prepared Al/p-InP Schottky diodes by I–V and C–V measurements, and showed that the effective barrier heights were varied diode to diode ranged from 0.83 ± 0.01 to 0.87 ± 0.01 eV (I–V) and 0.86 ± 0.04 to 1.00 ± 0.04 eV (C–V)). Very recently, Ashok et al. [27] studied the electrical characteristics of Er/p-InP Schottky diode at high temperature range (300–400 K) by I–V and C–V techniques, they reported that the barrier height, ideality factor and series resistance are strongly temperature dependent.

There are, however, only limited works on rare-earth metal/p-InP Schottky barrier diodes have been investigated [27,28]. A good Schottky contact will induce a large barrier height which can lead to better device characteristics such as small leakage current and high breakdown voltage. As the performance and reliability of Schottky barrier diodes are significantly influenced by the quality of the interface between the deposited metal and the semiconductor surface. Thus, formation and characterization of metal/InP devices has been the subject of a vast number of fundamental studies. Formation of semiconductor devices involves annealing at various temperatures. Therefore, it is necessary to understand what happens to the metal contacts during the annealing process. Thus, the main objective of the present work is to fabricate and characterize the Er Schottky contacts on p-type InP at different annealing temperatures. As far as we know, no one has investigated the electrical and structural