



HAL
open science

Low noise ohmic contacts on n and p type GaSb

M. Rolland, Sophie Gaillard, E. Villemain, D. Rigaud, M. Valenza

► **To cite this version:**

M. Rolland, Sophie Gaillard, E. Villemain, D. Rigaud, M. Valenza. Low noise ohmic contacts on n and p type GaSb. *Journal de Physique III*, 1993, 3 (9), pp.1825-1832. 10.1051/jp3:1993242 . jpa-00249045

HAL Id: jpa-00249045

<https://hal.science/jpa-00249045>

Submitted on 4 Feb 2008

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Classification

Physics Abstracts

72.70 — 73.00 — 81.15

Low noise ohmic contacts on n and p type GaSb

M. Rolland ⁽¹⁾, S. Gaillard ⁽¹⁾, E. Villemain ⁽¹⁾, D. Rigaud ⁽²⁾ and M. Valenza ⁽²⁾

⁽¹⁾ Equipe de Microoptoélectronique de Montpellier (CNRS URA 392) Université de Montpellier II, 34095 Montpellier Cedex 5, France

⁽²⁾ Centre d'Electronique de Montpellier (CNRS URA 391) Université de Montpellier II, 34095 Montpellier Cedex 5, France

(Received 10 November 1992, revised 25 January 1993, accepted 26 January 1993)

Résumé. — Plusieurs processus technologiques ont été étudiés pour élaborer des contacts ohmiques sur GaSb. Les résistivités de contact les plus faibles ont été obtenues avec un alliage Au-Zn sur GaSb de type p et un alliage Au-Te sur le type n. L'analyse des résultats montre que ces faibles résistivités sont dues à l'existence d'une zone surdopée à la surface du contact. L'analyse basse fréquence du bruit indique que les techniques utilisées nous permettent d'obtenir des contacts ne présentant pas de bruit en $1/f$.

Abstract. — Several metallization systems for producing ohmic contacts onto GaSb have been investigated. The minimization of contact resistivity was respectively obtained with Au-Zn on p type and Au-Te on n type. It has been shown that these results are due to an overdoped layer at the semiconductor surface. Low frequency noise measurements pointed out that the techniques used allow the realization of devices without $1/f$ contact noise.

1. Introduction.

Ohmic contacts with low contact resistivities are needed in order to obtain convenient performances of semiconductor devices. Contrary to other semiconductors such as Si and GaAs, the investigations on our present subject are very sparse [1, 2], although GaSb is used in near infrared photodetectors and solid state lasers which could be useful in high speed and long haul telecommunications.

We will present here the technical processes and the physical characteristics of ohmic contacts on n and p type GaSb. However it must be noted that convenient current-voltage curves do not a sufficient criterion of good ohmic contacts for high quality devices and excess $1/f$ noise is an essential aspect of the contact characterization.

2. Sample preparation and contact resistivity.

We used GaSb wafers with $\langle 100 \rangle$ orientation ; Te(n type) or Zn(p type) doped in range 10^{17} cm^{-3} to $4 \times 10^{18} \text{ cm}^{-3}$. Two polishing ways were used : a chemical-mechanical one made of a bromine-methanol solution (2 % Br) and another one with alumine powder ($1 \mu\text{m}$). Then

the samples are cleaned with trichlorethylene, acetone and methanol, and they are dried under N_2 flow.

2.1 p-TYPE GaSb. — Several metals or alloys were deposited on the substrates either by sputtering or thermal evaporation :

- a) Single gold evaporation (4 000 Å thickness) ;
- b) AuZn (5 %) sputtering (4 000 Å thickness) ;
- c) AuZn (10 %) evaporation on heated substrate (400 °C) ;
- d) Zn diffusion (500 °C for 48 h) followed by AuZn sputtering ;
- e) Au (200 Å) Zn (1 000 Å) Au (2 800 Å) multilayer (a process already employed by Sanada [3] onto GaAs). The first Au layer provides a good adherence of Zn onto the substrate.

