TAILORING OF THE METAL-N/P-TYPE GASB INTERFACE PROPERTIES FOR DEVICE PRODUCTION

K. VARBLIANSKA*, S.TZENEVA** , PH. COMNINOU***and D. NIHTIANOVA****

** Semiconductor Physics and Technology Laboratory, St. Kl. Ohridski University, Sofia, Bulgaria, BG1164Sofia, Galichitza33A, E-mail: inform@phys.uni-sofia.bg*
*** Faculty of Physics, St. Kl. Ohridski University, Sofia, Bulgaria*
****Aristotle University of Thessaloniki, Greece*
*****Institute of Mineralogy and Crystallography, BAS, Bulgaria*

Abstract. There are some difficulties in producing Schottky barriers (SB) to p-type GaSb and ohmic contacts (OC) to n-type GaSb connected with the physical nature of the GaSb itself. By applying low energy Ar ion sputtering at 200-700V and $(NH_4)_2S$ solution treatment of the p-type substrates we achieved a rectifying behavior of the p-GaSb/Pd contacts. The same procedure combined with a proper annealing led to the production of good n-GaSb/Pd/Ge/Au ohmic contacts. The electrical behavior of the SB and OC is inferred from their current-voltage characteristics on specially prepared diode structures. SEM and TEM investigations are conducted to specify the surface and interface reactions during the processing. We interpret these results in terms of the generation of such a Ga to Sb vacancy concentration ratio during the ion sputtering that enhances the incorporation of Ge and S as donor impurities in the GaSb surface.

Keywords: GaSb, Schottky, ohmic contacts,
PACS: 73.61.Ey III-V

INTRODUCTION

The need to create good Schottky and ohmic contacts in the semiconductor device production and investigation is well pronounced. The GaSb has two peculiarities: The Fermi level is closely pinned to the valence band edge; an existence of a native acceptor - Ga on Sb vacancy [1]. Due to the first one the metal contacts to p-GaSb are almost always ohmic. Due to the second one the intrinsic GaSb is p-type and it is difficult to grow highly doped n-type material for the production of low resistance ohmic contacts (OC). The aim of this work is to apply suitable pretreatments of the p/n – type GaSb so as to create a Schottky barrier (SB) to p-GaSb mainly and to observe their influence on the ohmic contact formation to n-GaSb.

In this investigation we have treated the GaSb substrates by Ar^+ ion etching at low voltages 200, 400 and 700V for 2-4 min and by soaking them into $(NH_4)_2S$) solution [2] which are denoted as CIS. The ion etched substrates only are denoted as CI. The above described procedures are applied on chemically etched GaSb denoted as C. p-GaSb/Pd and n-GaSb/Pd/Ge/Au ($n = 8x10^{17}cm^{-3}$) diode structures are produced on the so treated substrates. The back contacts are of Au and Au/Ge/Ni, respectively. Thermal evaporation is employed. The samples are annealed at temperatures 200 ^{0}C - 325^{0}C.

RESULTS AND DISCUSSION

p-GaSb/Pd The contacts which are deposited on the C-type surfaces are ohmic. The ones that are deposited on the p-GaSb chemically and ion etched wafers (CI) are almost ohmic no matter of the sputtering voltage. The I-V characteristics in fig. 1 are of a contact which is deposited on CIS type treated substrates at 200V and annealed at 200^{o}C. The as deposited one exhibits clearly a SB like behavior. The ion sputtering of the compound semiconductors is usually selective - at lower Ar^+ ion energies Ga is out sputtered from the GaSb surface first. This procedure may change the Ga to Sb vacancy concentration ratio changing thus the native acceptor concentration. It may introduce multiple donor states in the band gap as in the case of hydrogen plasma

