Available online at www.sciencedirect.com
SCIENCE DIRECT®
Nuclear Instruments and Methods in Physics Research B 237 (2005) 208–212
NIM B Beam Interactions with Materials & Atoms
www.elsevier.com/locate/nimb

Manufacturability of fully ion implanted planer-doped-barrier diodes in GaAs

R. Gwilliam [a,*], Y.Y. Wang [a], M.J. Kelly [b], M.J. Kearney [a]

[a] *Nodus Lab, Advanced Technology Institute, University of Surrey, Guildford GU2 7XH, UK*
[b] *Department of Engineering, University of Cambridge, Trumpington Street, Cambridge CB2 1PZ, UK*

Available online 24 June 2005

Abstract

Given the superior control of ion implantation over dopant incorporation during epitaxy, in addition to the throughput and hence cost advantages, we have attempted the design and fabrication of a GaAs planar-doped-barrier diode with pre-specified electrical properties, using a fully ion implanted fabrication technology. The process requirements for such a device are the stringent control of both the dopant depth distribution and the absolute dopant activation (simultaneously for both p-type and n-type dopants). In order to achieve a correct device geometry, implants from several MeV down to a few keV are required with an accuracy of better than 1% in both energy and dopant activation. In addition, there is a need to control any dopant redistribution during annealing. Here, we present the results of a model to describe the device performance using the TRIM ion implant simulation code along with experimental results on the doping profiles achieved and the eventual device results obtained from such structures.

PACS: 81.05.Ea; 61.72.Vv; 84.40.Lj; 07.57.Kp

Keywords: Ion implantation; Planar-doped-barrier diode; GaAs; Detectors

1. Introduction

The n–i–p–i–n planar-doped-barrier (pdb) diode [1] was introduced in 1980 whose properties could be tailored through the choice of doping and thickness of various layers that would subsequently be grown by epitaxy. It evolved from an earlier n–p–n diode (the Camel diode) made by an all-implant process [2]. Subsequent studies showed that this diode has superior properties, compared with the Schottky diode, as a microwave detector [3]. In addition to the advantages of tailoring (low-barrier detectors, zero-bias detectors etc.), the pdb diode has a reduced sensitivity to

* Corresponding author. Tel.: +44 1483 689845; fax: +44 1483 689857.
E-mail address: r.gwilliam@surrey.ac.uk (R. Gwilliam).

0168-583X/$ - see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.nimb.2005.04.102

ambient temperature of operation, greater dynamic range at low temperature, and much greater resistance to burn-out under intense pulses [3]. The pdb diode has been in and out of production, but its full advantages have not been realised due to an inadequate control over the doping-thickness product of the critical p-doped layer during crystal growth using either molecular beam epitaxy or metal-organic-chemical vapour deposition. To take full advantage of the tailoring of device characteristics, an accuracy and precision of less than 2% is highly desirable, a factor of typically two or three below that routinely offered by epitaxy houses. Over the last three decades, however, the metrology of ion implantation has improved with the demands made by the tight tolerances required for VLSI circuits, and a 0.5% accuracy of total ion dose is around the state-of-the-art, although dopant activation is required to be controlled to the same level. With this in mind, we have revisited the all-implanted planar-doped-barrier structure, with the aim of determining if a fully implanted device could now be fabricated as a low cost alternative to the conventional epitaxy routes.

2. Device design

The electrostatics of the n–i–p–i–n structure have been fully analysed elsewhere [2] and a simple computer simulation that solves self-consistently the Poisson equation together with the drift-diffusion equation has been generated [4]. TRIM [5], the most commonly used software code for simulating implantation profiles, has been used as an input to the device modelling software. Using the above, we have found that three implants are sufficient to generate the desired *I–V* characteristics in semi-insulating GaAs. The required implants include a deep (2–4 MeV) Si^+ implant that provides the back (n-type) contact layer at between 1.5 and 2.5 μm below the wafer surface, and a shallower Si^+ implant providing the top contact which could be supplemented by a lower energy implant to provide a lower resistance ohmic contact (improving the current transport through the device). The key implant to the device operation is the p-type implant, which must both compensate the tail of the Si implant and provide a small p-type barrier controlling the device characteristics. A typical implant dopant profile simulation from TRIM, together with the net predicted carrier concentration (assuming 100% dopant activation and zero diffusion) is shown in Fig. 1. The corresponding simulated current–voltage characteristic is given in Fig. 2 together with predicted curves for a variance in p-doping at around the 5% level.

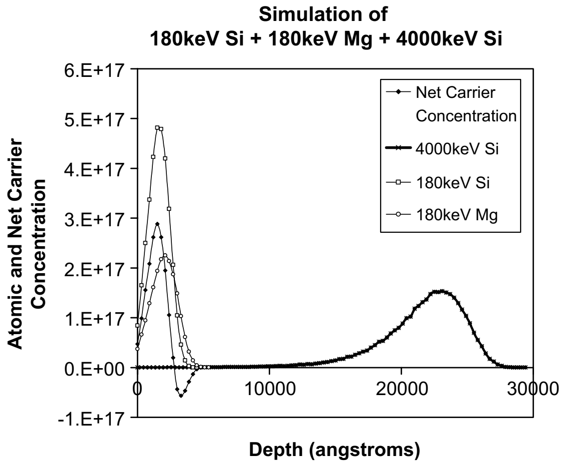

Fig. 1. TRIM simulation of doping profile of an asymmetric planar-doped-barrier diode, showing the profiles generated by each of the three implants and the net carrier concentration.

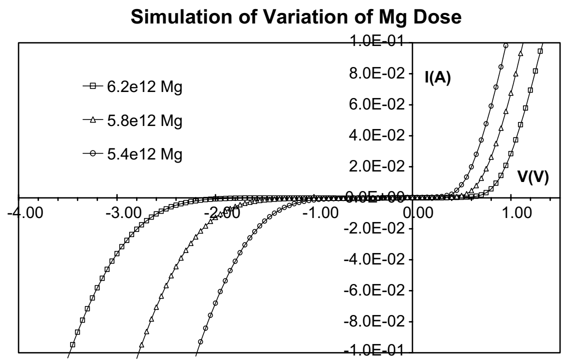

Fig. 2. Predicted sensitivity of the *I–V* characteristics to variations in the implanted Mg dose.