All samples (except c) are then annealed up to 430 °C under pure hydrogen flow. As the detailed experimental procedures are described elsewhere [4], we will only report here the main results concerning the contact resistivity ρ_c . (c) and (d) processes lead to $\rho_c = 10^{-5} \Omega\text{cm}^2$ for a carrier concentration $p = 10^{18} \text{cm}^{-3}$.

All the results are reported in table I.

Table I.

Process on GaSb(p) $ N_A - N_D = 10^{18} \text{cm}^{-3}$	$\rho_c (\Omega\text{cm}^2)$
Au/Zn thermal evaporation	4×10^{-5}
Au/Zn/Au thermal evaporation	2×10^{-5}
Au/Zn sputtering	1×10^{-5}
Zn diffusion + AuZn sputtering	8×10^{-6}

SIMS technique was applied to analyse the in-depth profile of the metallurgical composition through the contact but above all the repartition of the Zn dopant layer.

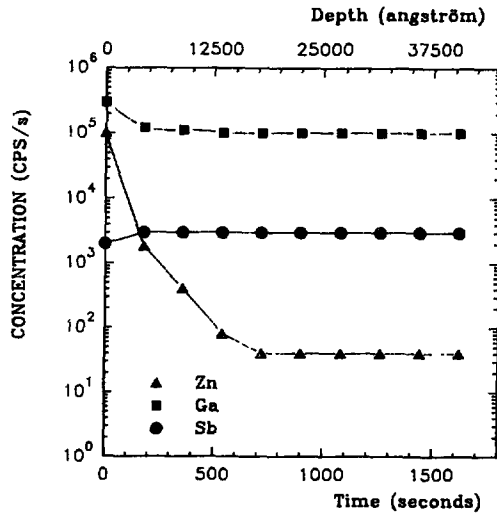
In figure 1a the Zn diffusion profile (sample (d) before sputtering) is reported : if we assume that the weak amount of Zn in GaSb crystal does not affect the etching rate in this material ($25 \text{Å}\cdot\text{s}^{-1}$), we estimate to 1.4 μm the depth of the overdoped layer.

Figure 1b shows similar analysis for sample (c) : an AuZn alloy is evaporated on GaSb substrate heated at 400 °C. A modification in the etching rate is noticeable and varies according to the composition. Such a phenomenon has already been noted in the neighbouring system Au-GaAs [3]. Thus we have not been able to scale the true distances on the X axis for this figure. Consequently on these curves we can only consider the relative intensities corresponding to the various elements. Nevertheless it is interesting to note that there is an amount of Zn under the contact which produces an overdoping of the sample and allows a decrease of the contact resistivity.

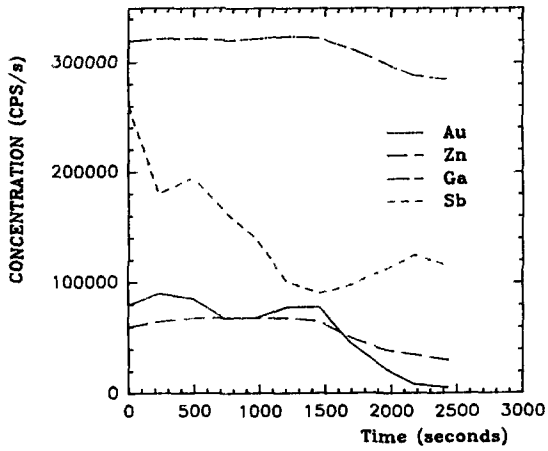
The figure 1c exhibits similar results for sample (d) : an amount of Zn is also observed and, here too, the contact resistivity is low ($\rho_c = 8 \times 10^{-6} \Omega\text{cm}^2$).

2.2 n TYPE GaSb. — A compilation of our results obtained with various metallizations is reported in table II.

