Vol. 82 (1992) *ACTA PHYSICA POLONICA A* No 5

Proceedings of the XXI International School of Semiconducting Compounds, Jaszowiec 1992

ATOMIC SCALE MORPHOLOGY OF THIN Au(Zn)/GaAs OHMIC CONTACTS

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Very thin Au(Zn) contacts to *p*-GaAs were studied by means of transmission electron microscopy and secondary ion mass spectrometry. It was found that such contacts when cap annealed became ohmic, even though the reaction between the metallization and GaAs is confined to a very close vicinity of the interface.

PACS numbers: 73.40.Ns

Recent studies on gold based contacts to GaAs reveled that these contacts are much more controllable and predictable than it is commonly believed, especially if reactions at the metal/semiconductor interface are minimized. It has been demonstrated that the Au–GaAs interaction can be suppressed by the application of a capping layer over the contact during the thermal processing [1]. The effectiveness of the capping layer is due to its ability to suppress the sublimation of arsenic from the free surface of the contact metallization.

It is to be expected that the extent of the interfacial reaction in Au based ohmic contacts to GaAs could be further restricted by the use of metallization with a reduced content of Au. Thus, the purpose of this work is to present a new design of Au(Zn) metallization with limited amount of Au enabling fabrication of ohmic contacts with improved microstructure and electrical properties.

Experiments were performed using (001) oriented Zn doped *p*-GaAs with net hole concentration $p = 6 \times 10^{17}$ cm^{-3}. The surface of GaAs was degreased and etched in $20NH_4OH$–$7H_2O_2$–$973H_2O$, followed by rinsing in DI H_2O and in $10NH_4OH$–$1H_2O$. Au(Zn) metallization was fabricated by sequential vacuum evaporation of Au(20 nm)/Zn(10 nm)/Au(60 nm) sandwich structure. The content of Au and Zn was reduced by a factor of 4 relative to the standard "thick" Au(Zn) contact [2]. 200 nm Al_2O_3 capping layer was deposited by RF magnetron sputtering. Heat treatments were carried out in flowing H_2. After annealing the capping layer was removed in 20% KOH.

Transmission electron microscopy (TEM) in cross-sectional mode in conjunction with secondary ion mass spectrometry (SIMS) were used to investigate the microstructure and composition of the contacts. Arsenic evaporative losses during thermal processing were measured by means of Cr collector method [3, 4].

Low resistivity of thin Au(Zn)/p-GaAs ohmic contacts ($r_c = 4\times10^{-5}$ Ωcm^2) was obtained after heat treatment at 400 – 420°C for 3 min.

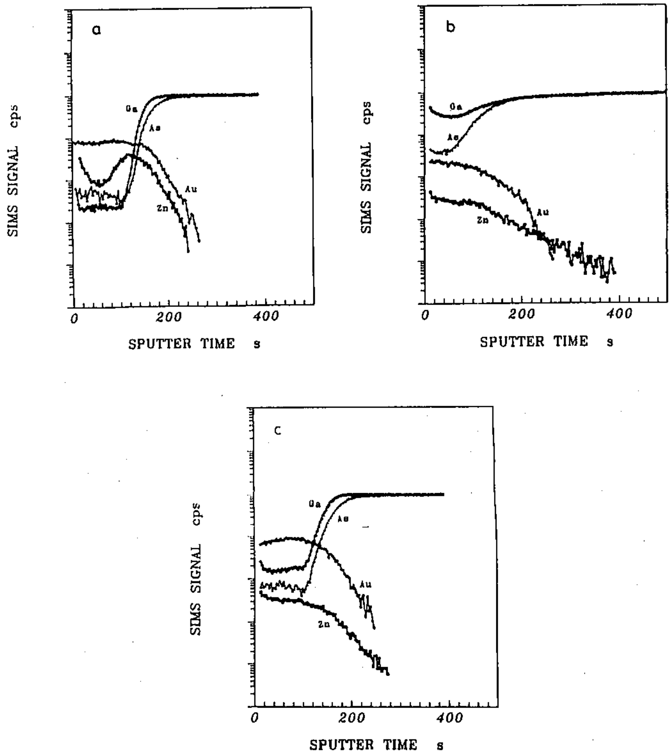

Fig. 1. SIMS depth profiles of p-GaAs/Au(20 nm)/Zn(10 nm)/Au(60 nm) contact: (a) as-deposited, (b) annealed at 400°C for 3 min, (c) cap annealed at 400°C for 3 min.

