Low-resistive ohmic contacts to *n*- $InAs_{0.91}Sb_{0.09}$ for GaSb-based VCSELs in the mid-infrared range

S. Arafin, A. Bachmann, K. Kashani-Shirazi, S. Priyabadini and M.-C. Amann

Walter Schottky Institut, Technische Universität München, Am Coulombwall 3, 85748 Garching, Germany

GaSb-based vertical-cavity surface-emitting lasers (VCSEL) are one of the most promising candidates for realizing trace-gas sensing systems using tunable diode laser absorption spectroscopy (TDLAS) in the mid-infrared wavelength regime [1]. Single mode, continuous-wave electrically pumped GaSb-based VCSELs operating at ~2.3 µm up to 50ºC [2] and CO and CH_4 sensing systems utilizing these lasers [3] have been demonstrated recently. In this work we present low resistive and thermally stable ohmic contacts to lattice-matched MBE grown Te doped *n*-type $InAs_{0.91}Sb_{0.09}$ layers which are suitable for GaSb-based VCSELs. The reason for using InAsSb as the contact layer is that this material can be doped up to as high as 1×10^{20} cm^{-3}, which overcomes the problem of the doping limit (2.5×10^{18} cm^{-3}) for Te dopant in *n*-type GaSb [4]. Besides, the main challenge of getting very good ohmic contacts on GaSb-based material system is to avoid the native oxides formed very quickly on the surface of these materials compared to the GaAs-based material system [5]. Consequently, special surface treatment in addition to the conventional acid dipping becomes necessary to minimize the surface oxides prior to metallization. Lauer et al. [6] demonstrated a procedure of removing the native oxides by Ar-plasma based dry etching and subsequently depositing the Ti/Pt/Au metals. In this work, a wet chemical etching step e.g. HCl dipping is involved to remove the surface oxides and then for preventing the further formation of the oxides, the samples are rinsed with a $(NH_4)_2S$ solution (with pH = 9) for 40 s and promptly loaded into the Ti/Pt/Au metallization chamber afterwards for top and backside contact. It is expected that by the sulfide passivation process, the dangling bonds at the contact surface are terminated in the form of S-In, S-As and S-Sb, which also leads to reduced ohmic contact since it allows the intimate contact between the metal and semiconductor [7]. Thus, we achieve the linear *I-V* characteristics with a contact resistivity as low as 5.11×10^{-6} Ω cm^2 without any annealing and over a very high current density range like ± 70 kA/cm^2 as shown in Fig.1, which is an adequate value for the operation of GaSb based VCSELs above the threshold current. In addition, a reduction of the contact resistivity is also observed after annealing at 350°C for 90 s which causes no problem for the active region of GaSb-based VCSEL [8].

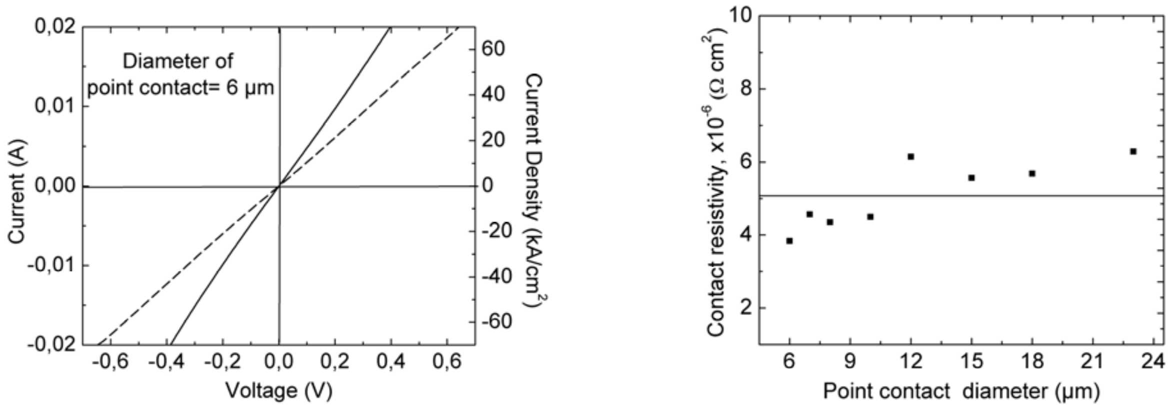

Fig. 1.Current versus voltage (*I-V*) characteristics without annealing for the test structures with contact diameter 6 µm (left) where the solid and dashed lines represents the samples processed by HCl dip and sulfide treated both and only HCl dip respectively. The calculated contact resistivity by using the method in ref [9] for different point contact diameters (right).

This work has been supported by the European Union via NEMIS (contract no. FP6-2005-IST-5-031845) and the German Federal Ministry of Education and Research via NOSE (contract no. 13N8772).

References

[1] C. Lauer, S. Szalay, G. Böhm, C. Lin, F. Köhler, and M.-C. Amann, IEEE Trans. Instrum. Meas. Vol. 54, pp.1214-1218, (2005).
[2] A. Bachmann, K. Kashani-Shirazi and M.-C. Amann, Conference Digest, Proc. of 21st ISLC, pp. 39-40 (2008).
[3] J. Chen, A. Hangauer, A. Bachmann, T. Lim, K. Kashani-Shirazi, R. Strzoda and M. C. Amann, European Semiconductor Laser Workshop (ESLW), Eindhoven, Netherlands (2008).
[4] T. Chiu, J. Ditzenberger, H. Luftman, W. Tsang and N. Ha, Appl. Phys. Lett. Vol. 56, pp. 1688-1690 (1990).
[5] Y. Mizokawa, O. Komoda and S. Miyase, Thin Solid Films, Vol. 156, pp. 127-143 (1987).
[6] C. Lauer, O. Dier and M. C. Amann, Semiconductor Science and Technology, Vol. 21, pp. 1274-1277 (2006).
[7] J.A. Robinson and S.E. Mohney, J. Appl. Phys. Vol. 96, pp. 2684-2688 (2004).
[8] O. Dier, S Dachs, M. Grau, C. Lin, C. Lauer and M. C. Amann, Appl. Phys. Lett., Vol. 86, pp.151120 (1-3) (2005).
[9] G. Franz and M. C. Amann, J. Electrochem. Soc., Vol. 140, pp. 847-850 (1993).