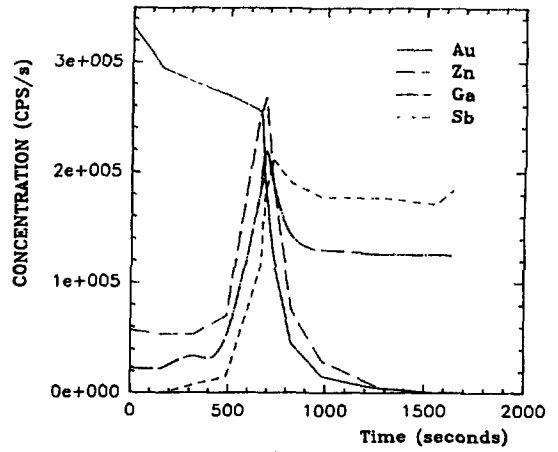
The best results are obtained by successive thermal evaporation of Te (600 Å) and Au



a)



b)



c)

Fig. 1. — a) SIMS concentration profiles for Zn diffusion (d process without sputtering). b) SIMS concentration profiles for c process. c) SIMS concentration profiles for d process.

Table II.

Process on GaSb(n) $ N_A - N_D = 1.5 \times 10^{18} \text{ cm}^{-3}$	$\rho_c (\Omega\text{cm}^2)$
Au/Ge/Ni thermal evaporation	4×10^{-6}
Sb/Au thermal evaporation	3×10^{-6}
Te/Au thermal evaporation	1×10^{-6}

(3 400 Å) which are thermally alloyed under pure H₂ flow in two different ways :

- i) Annealed at 420 °C for 30 s : $\rho_c = 3 \times 10^{-6} \Omega\text{cm}^2$.
- ii) Annealed for 1 h at 380 °C, then 5 s at 450 °C : $\rho_c < 10^{-6} \Omega\text{cm}^2$.

Both results correspond to $|N_D - N_A| = 1.5 \times 10^{18} \text{cm}^{-3}$

Concerning the two polishing methods we generally measure a contact resistivity 30 % lower for the mechanically etched samples than, for the chemical ones ; such a difference may be attributed to a better penetration of the dopant layer in the semiconductor.

3. Sample preparation for noise studies.

Thin parallelepipedic samples ($8 \times 0.15 \times 0.5 \text{mm}^3$) were polished and cleaned as described above. Two kinds of metallizations were used for p type : evaporated pure Au and AuZn (5 %) deposited by sputtering, whereas there was only one metallization for n type (Te-Au). Indium plots ($\Phi 150 \mu\text{m}$) were evaporated and alloyed at 200 °C under H₂ atmosphere, thus facilitating gold bonding wires by thermocompression. Viewgraphs (Figs. 2a and 2b) exhibit the sample device.

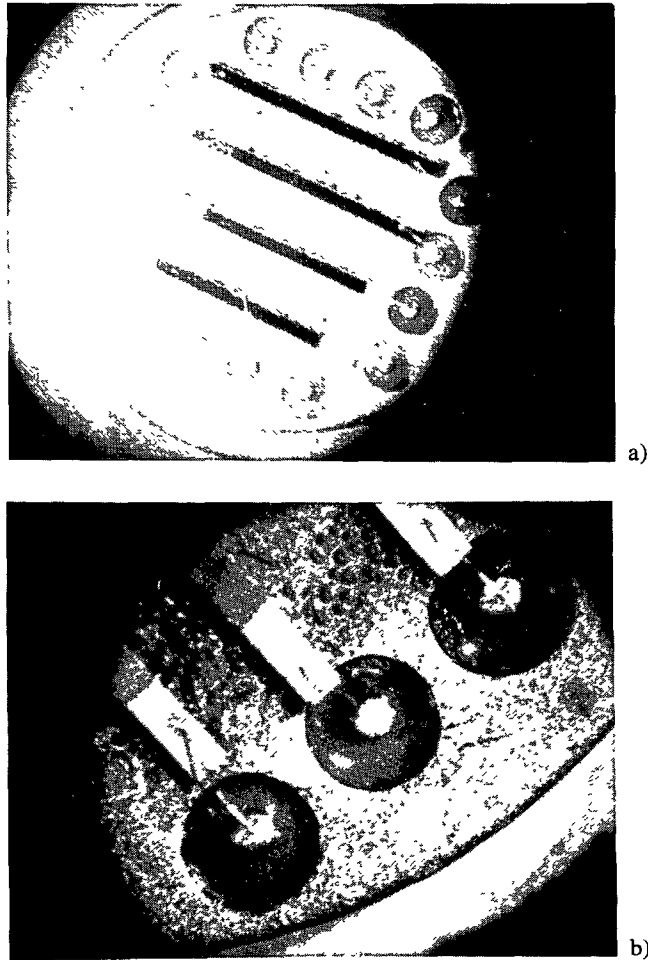


Fig. 2. — Sample mounting for noise measurements.