CP899, *Sixth International Conference of the Balkan Physical Union,* edited by S. A. Cetin and I. Hikmet

treatment [3]. As a result p- to n-types conversion may have taken place in a very thin GaSb surface layer. On the other hand the S passivates the Ga and Sb dangling bonds on the GaSb surface during the sulfurization. We believe that at this stage the Fermi level unpins and the formation of a Schottky like contact to p-GaSb takes place. After the ion etching at 400V and 700V the CIS type structures have similar I-V characteristics. If we accept that the current transport takes place within a thin "converted layer", then we can roughly calculate the barrier height applying the thermionic emission theory to n-type GaSb [4]. The estimated value is 0.39 eV. Under heat treatment at T > 200°C the diodes begin to loose their rectifying behavior which is explained with the vanishing of the transformed surface layer due to mutual diffusion of the contacts elements. High resolution SEM cross-section observations of ion sputtered GaSb surfaces at 400 and 700V revealed nearly a 200 nm thick surface layer of ion penetration.

n-GaSb/Pd/Ge/Au This OC (125 nm Ge, 50nm Pd) created initially for the GaAs and its solid solutions is well studied [5]. The lowest contact resistance is measured when a Ge epitaxial layer on top of the GaAs has grown and the excess Ge is incorporated into the Ga vacancies as n-type impurity after annealing at 325°C. In fig 2 the I-V dependencies of the diode structures produced on C, CI and CIS type treated n-GaSb substrates after the annealing at 325°C are shown. The first one (C) behaves like a SB in the TFE mode contrary to the OC on n-GaAs. The rest ones exhibit an ohmic character. The CIS type contacts become ohmic even at 200°C which is below the temperature of the Ge epitaxy. Therefore the mechanism of the n-GaSb OC formation differs from that of the n-GaAs. The low energy ion sputtering (200V) removes selectively the Ga which promotes the incorporation of the Ge as a donor impurity and reduces the acceptor like anticite defects. The sulfurization supplies S atoms which act as donor impurities as well. Thus the n-type surface doping of the GaSb is increased which results in good ohmic characteristics. The HRTEM investigation of a C type contact cross-section exhibits randomly incorporated epitaxial Ge grains at the contact interface after annealing at 325°C which may explain the poor behavior of the C type OC. Therefore the improvement of the OC characteristics is manly influenced by the ion induced Ga to Sb vacancy concentration ratio in the GaSb near surface layer at T< 325°C. At higher sputtering voltages (400V and 700V) an intensive Sb out sputtering starts as well and the OC characteristics deteriorate due to the Ge amphoteric properties (the Ge incorporates on the Sb vacancies as a p-type impurity).

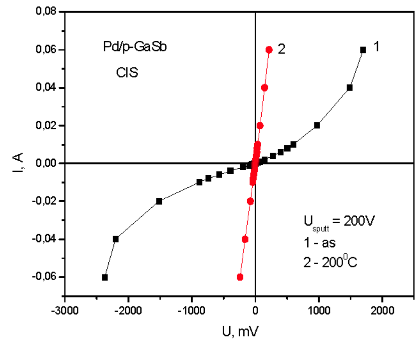

FIGURE 1. I-V characteristics of CIS type Pd/p-GaSb diode structure annealed at 200°C (U_{sput} = 200V)

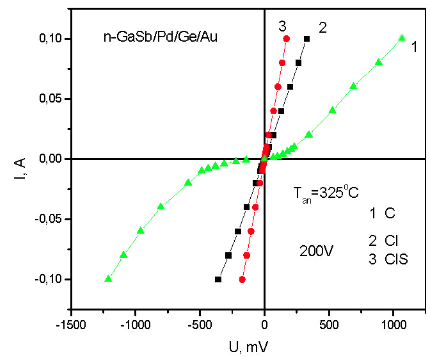

FIGURE 2. I-V characteristics of C, CI and CIS type n-GaSb/PdGeAu structures ion etched at 200 V and annealed at 325°C

REFERENCES

1. P. S. Dutta, H. Bhat and V. Kumar, Appl. Phys. Letters 81, 5821-5870 (1997).
2. P. S. Dutta, K. Sangunni, H. Bhat and V. Kumar, Appl. Phys. Letters 65, 1695-1697 (1994).
3. P. S. Dutta, K. Sangunni, H. Bhat and V. Kumar, Appl. Phys. Letters 66, 1986-1988 (1995).
4. S. M. Sze, Physics of Semiconductor Devices, edited by John Wiley & Sons, NY, 1981.
5. E. D. Marshall, W. Chen, C. Wu, S. Lau and T. Kuech, Appl. Phys. Letters 47, 298 (1985).