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Semiconductor characterization by scanning ion beam induced charge (IBIC) microscopy

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Abstract

The acronym IBIC (ion beam induced charge) was coined in the early 1990s to indicate a scanning microscopy technique which uses MeV ion beams as probes to image the basic electronic properties of semiconductor materials and devices. Since then, IBIC has become a widespread analytical technique to characterize materials for electronics or for radiation detection, as testified by more than 200 papers published so far in peer-reviewed journals. Its success stems from the valuable information IBIC can provide on charge transport phenomena occurring in finished devices, not easily obtainable by other analytical techniques. However, IBIC analysis requires a robust theoretical background to correctly interpret experimental data. In order to illustrate the importance of using a rigorous mathematical formalism, we present in this paper a benchmark IBIC experiment aimed to test the validity of the interpretative model based on the Gunn's theorem and to provide an example of the analytical capability of IBIC to characterize semiconductor devices.

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Keywords: Semiconductors; Electronic properties; Ion beam induced charge

1. Introduction

The measurement of the charge induced at a sensing electrode by the motion of free carriers generated in a semiconductor material by MeV ion beams can be dated back to the 1930s [1], when the first studies on radiation induced conductivity were carried out on AgCl crystals. Since then, the analysis of the charge pulses generated by MeV ions (mainly alpha particles from a radioactive source), greatly contributed to determine the value of the fundamental electronic features of silicon and wide band gap semiconductors. The availability of MeV ion accelerators, which can provide more controlled beams, different ion species and energies, triggered a renewed interest in this technique, mainly motivated by the possibility of probing samples at different depths. With the advent of highly focused ion beams, IBIC spectroscopy turned into a spectro-microscopic technique able not only to measure, but also to image basic transport properties, dislocations, defects and buried junctions in semiconductors materials and devices. Comprehensive reviews of the main IBIC applications can be found in the fundamental book [2] and in a more updated publication [3].

Although the theory underlying the formation of IBIC signal was developed more than 70 years ago [4,5], it is not rare to find in literature improper or incomplete interpretations of the charge collection mechanism, which often

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