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# DUAL ROLE OF TiN REACTION BARRIER IN GOLD BASED METALLIZATION TO GaAs

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Reactively sputtered TiN films were evaluated as annealing cap improving the formation of Au(Zn) ohmic contact and as antidiffusion barrier protecting contact metallization and underlying GaAs against reaction with Au overlayers.

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Presenting an interesting combination of properties such as high thermal stability, high electrical conductivity and hardness, good resistance to corrosion, TiN thin films are of great interest in various applications, such as the technology of coatings resistant to severe environments and the technology of advanced metallizations for semiconductor devices [1–5]. In this paper we describe an approach for improving the reliability of multilayer gold based metallization on GaAs by applying TiN as a reaction barrier. TiN films were evaluated as: (1) an annealing cap enabling formation of improved Au(Zn) ohmic contact to *p*-GaAs, and (2) a diffusion barrier protecting contact metallization and underlying GaAs from reacting with gold overlayers used for bonding and interconnection purposes.

(100) GaAs wafers Zn doped to $p = 1.2 \times 10^{18}$ cm$^{-3}$ were used in the present experiments. Barrier TiN films were prepared by reactive RF bias magnetron sputtering from Ti target in a Leybold L560 Universal Coating System with the base pressure of $1.5 \times 10^{-6}$ hPa. Deposition was carried out in mixed Ar+$N_2$ discharges with the flow rates of the individual gas adjusted by mass flow controllers. N/Ti ratios in as deposited films were measured using 2 MeV $He^+$ Rutherford backscattering (RBS), while X-ray diffraction was used to determine lattice parameters and preferred orientation. Four-probe method was applied to evaluate electric sheet resistance of TiN films. Au(Zn) contact metallization was deposited by sequential evaporation of 40 nm Au/40 nm Zn/274 nm Au layers; it needed a heat treatment for 3 min at 420°C to form an ohmic contact with *p*-GaAs. 150 nm thick Au films were used as contact overlayers.

Since the sublimation of As is a strong driving force for thermally induced reaction between Au and GaAs, to prove the applicability of TiN as a reaction

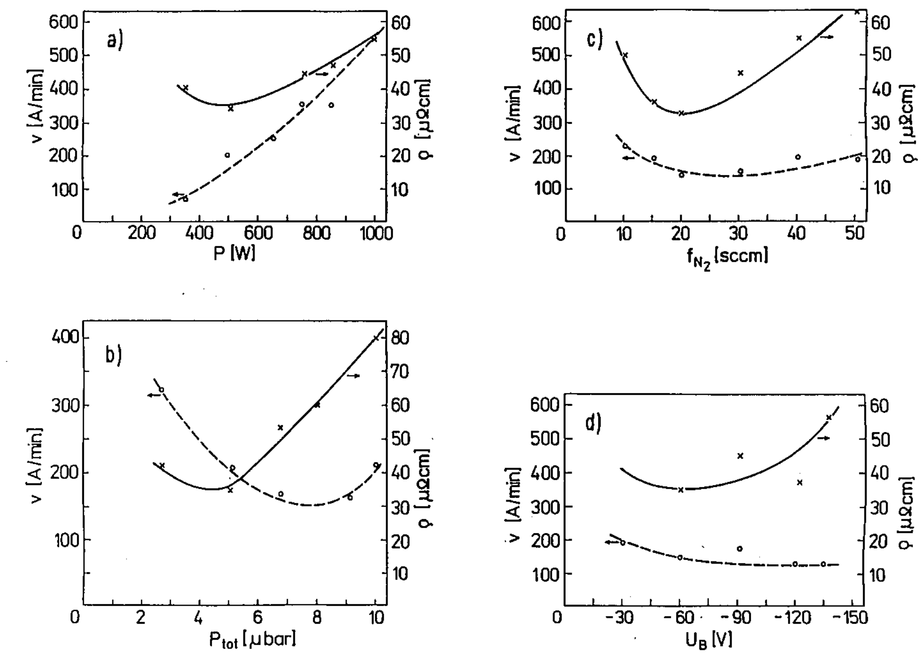


Fig. 1. The dependence of resistivity and rate of deposition of TiN films on: (a) the power applied to the plasma, (b) the total pressure, (c) the $N_2$ flow, (d) the substrate bias voltage; $P = 500$ W, $N_2/Ar = 0.18$, $f_{Ar} = 100$ sccm, $U_B = -60$ V, when constant.

barrier, in our studies, the measurements of As losses during thermal processing were of special concern. The arsenic release from GaAs/Au(Zn)/TiN and GaAs/Au(Zn)/TiN/Au structures was examined by a Cr-collector method [6, 7]. It consists in capturing the evaporating As species within Cr/$SiO_2$/Si collectors placed during thermal processing, face-to-face, on top of metallized GaAs surfaces. Heat treatments were carried out by means of furnace annealing under flowing $H_2$. After annealings the content of As in the Cr collector films as well as the metallized GaAs samples were analyzed with RBS technique using 2 MeV $He^+$ ions. In addition to the large area samples which were used for metallurgical studies, the patterned samples for the specific contact resistance measurements were prepared by standard photolithographic techniques.