Figure 1 presents SIMS depth profiles of the as deposited as well as capless and cap annealed contacts. The extensive reaction at the metal/semiconductor interface observed in contacts processed without capping layer is accompanied by arsenic release of 14.6 × 10^{15} at/cm^2. It should be noted that As losses of similar magnitude have been detected during cap annealing of standard "thick" Au(Zn)/p-GaAs ohmic contacts [4]. Significantly reduced out-diffusion of the substrate components was achieved when thin contacts were heat treated with Al_2O_3 overlayer. In this case As evaporative losses were below the detection limit of the

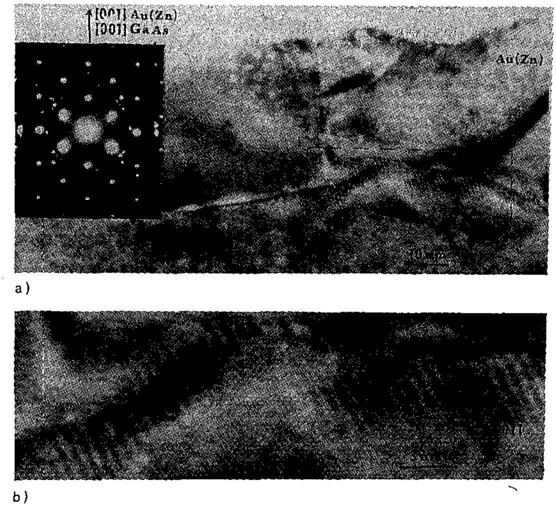

Fig. 2. (a) Cross-section TEM micrograph of Au(20 nm)/Zn(10 nm)/Au(60 nm)/GaAs contact after cap annealing at 420°C for 3 min, and corresponding diffraction pattern; (b) magnified marked region of micrograph (a). Moire fringes appear due to superposition of slightly dezoriented GaAs and Au(Zn) crystals.

method (0.2×10^{15} at/cm^2), which corresponds to less than one monolayer of the decomposed GaAs.

The Au(Zn)/*p*-GaAs interface was studied in detail by TEM. As-deposited metallization consisted of randomly oriented crystal grains of 15–35 nm in size, and selected-area-diffraction (SAD) pattern was characteristic of pure Au. This means that Zn atoms must have been incorporated into Au grains during the process of deposition of metallization. The resultant phase is certainly α-AuZn solid solution whose lattice parameters are too close to those of pure Au to be distinguished by electron diffraction. It should also be noted that before heat treatment there is an oxide layer present at the interface.

Figure 2 shows cross-section micrographs of the ohmic contact structure. Upon annealing the dimensions of the grains increased to 60-100 nm. The oxide layer seems to be dispersed and most of grains are in the (011) orientation parallel to the (011) GaAs substrate orientation. Grains remain randomly oriented in the (001) plane. Energy-dispersive X-ray spectrometry studies indicated that grains in contacts annealed under capping layer contained 85 at% of Au, 14 at% of Zn and less than 1 at% of Ga, which is consistent with the results obtained from SIMS analysis and from the measurements of As losses. We did not find any additional crystallographic phases at the metal/semiconductor interface. This is in contrast with standard "thick" contacts, where phase transitions were observed after different stages of the ohmic contact fabrication [1, 2].

The above results indicate strongly that the microstructure of the thin Au(Zn)/*p*-GaAs contact remains virtually intact after cap annealing. Thermal interaction between Au(Zn) metallization and GaAs, necessary to achieve ohmic behavior, is restricted to a very close vicinity of the interface. Disruption of the native oxide seems indispensable to enable Zn atoms to locate in tha GaAs lattice.

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