In figures 3a and 3b the spectral density of noise current is plotted *versus* frequency for samples respectively treated under pure H₂ flow and forming gaz (5 % H₂). The 1/f excess noise obviously appears for the second sample, while, even at f = 10 Hz and for a current density j = 77 A cm⁻², this phenomenon is not observed when H₂ is used. This proves the

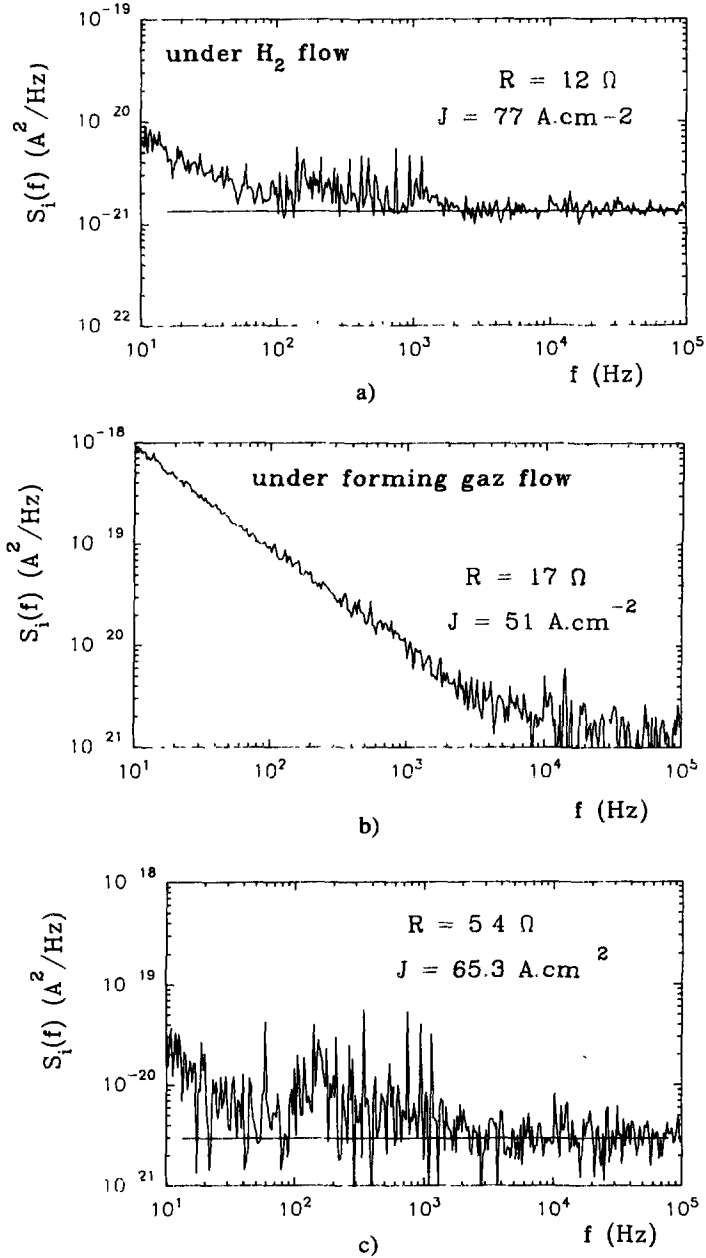


Fig. 3. — Noise spectra for p type GaSb ohmic contacts chemical-mechanical polishing Au deposition (4 000 Å) annealed at 400 °C during 20 s : a) under H₂ flow, b) under forming gaz flow, c) noise spectrum for p type GaSb ohmic contacts chemical-mechanical polishing AuZn sputtering annealed at 400 °C during 20 s under H₂ flow.