Figure 1 shows the average deposition rate and the sheet resistance of TiN films as a function of applied parameters of reactive bias magnetron sputtering. All TiN films grown in these experiments were stoichiometric with lattice parameter 4.24 Å. They were polycrystalline with randomly oriented grains of the size not exceeding 1 $\mu$m. The most important point from these data is that adjusting growth parameters TiN films with electrical resistivity close to that of bulk material [5] can be obtained. 100 $\mu$m thick TiN films deposited at $p = 5.8 \times 10^{-3}$ hPa, $N_2/Ar = 0.18$, $U_B = -60$ V and $P = 500$ W were further analyzed for their applicability as a reaction barrier.

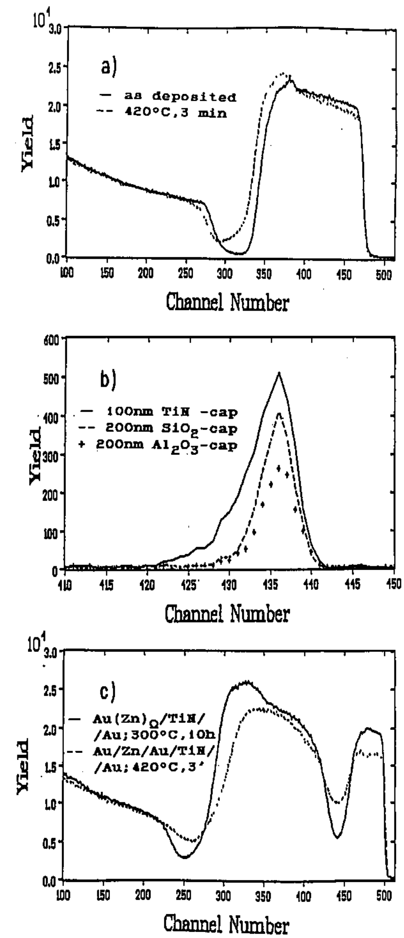


Fig. 2. 2 MeV $^4He^+$ RBS spectra of: (a) GaAs/Au/Zn/Au/TiN sample before and after annealing at 420°C for 3min, (b) Si/$SiO_2$/Cr collectors heat treated in contact with GaAs/Au/Zn/Au samples capped with TiN, $Al_2O_3$, or $SiO_2$ films for the annealing at 420°C for 3 min, (c) GaAs/Au(Zn)/TiN/Au contact aged for 10 h at 300°C, and GaAs/Au/Zn/Au/TiN/Au metallization annealed for 3 min at 420°C.

Figures 2a and 2b illustrate the applicability of TiN film as annealing cap during formation of Au(Zn) ohmic contact (heat treatment at 420°C for 3 min). 200 nm thick RF magnetron sputtered $SiO_2$ and $Al_2O_3$ caps were used for comparison. Figure 2a shows 2 MeV $He^+$ RBS spectra of as deposited and heat treated GaAs/Au/Zn/Au/TiN metallization, in Fig. 2b the portion of RBS spectra obtained from respective Cr collectors is displayed. The total amount of As losses from GaAs/Au(Zn) contact capped with TiN ($1.3 \times 10^{16}$ at./cm$^2$) is slightly higher than for substituting insulating caps ($6.2 \times 10^{15}$ at./cm$^2$ for $SiO_2$ and $4.4 \times 10^{15}$

at./cm$^2$ for $Al_2O_3$), but about an order of magnitude lower than for contacts annealed without capping layer ($1.1 \times 10^{17}$ at./cm$^2$) [7]. These data prove the effectiveness of TiN capping layer in suppressing the decomposition of GaAs during formation of ohmic contact. Figure 2c displays RBS spectra of multilayer Au/Zn/Au/TiN/Au metallization after heat treatment corresponding to the formation of ohmic contact and of the $Au(Zn)_\Omega$ /TiN/Au structure after aging at 300°C for 10 hours. The respective As losses were $4.6\times10^{16}$ at./cm$^2$ and $4.1\times10^{14}$ at./cm$^2$, indicating that TiN films are promising antidiffusion barrier during device processing.

The specific contact resistance of Au(Zn) ohmic contact annealed under TiN cap is lower than that prepared without capping layer ($3.7 \times 10^{-5}$ $\Omega$ cm$^2$ and $6.9\times10^{-5}$ $\Omega$ cm$^2$ respectively). TiN barrier was also found to improve aging characteristics of multilayer metallization. Contact resistance of GaAs/$Au(Zn)_\Omega$ /Au samples increased from $3.6 \times 10^{-5}$ $\Omega$ cm$^2$ to $6.3 \times 10^{-5}$ $\Omega$ cm$^2$ after annealing for 10 hours at 300°C but did not change when TiN barrier was inserted between contact metallization and Au overlayer.

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