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Characterization of ohmic contacts on n- and p-type GaSb

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Abstract

Ohmic contacts on GaSb were achieved using Zn–Au multilayers for p-type GaSb and Te–Au multilayers for n-type GaSb. Contacts were electrically characterized by their specific resistance, which could be obtained currently as low as 10^{-5} Ω cm^2 for p-type GaSb and 10^{-6} Ω cm^2 for n-type GaSb. The surface composition was studied by means of secondary ion mass spectrometry, which showed that interface alloying gives the best results.

1. Introduction

Ohmic contacts are widely investigated in semiconductor technology, especially concerning Si and GaAs, which dominate device applications. GaSb-based devices, mainly restricted to IR photodetectors and solid state lasers, in association with fluoride glasses, could have potential applications in high speed, long distance telecommunications. Both components need high performance ohmic contacts but at present, little work has been devoted to this subject [1–5]. In this paper, we study the characteristics of Zn–Au (p-type GaSb) and Te–Au (n-type GaSb) multilayers. Contacts are characterized by their specific resistance measured by the transmission line method (TLM). Their compositions have been revealed by means of secondary ion mass spectroscopy (SIMS) techniques. These studies allowed us to optimize the semiconductor surface preparation and metal deposition, as well as the subsequent thermal treatment.

2. Sample preparation

We used GaSb ⟨100⟩ substrates, Te or Zn doped in the range from 10^{17} to 4×10^{18} cm^{-3}. The surface preparation was achieved using chemicomechanical polishing with a Br–methanol (2%–98%) solution. The wafers were then cleaned in the usual organic solvent (trichlorethylene, acetone, methanol) and dried under N_2 flow. Two techniques were employed for metal deposition: thermal evaporation (10^{-6} Torr; cold or heated substrate) and sputtering.

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2.1. Contacts onto p-type GaSb

Several kinds of multilayers were realized as follows:

successive depositions of Au (200 Å)/Zn (300 Å)/Au (3400 Å) by thermal evaporation, a technique already employed by Sanada and Wada [4] onto GaAs.

thermal evaporation of Au–Zn alloys (90%–10% in weight) onto heated substrate ($T_{substrate} \approx 400$ °C);

a single deposition from a commercial Au–Zn alloy (95%–5% in weight) by the sputtering process;

Au–Zn sputtering on a Zn-diffused substrate. Using the classical lift-off photolithography technique, we realized Zn diffusion into the GaSb samples (48 h at 500 °C), followed by a sputtering deposition 4000 Å thick Au–Zn.

All these contacts were then alloyed at 430 °C for 5 s under a pure H_2 flow.

2.2. Contacts onto n-type GaSb

As GaSb wafers are Te doped, we used a technique similar to the previous technique for p-type GaSb and tried to obtain Te overdoping of the semiconductor surface under the contact.

A uniform layer of Te of thickness varying from 300 to 1200 Å was deposited by thermal evaporation, followed by a layer of Au (3700–2800 Å). The samples were then heated under a pure H_2 flow. A large range of temperatures and heating times have been investigated.

3. Contact analysis

3.1. p-type GaSb

The main point of interest in the multilayer Au/Zn/Au contact is in providing good adhesion between the multilayer metal structure and the semiconductor

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surface. However, during the following thermal annealing, we always observe a preferential alloying of Zn with Au rather than with GaSb and, consequently, insufficient overdoping occurs at the contact interface.

The thermal evaporation of Au–Zn onto a heated substrate (400 °C) allows us to solve this problem: a Zn tail into GaSb can be seen clearly in Fig. 1. Such an observation is corroborated by a low contact resistivity ($\rho_c \approx 10^{-5}$ Ω cm^2 for $|N_A - N_D| = 10^{18}$ cm^3). We can suppose that Zn is first deposited and reacts with the GaSb sample heated at 400 °C. However, it should be noted that heating a GaSb sample under an H_2 flow at 500 °C for 1 h reduces the Sb content in the surface, as shown by Fig. 2. (All the SIMS analyses performed on non-heated GaSb samples show a surface accumulation of Sb).

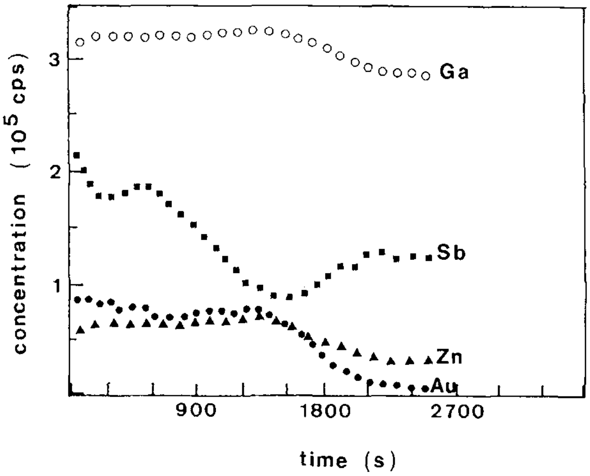

Fig. 1. SIMS profiles of the alloyed system GaSb/Au–Zn obtained by Au–Zn thermal evaporation onto a heated semiconductor (400 °C).

