Vol. 84 (1993) *ACTA PHYSICA POLONICA A* No. 3

Proceedings of the XXII International School of Semiconducting Compounds, Jaszowiec 1993

INTERACTION BETWEEN THIN FILMS OF ZINC AND (100) GaAs*

E. Kamińska, A. Piotrowska, R. Żarecka

Institute of Electron Technology, Al. Lotników 32/46, 02-668 Warszawa, Poland

and E. Mizera

Institute of Physics, Polish Academy of Sciences
Al. Lotników 32/46, 02-668 Warszawa, Poland

Interfacial reactions between thin films of Zn and GaAs were studied by means of transmission electron microscopy. Low-temperature interaction is governed by the penetration of Zn into the native oxide layer at the metal/GaAs interface. At 360°C the formation of Zn_3As_2 phase, highly oriented with respect to the (100) substrate takes place.

PACS numbers: 73.40.Ns

Zinc is currently being used as a dopant element in ohmic contact metallization systems to *p*-type GaAs. The results of our recent studies on interfacial reactions occurring during formation of Au(Zn)/*p*-GaAs ohmic contact indicate that Zn plays a more universal role facilitating the dispersion of the native oxide on GaAs [1]. On the other hand, in plating and soldering technologies zinc is widely used as a component enabling one the cleaning of metallic surfaces before further processing [2, 3]. To our knowledge, the precise mechanism of these "cleaning action" of zinc has not been yet established.

The aim of the present work is to elucidate the metallurgical behavior of Zn in contact with GaAs. The microstructural analysis of the Zn/GaAs interface, under as-deposited state and annealed conditions, was carried out by transmission electron microscopy (TEM) methods. Emphasis was placed on the determination of the structure and composition of reaction products. High resolution electron microscopy (HREM) images were recorded with the JEOL JEM 2000EX (200 keV).

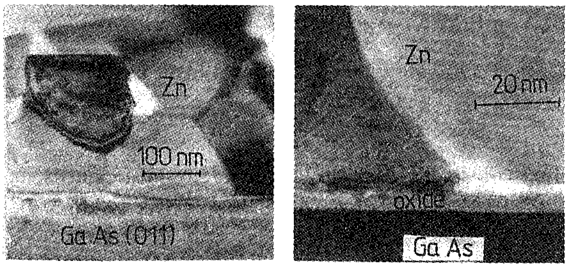
The substrates used in this study were (100) oriented *p*-type GaAs wafers doped with Zn to a concentration of 8×10^{17} cm^{-3}. Prior to metal deposition the samples were degreased in trichloroethylene (TCE), acetone and isopropyl alcohol, and then etched in solution of $NH_4OH:H_2O_2:H_2O$ (20:7:973), followed by a rinse in deionized H_2O and immersion into $NH_4OH:H_2O$ (1:10) for 10 s. Zinc films, 150 nm thick, were deposited by vacuum thermal evaporation using 99.999% Zn source, in

---

*This work was supported by the grant No. 8-8026-92-03 of the Committee for Scientific Research.

a system with a base pressure of 1×10^{-7} Torr, at a rate 0.05 nm/s. To prevent the sublimation of Zn and As from the contact region the samples were capped with 200 nm thick rf-magnetron-sputtered SiO_2 before annealing. Heat treatments were performed in flowing H_2 at temperatures ranging from 200 to 360°C for 10 min. Cross-sectional TEM specimens were prepared by mechanical polishing, dimpling and ion milling.

The microstructure of the as-deposited Zn/GaAs contact is shown in Fig. 1a. Zn films are crystalline in nature and consist of grains of 150–200 nm in size, strongly textured, with the orientation relationship: $(2\bar{1}\bar{1}0)_{Zn} \parallel (011)_{GaAs}$ and $[0001]_{Zn} \parallel [100]_{GaAs}$. This orientation relationship was preserved upon annealing up to around 320°C.



a b

Fig. 1. (011) TEM micrographs of (a) as-deposited Zn/GaAs contact, (b) as-deposited Zn/anodic oxide/GaAs contact.

