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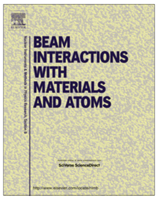

Modeling of ion beam induced charge sharing experiments for the design of high resolution position sensitive detectors

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ABSTRACT

In a multi-electrode device, the motion of free charge carriers generated by ionizing radiation induces currents on all the electrodes surrounding the active region [1]. The amount of charge induced in each sensitive electrode is a function of the device geometry, the transport parameters and the generation profile. Hence this charge sharing effect allows the signal from each sensitive electrode to provide information about the electrical characteristics of the device, as well as information on the location and the profile of each ionization track.

The effectiveness of such approach was recently demonstrated in Ion Beam Induced Charge (IBIC) experiments carried out using a 2 MeV He microbeam scanning over a sub-100 μm scale silicon device, where the ion strike location point was evaluated through a comparative analysis of the charge induced in two independent surface electrodes coupled to independent data acquisition systems [2].

In this report, we show that the Monte Carlo method [3] can be efficiently exploited to simulate this IBIC experiment and to model the experimental data, shedding light on the role played by carrier diffusion, electronic noise and ion beam spot size on the induction of charge in the sensitive electrodes. Moreover, the Monte Carlo method shows that information on the ion strike position can be obtained from the charge signals from the sensitive electrodes.

1. Introduction

Ion beam induced charge is a widespread technique used since 1993 to characterize electronic materials and devices. Many previous papers have underlined the potential of this technique to investigate with micron resolution both qualitatively and quantitatively the transport properties of semiconductors [4], the damage induced by focused ion beams and, simultaneously, the effect of damage on the carrier transport properties [5] and the analysis of single event effects in microelectronic devices [6].

An important feature which makes IBIC particularly attractive for material science is the availability of a robust theoretical background [1,4,7], which allows the extraction of practically all the information needed to qualify materials from the electronic point of view and to analyse the performance of electronic devices in a radiation environment.

Recently, IBIC has acquired further interest for the measurement of the ion strike location in multielectrode devices. Examples include the development of single atom deterministic doping techniques, which are now emerging [2,8–10] for potential applications in solid state quantum information processing devices and addressing issues with variations in classical device characteristics arising from statistical doping. For such purposes the evaluation of the induced charge shared between the electrodes could be used for the measurement of the ion strike location to sub-micron precision. The achievement of this goal requires accurate analysis of the induced charge pulse formation mechanism and a suitable investigation of the main physical phenomena influencing the measurement.

In this paper, we present a model based on the Shockley–Ramo–Gunn theorem [4,7] and developed through a Monte Carlo approach [3]. We apply this model to an experiment recently reported by Jong et al. [2] which aimed to investigate the charge sharing phenomena occurring in a multi-electrode silicon p–i–n device.

The motivation of such investigation is firstly to validate the model in a charge sharing configuration through a direct comparison of the Monte Carlo simulation with the experimental results; secondly to extract information on the role played by electrons and holes in the induced charge signal formation and on the effects of electronic noise and microbeam spot size on the definition of the Charge Collection Efficiency (CCE) profiles; finally, to assess the

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