fundamental part played by the nature of the atmosphere, and has also been verified for a large quantity of samples. Such a result also suggests that the main part (not all) of the $1/f$ noise takes place in contacts and not in semiconductor bulk. In comparison with figure 3c we also deduce that the nature of the metal deposited does not affect the excess noise. On the other hand, figures 4a and 4b show that whatever the polishing methods, the behaviour of the $1/f$ noise is not considerably affected.

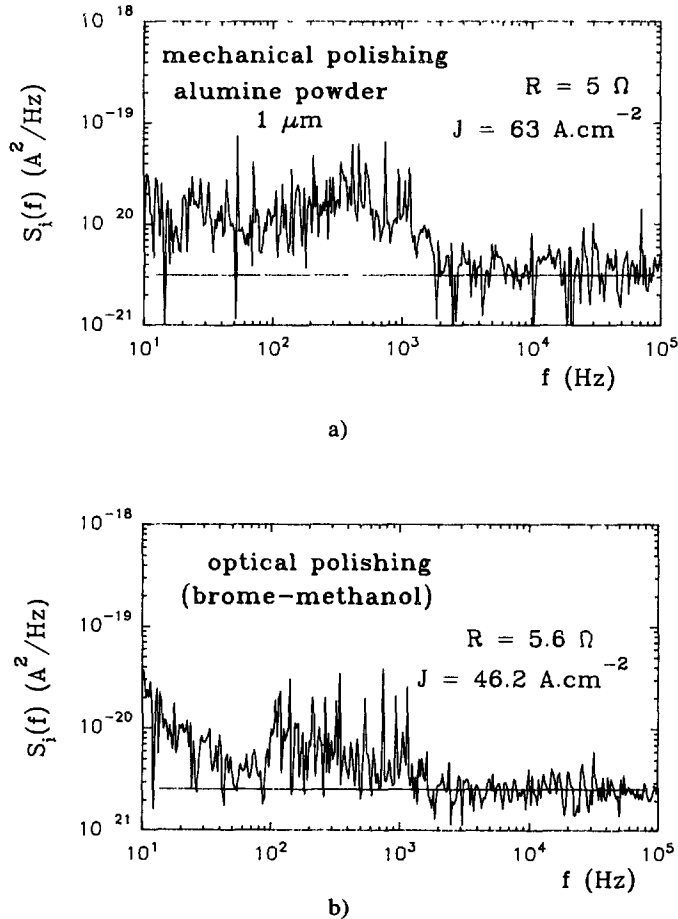


Fig. 4. — Noise spectra for p type GaSb ohmic contacts AuZn sputtering annealed at 200°C during 300 s under H_2 flow : a) mechanical polishing, b) optical polishing.

Finally, figure 5 shows that the plot of $S_i(f)$ versus the (sample) current density ranges from j^2 to j^3 , and indicates that all the contact surface is not affected by the phenomenon, as $S_i(f)$ contact noise is normally defined by [5] :

$$S_i(f) = \frac{1}{f} \int_S j^2 dS .$$

Consequently we may suppose that the local current density changes with the polarization level.