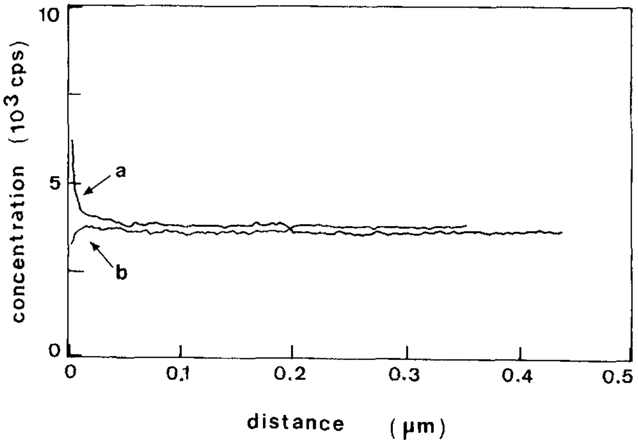

Fig. 2. Sb SIMS profiles of (a) non-heated GaSb wafer and (b) a similar sample heated for 1 h at 500 °C.

The preliminary diffusion of Zn appears to be very favourable: the high Zn content at the interface, as shown in Fig. 3, leads to $\rho_c = 8 \times 10^{-6}$ Ω cm^2 for a similar sample.

An overall picture of the typical contact resistivities obtained by the various processes employed here is reported in Fig. 4.

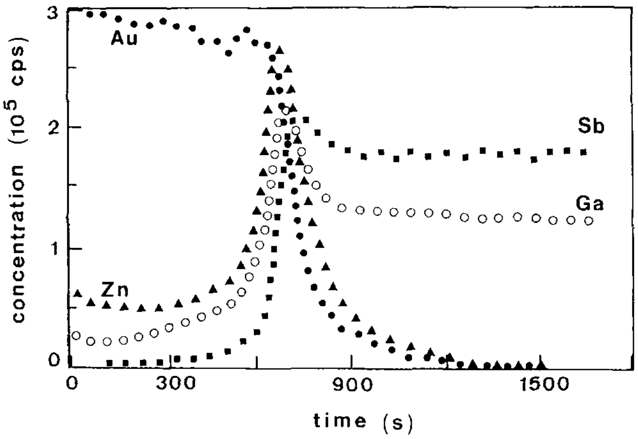

Fig. 3. SIMS profiles of a Zn-diffused GaSb wafer after AuZn sputtering and thermal treatment at 200 °C for 10 min.

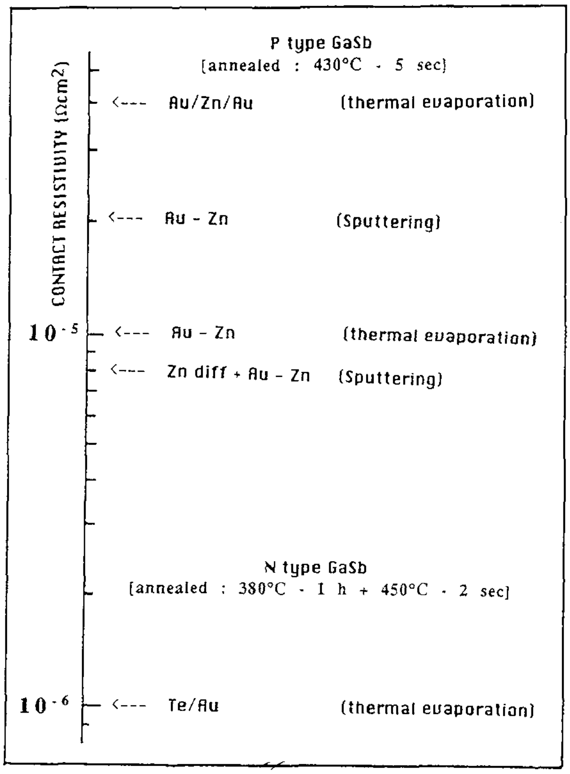

Fig. 4. Contact resistivities obtained with the various different techniques.

