Extended Abstracts of the 1991 International Conference on Solid State Devices and Materials, Yokohama, 1991, pp. 271-272 **S-C-2**

Invited

Atomic Scale Characterisation and Control of Heterojunctions and Schottky Barriers in Compound Semiconductors

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Heterojunction interfaces have been controlled by p-type δ-doping of the interface. Results for InAs-GaAs are described. The barrier heights have been probed by current-voltage measurements and by Ballistic Electron Emission Microscopy (BEEM).

Heterojunctions and contacts dominate the electrical behaviour of a large number of solid state electronic devices. Whereas many aspects of the bulk semiconductor can be controlled to a remarkable degree during growth of the material, the control of interfaces is a new area now beginning the bear fruit. In this paper we describe experiments aimed at controlling band discontinuities and Schottky barriers by δ-doping the semiconductor close to the interface. We show that a substantial degree of control is possible in both situations.

Here we concentrate on two systems, namely Al-GaAs contact and the InAs-GaAs heterojunction. Samples were grown by MBE in a VG Scientific V80H reactor. Metallisation could be achieved in-situ or in an attached uhv metallisation chamber. Delta doping of the GaAs was carried out with Be for p-type and Si for n-type.

Figure 1 shows the appropriate band diagram for the InAs-GaAs heterojunction. The conduction band discontinuity, ΔE_C, was measured in the following way. First the barrier ϕ_b was established by the I-V technique. Forward and reverse characteristics are shown in Figure 2. The diodes are well described on the basis of thermionic emission theory, giving a value of 0.62 eV of ϕ. To obtain ΔE_C the value of $\Sigma+\Delta_1$ was calculated by solving Poisson's equation on either side of the interface. This yields a value of 0.72 eV for ϕ. Also shown in Figure 2 is the I-V characteristic for the δ-doped heterojunction. Here 2 x 10^{13} Be

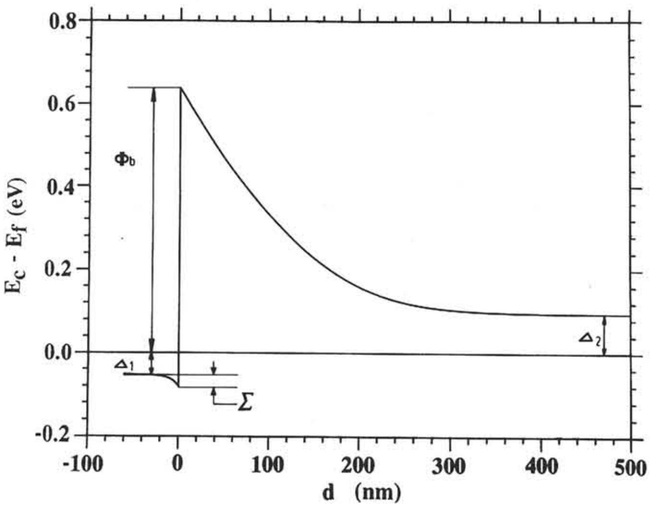


Figure 1 Band profile for the InAs-GaAs interface. The InAs is on the left and GaAs on the right.

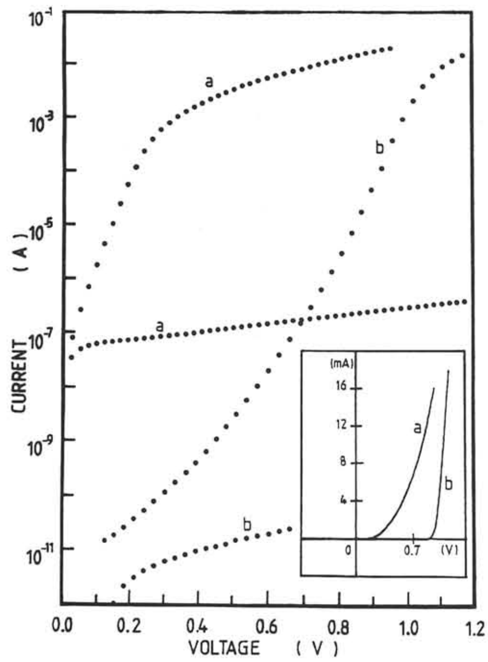
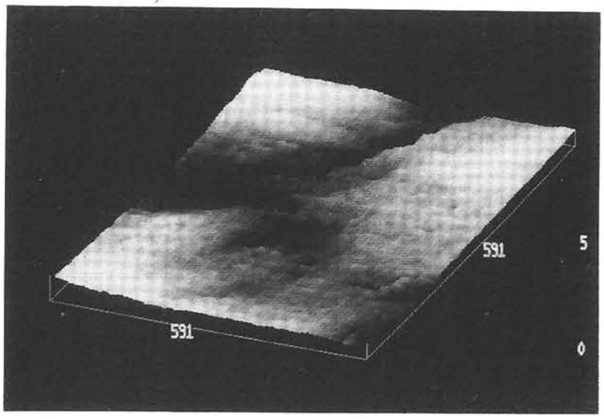


Figure 2 Current-voltage plots for (a) a normal InAs-GaAs heterojunction, and (b) a similar junction but which has been δ-doped with Be. Forward and reverse characteristics are shown.

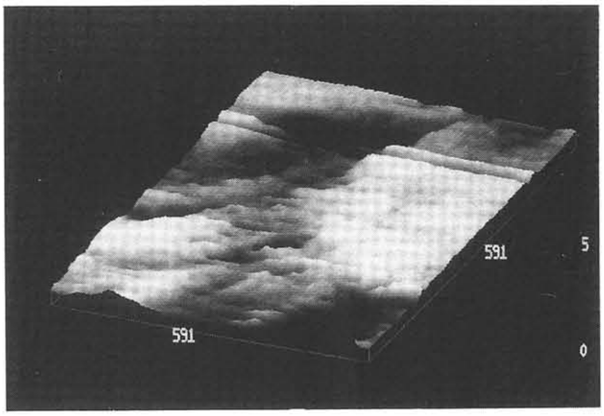
atoms/cm^2 were situated at a nominal distance of 5nm from the interface, in the GaAs. The influence on the I-V characteristic is drastic and a substantial part of the forward bias current is again well described by thermionic emission theory with a value of ΔE_C of 1.2 eV. Calculations of the effect of the δ-doped layer have been carried out for several doping concentrations and for different distances of the δ-layer from the interface. For a distance of 5nm no further barrier enhancement is obtained for Be doping concentrations in excess of $\sim 10^{13}$cm^{-2}.

Similar investigations for the Al-GaAs (n-type) contact show that the Schottky barrier at this interface can be enhanced to around 1 eV by a Be δ-layer. As is well known contacts with extremely low effective barriers can be generated by doping with Si.

Finally we also discuss the exploration of Schottky barriers at the InAs-GaAs heterojunction by Ballistic Electron Emission Microscopy (BEEM). Maps of topography and BEEM current are shown in Figure 3(a) and (b).



(a)



(b)

Figure 3 (a) Topography of thin Au layer on InAs for an InAs-GaAs heterojunction and (b) BEEM current for the same heterojunction.

References
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