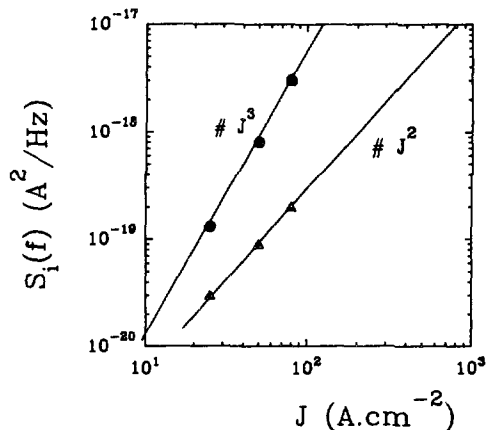
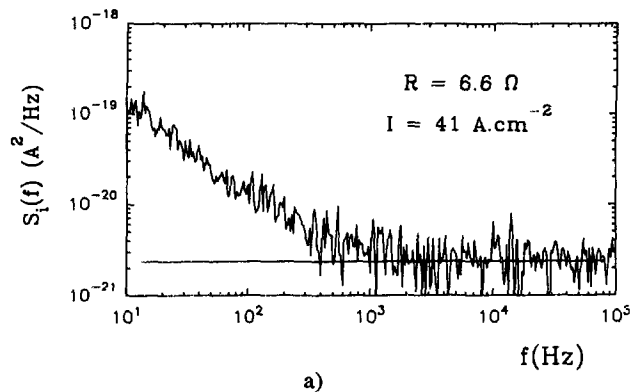
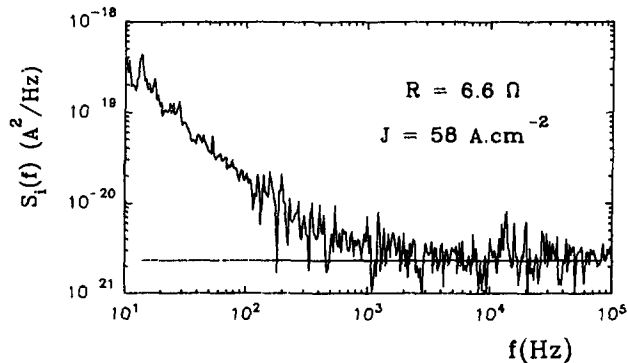


Fig. 5. — $S_i(f)$ versus current density at $f = 10$ Hz for GaSb ohmic contacts.

Similar studies have also been performed on n type GaSb (results are shown in Figs. 6a and 6b). As proved in comparison with the thermal noise level, a weak excess noise at low frequency can be observed.



a)



b)

Fig. 6. — Noise spectra for n type GaSb ohmic contacts : a) $J = 41$ A.cm⁻² b) $J = 58$ A.cm⁻²

4. Conclusion.

Preparation of ohmic contacts has been described. Several ways have been investigated.

For p type material the Au-Zn system gives the best results by two different processes : thermal evaporation of Au-Zn (10 %) on heated (400 °C) substrate or Au-Zn (5 %) sputtering after Zn diffusion that leads to a specific contact resistance $\rho_c = 8 \times 10^{-6} \Omega\text{cm}^2$.

Concerning n type GaSb the successive evaporations of Te (600 Å) and Au (3 400 Å) alloyed at 430 °C gives $\rho_c < 10^{-6} \Omega\text{cm}^2$.

The noise behaviour was also studied and showed that an adequate thermal treatment (H_2) drastically reduces the $1/f$ excess noise that does not appear even at $f = 10$ Hz and current density $j = 80 \text{ Acm}^{-2}$. In addition, the polishing method, a mechanical or a mechanochemical one does not significantly affect the contact resistivity or the excess noise. Such experimental results could improve the GaSb electronic devices.

References

- [1] Heinz Ch., Ohmic contacts to p and n type GaSb, *Int J. Electron.* **54** (1983) 247-254.
- [2] Oliveira J. B. B., Olivieri C. A., Galzerani J. C., Paza A. A., de Prince F. C., Properties of AuZn ohmic contacts to p-GaSb, *J Appl. Phys.* **66** (1989) 5484-5487.
- [3] Sanada T., Wada O., Ohmic contacts to p-GaAs with Au/Zn/Au structure. *Jpn J. Appl. Phys.* **19** (1980) L 491-L 494.
- [4] Villemain E., Gaillard S., Rolland M. and Joullie A., Characterizations of ohmic contacts on n and p type GaSb, Exmatec'92, ECL Lyon (may 1992), accepted in *Mat. Sc. Eng.* (to be published).
- [5] Rolland M., Nougier J. P., Gasquet D., Alabedra R., Low noise « ohmic » contacts on n-type Silicon, *Solids State Electron.* **20** (1977) 323-331.

