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A review of ion beam induced charge microscopy

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Abstract

Since its development in the early 1990's, ion beam induced charge (IBIC) microscopy has found widespread applications in many microprobe laboratories for the analysis of microelectronic devices, dislocations, semiconductor radiation detectors, semi-insulating materials, high power transistors, charge-coupled arrays, solar cells, light emitting diodes, and in conjunction with Single Event Upset imaging. Several modalities of the techniques have been developed, such as lateral IBIC and time-resolved IBIC. The theoretical model of IBIC generation and collection has developed from a one-dimensional model of charge drift and diffusion to a detailed model of the motion of ion charge carriers in semiconductors and insulators. This paper reviews the current state-of-the-art of IBIC theory and applications.

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1. Introduction

Many types of charged particle and electromagnetic radiation, such as electrons, ions, ultra violet light can supply enough energy to a semiconductor or insulator lattice during an interaction to promote bound electrons from the valence band to the conduction band and to create electron–hole, e–h, pairs. All forms of charge collection microscopy use this principle to create large quantities of e–h pairs which are separated in the presence of an external or a built-in electric field. The measured charge or current depends on the amount of trapping and recombination at point and extended defects, the doping density, minority carrier diffusion length, electric field strength, mobility and collection geometry. In charge collection microscopy spatially-resolved images, linescans or spectra from specific locations from the sample are recorded which enables one or more of these quantities to be measured. There are a variety of other forms of charge collection microscopy and spectroscopy, with several Conference Series devoted to these and related subjects. EBIC (electron beam induced current) which uses a highly focused keV electron beam is the most commonly-used mode of charge collection microscopy [1]. OBIC/LBIC (optical/laser beam induced current) which uses a focused laser beam is another widely-used mode [2] and there is an X-ray mode based on synchrotron radiation [3].

IBIC microscopy typically uses a current of 0.1–10 fA (approximately 1–10,000 ions/s) of light MeV ions and measures individual charge pulses, rather than continuous variations in an induced charge/current as in other forms of charge/current collection microscopy. Analysis at such low beam currents is possible because each incident ion generates enough e–h pairs in semiconductor and insulating materials to produce a charge pulse which is measurable above the device noise level. Fig. 1 shows the basic analytical geometries used for IBIC analysis of

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