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ScienceDirect

Nuclear Instruments and Methods in Physics Research B 260 (2007) 259–263

NIM B
Beam Interactions with Materials & Atoms

www.elsevier.com/locate/nimb

Measurement of charge collection profiles in irradiated silicon diodes by lateral IBIC technique

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Abstract

The control of the carrier lifetime profile in semiconductor power devices is of fundamental importance to optimize device parameters. With respect to traditional technologies such as diffusion of metallic impurities, light ion irradiation at low doses provides precise spatial localization of defects acting as carrier traps and recombination centres. Hence, the generation of suitable lifetime profiles obtained by controlling ion fluence and energy allows the reduction of turn-off times and switching losses in power electronic devices.

In order to characterise the effects of ion irradiation on carrier lifetime profiles, we have used the ion beam induced charge collection (IBIC) technique in lateral geometry to measure charge collection efficiency (CCE) profiles in silicon p+/n/n+ diodes under different applied bias conditions before and after a frontal 6.5 MeV He++ ion implantation at a total fluence of 2×10^{12} ions/cm^2. After the irradiation, the profile shows a clear drop of charge collection efficiency which occurs at the end of the ion range.

The formalism based on Shockley–Ramo–Gunn's theorem was applied to interpret the CCE profiles in both virgin and irradiated samples and to assess the free carrier lifetime profile modification following the radiation damage.

PACS: 72.20.Jv; 41.75.Ak; 61.80.−x

Keywords: Semiconductors; Electronic properties; Ion beam induced charge collection; Radiation damage

1. Introduction

High energy ion irradiation of semiconductor devices is a well established technique for the controlled modification of semiconductor transport properties, due to the extreme sensitivity of the carrier lifetime to point defects produced by interaction with radiation [1].

Ions with energies in the MeV range induce the creation of pairs of vacancies and recoiling target atoms (i.e. Frenkel pairs) toward the end of the ion track, when elastic collisions with atoms prevail on the electronic stopping. This implies a non-uniform distribution of defects peaked at the penetration depth and, consequently, the possibility of controlling the depth distribution density of recombination centres by varying the ion energy. This peculiarity, as well as the high reproducibility of the ion damage due to the accurate control of the ion fluence and the possibility of performing the irradiation on the finished diode, without having to consider the introduction of impurities from the outer surface, represent the main advantages of the ion irradiation technique for carrier lifetime control compared with other conventional techniques (Au or Pt diffusion or MeV electron irradiation).

An important example of application of such a technique is in the fabrication of high power fast rectifier

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doi:10.1016/j.nimb.2007.02.031