ELSEVIER

Materials Science and Engineering B102 (2003) 193–197

MATERIALS SCIENCE & ENGINEERING B

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Time-resolved ion beam-induced charge collection measurement of minority carrier lifetime in semiconductor power devices by using Gunn's theorem

C. Manfredotti [a,*], F. Fizzotti [a], A. Lo Giudice [a], M. Jaksic [b], Z. Pastuovic [b], C. Paolini [a], P. Olivero [a], E. Vittone [a]

[a] *Experimental Physics Department, INFM-National Institute for the Physics of Matter, UdR University of Torino, Torino 10125, Italy*
[b] *Department of Experimental Physics, Ruder Bošković Institute (RBI), P.O. Box 180, 10002 Zagreb, Croatia*

Received 13 April 2002; received in revised form 19 August 2002; accepted 21 October 2002

Abstract

Ion microbeam techniques like ion beam-induced charge collection (IBICC) are very powerful methods in order to investigate and to map the transport properties in different technologically important semiconductors and in particular in materials proposed for nuclear detection. Time-resolved ion beam-induced charge collection (TRIBICC) represents a further improvement with respect to more traditional IBICC, since it can supply not only the charge collection efficiency (and through it data on mobility and trapping time of carriers in drift regions) but also the time behaviours of the charge collection. For long collection times, this means to gather information, also about diffusion lengths and lifetimes of carriers in the diffusion regions, which are always present in undepleted electronic devices, in particular power devices, and which are of paramount importance as inputs for simulation codes. By TRIBICC, in fact, some difficulties could be avoided in analysis of data collected in cases when lifetimes and shaping times of electronic chain are similar, and the sensitivity of the method is worse. In order to suitably analyse TRIBICC data, a theoretical model should be available: in general, Ramo's theorem is used, but its validity in cases when space charge is present is questionable. A more general and powerful method is presented in this work by using Gunn's theorem and a particular formulation of the generation function in order to solve the adjoint of the continuity equation in the time-dependent case. An application of this method to a commercial power device is presented and discussed.

Keywords: Ion beam-induced charge collection; Silicon device characterisation; Carrier lifetime

PACS numbers: 73.50.Gr; 85.30.De

1. Introduction

The knowledge of important parameters like minority carriers lifetime is of paramount importance not only for semiconductor materials producers, but also for computer-aided engineering CAE applications in which a first value, even approximate, of these parameters is needed in order to carry out device simulations for design implementations, being sure to remain in a realistic physical region. The methods used for minority carriers lifetime evaluation generally present some drawbacks, since either they are based on some model of the device (reverse recovery) or they can be applied only to specified samples of the material and not to the finished device (photoconductive decay). Ion beam-induced charge collection (IBICC) and time-resolved ion beam-induced charge collection (TRIBICC) in frontal version do not display any drawbacks, apart from the need to dispose of an ion accelerator, since they can be easily applied to a finished device, the depth of investigation can be pushed towards 100 μm (what is generally needed for power devices) and, particularly in the case of TRIBICC, they can be used in a wide range of lifetime

* Corresponding author. Tel.: +39-011-670-7306; fax: +39-011-669-1104.
E-mail address: manfredotti@to.infn.it (C. Manfredotti).

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doi:10.1016/S0921-5107(02)00656-6