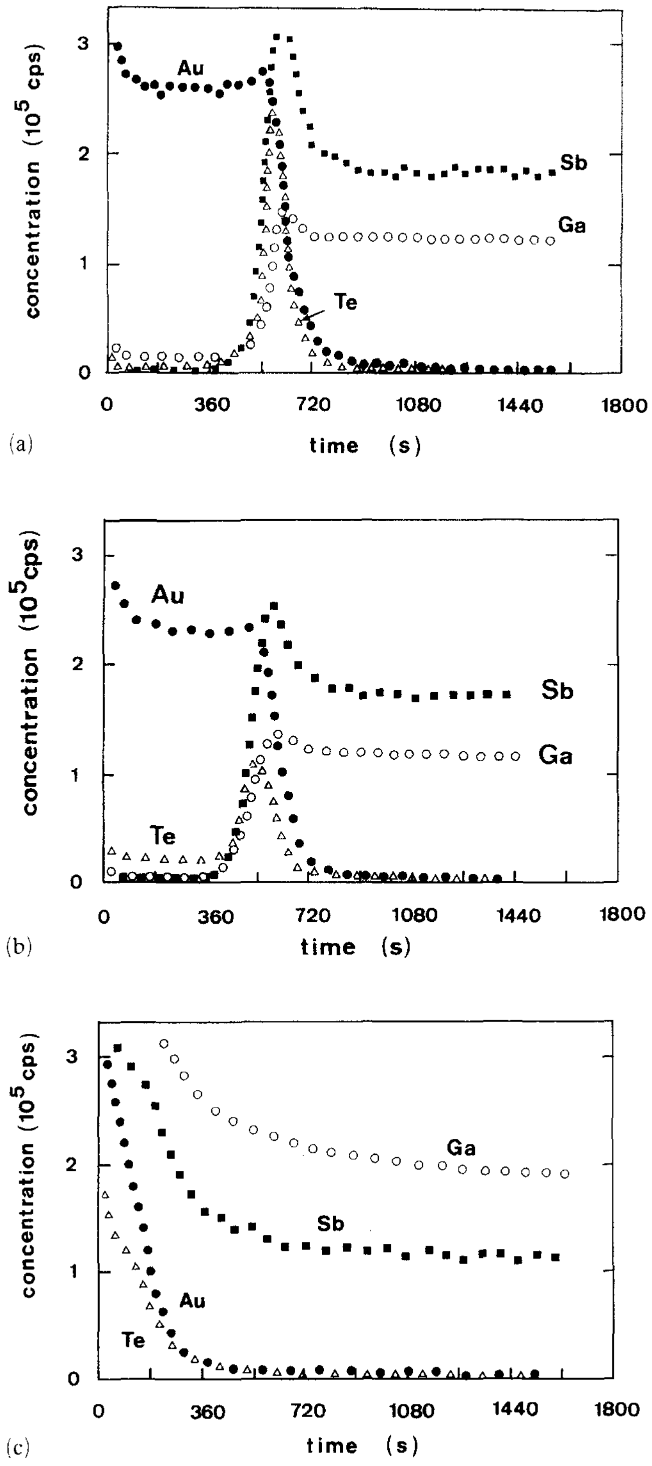

Fig. 5. SIMS analysis of Te–Au/GaSb contact: (a) initial profile (non-heated surface); (b) sample heated at 335 °C for 10 s; (c) sample heated at 380 °C (1 h) and then 450 °C (2 s).

3.2. n-type GaSb

Although Te has a noticeable resistivity (1.6×10^{-1} Ω cm), its thickness does not affect considerably the specific contact resistance. A moderate increase is only observed with a Te thickness of more than 600 Å.

Contact resistivities of the order of 10^{-6} Ω cm^2 have been obtained (with substrates having $(N_D - N_A) \approx 1 \times 10^{18}$ cm^{-3}) using long annealing times (about 1 h) at low temperatures (about 350 °C) or short annealing times (about 2 s) at higher temperatures (about 450 °C). The best results ($\rho_c < 10^{-6}$ Ω cm^2) have been obtained by combining these two procedures, *e.g.* 1 h at 380 °C and then 2 s at 450 °C, always under a pure H_2 flow. It should be noted that 10^{-6} Ω cm^2 is the limit of our measurement apparatus, so some uncertainty remains about the true value.

An evaluation of the various element concentrations *vs.* the thermal treatments is shown by the SIMS analysis through the contact, as shown in Fig. 5. It is clear that, as is the case for the AuZn/GaSb (p) contact (see Fig. 1), the lowest contact resistivities are obtained after interface alloying, *i.e.* when the sample surface contains large quantities of Ga and Sb.

4. Conclusions

The preparation of ohmic contacts onto n- and p-type GaSb has been described. Au–Zn and Au–Te multilayer depositions have been optimized, as well as the adequate thermal processes of alloying. Contact resistivities of $\rho_c = 10^{-5}$ Ω cm^2 and $\rho_c \approx 10^{-6}$ Ω cm^2 have been obtained, respectively, on p- and n-type GaSb ($|N_A - N_D| = 10^{18}$ cm^{-3}). The SIMS profile analysis proves the existence of a perturbed surface region with high Ga and Sb contents, giving the lowest values of contact resistivity.

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