The most significant feature of the low-temperature interaction of Zn with GaAs, which occurs during deposition and/or preparation of TEM specimens (about 100°C) is the penetration of Zn into the residual oxide remaining at the surface of GaAs after etching. Such a native oxide layer (1–1.5 nm thick) is always present under conventional processing conditions which involve exposure of the GaAs surface to air prior to metal deposition.

To get further insight into the interaction of Zn with oxides, an attempt was made to deliberately incorporate about 10 nm thick oxide layer, by anodic oxidation of GaAs surface before depositing Zn (Fig. 1b). High-resolution images of Zn/GaAs and Zn/oxide/GaAs interfaces are presented in Fig. 2a and Fig. 2b. The interface between Zn and GaAs is abrupt and atomically flat. The cross-section micrograph of Zn/oxide/GaAs sample clearly demonstrates that Zn is a dominant moving species.

Zn shows no evidence of reaction with the semiconductor substrate during deposition and annealing up to about 320°C. Annealing at 360°C for 10 min produced a noticeable change in the contact microstructure. A new cubic Zn_3As_2 phase with $a = 1.182$ nm was identified by electron diffraction. Zn_3As_2 is lattice matched to GaAs substrate, with epitaxial relationship $(011)_{Zn_3As_2} \parallel (011)_{GaAs}$ and $[100]_{Zn_3As_2} \parallel [100]_{GaAs}$. The corresponding high-resolution image and selective diffraction pattern are shown in Fig. 2c.

In summary, the low-temperature interaction between Zn and GaAs is gov-

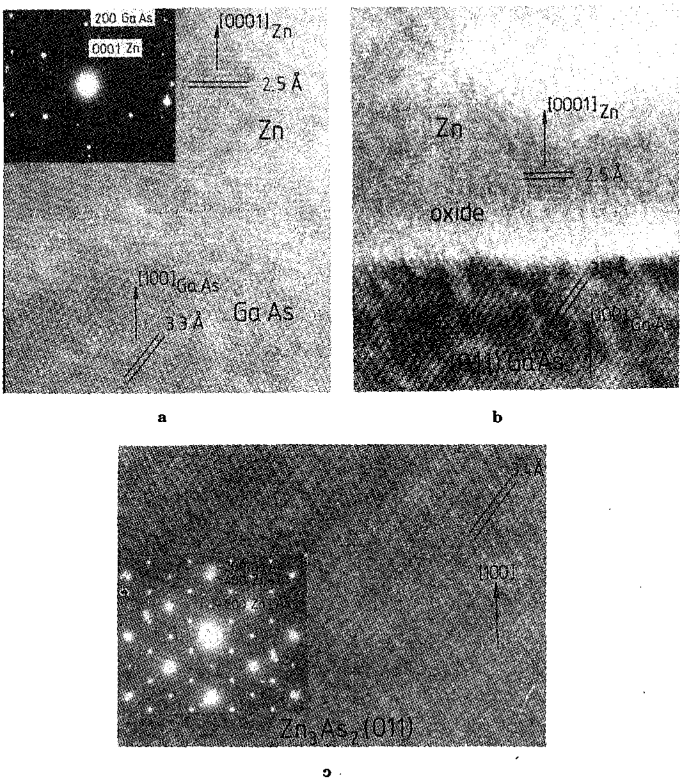


Fig. 2. (011) HREM micrographs and corresponding SAD patterns of (a) as-deposited Zn/GaAs contact, (b) as-deposited Zn/anodic oxide/GaAs contact, showing the penetration of Zn into the oxide, (c) Zn_3As_2 phase.

erned by the penetration of Zn into the native oxide layer. For this reason, metallization systems containing Zn such as AuZn, react with GaAs in a more laterally uniform manner than pure Au.

References

[1] E. Kamińska, A. Piotrowska, R. Żarecka, A. Barcz, E. Mizera, S. Kwiatkowski, *Acta Phys. Pol. A* **82**, 853 (1992).

[2] H.H. Manko, *Solders and Soldering,* McGraw-Hill, New York 1964.

[3] W.G. Zelley, in: *Modern Electroplating,* 2nd ed., Ed. F.A. Lowenheim, Wiley, New York 1963, p. 556.