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The ALCHIMIA project for the characterisation of semiconductor materials and devices by means of ion microscopy

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The ALCHIMIA (Analysis of Luminescence and CHarge collection Induced by Micro Ion beAms) project is an INFN research aimed to characterise by means of an ion microbeam, the electronic properties of semiconductor and insulator materials and devices [1]. In this research we applied the expertise acquired during the previous MICROEL project in IBIC (Ion Beam induced Charge) and IBIL (Ion beam Induced Luminescence) techniques to characterise advanced materials and devices such as natural and CVD diamond[2,3,4], GaAs[5,6,7], CdTe[8] and silicon[9,10]. The work was carried out at the microbeam facility of the AN2000 accelerator at LNL

natural and CVD diamond

Diamond has been extensively studied by means of the IBIC technique in order to analyse its transport properties and to evaluate the spatial uniformity of the charge collection efficiency. However, due to its scintillating nature, diamond is also suitable to be characterised by ionoluminescence which is employed as a sensitive method to map radiative recombination centres. We have explored the combined use of IBIL and IBIC as a tool to characterise the electronic and scintillating properties of "detector grade" CVD diamond samples. IBIC maps show typical columnar structures easily referable to the crystal morphology, whereas IBIL maps put in evidence regions where radiative recombination occurs.

gallium arsenide

GaAs Schottky diodes have been analysed by means of the IBIC technique in order to evaluate the uniformity of the charge collection efficiency. The IBIC maps clearly show two "electronic phases", i.e. spatially distinct regions with different charge collection efficiencies (cce). The behaviour of the response of such detectors as a function of the bias voltage has been analysed with 2 MeV proton micro beams both in unirradiated and in strongly irradiated samples (24 GeV/c, fluence up to 17×10^{13} protons/cm^2). The cce maps show a clear improvement in response uniformity of the detector as the irradiated dose increases. Such a result explains the observed improvement of energy resolution of irradiated detectors with respect to unirradiated ones.

cadmium telluride

Collection efficiency profiles as determined by the lateral IBIC technique have been considered to evaluate the spectroscopic performances of a cadmium telluride (CdTe) nuclear radiation detector. Experimental collection efficiency profiles were used as input data of the "ISIDE" Monte Carlo programme to simulate the CdTe response to gamma rays produced by ^{57}Co. A systematic investigation of such spectra obtained under different detection conditions shows the effects of non constant collection efficiency profiles and ballistic deficit on the energy resolution of the detector.

silicon

The transport properties of silicon p+/n/n+ diodes with a junction depth of about 47 micrometer have been investigated by means of the lateral IBIC technique. Cross section of the samples have been irradiated by a low intensity proton microbeam and the charge pulses have been recorded as a function of incident proton position. The charge collection efficiency profiles show broad plateaux with values close to 1. The region where the electric field is absent shows exponentially decreasing charge collection efficiency profiles. The estimate of the decay rate allows the diffusion length of the minority carriers in the bulk of the device to be measured. The entire cce profile is in full agreement with the IBIC theory based on the extended Ramo theorem, which provides a very effective tool for quantitative estimates of transport parameters in semiconductor devices.

References

[1] C.Manfredotti, F. Fizzotti, P. Polesello, E. Vittone, M. Truccato, A. LoGiudice, M.Jaksic, P. Rossi, Nucl. Instr. And Meth. In Phys. Res. B 136-138 (1998) 1333-1339

[2] C.Manfredotti, G. Apostolo, A. LoGiudice, P. Polesello, G. Cinque, M. Truccato, E. Vittone, G. Egeni, V. Rudello, P. Rossi, Diamond and Rel. Materials 7 (1998) 742-747

[3] C.Manfredotti, F.Fizzotti, P.Polesello, E.Vittone, Presented at 2nd Int. Conf. on Radiat. Effects on Semicond. Mat., Detectors and Devices, Firenze (Italy), 4-6 March 1998, to be pub. in Nucl. Instr. and Meth. in Phys. Res. A

[4] C. Manfredotti , F. Fizzotti, A. Lo Giudice, P. Polesello ,E.Vittone, M.Truccato, P. Rossi, Presented at "6th Int. Conf. on New Diamond Science and Technology", Pretoria, South Africa, 31-8/4-9 1998, to be pub. in Diamond and Rel. Mater.

[5] F.Nava, P. Vanni, C. Canali, G. Apostolo, C. Manfredotti, P. Polesello, E. Vittone, IEEE Transaction on nuclear Science 45,3 (1998) 609-616

[6] F.Nava, P.Vanni, U.Biggeri, E.Vittone, C.Lanzieri, G.Bertuccio, C.Canali, Nucl. Instr. and Meth. in Phys. Res. A 410 (1998) 68-73

[7] E.Vittone, C. Manfredotti, F. Fizzotti, K.Mirri, E.Gargioni, P. Polesello, A. Lo Giudice,S.Galassini, F.Nava, P.Vanni, P.Rossi, Presented at 6th Int. Conf. on Nucl. Microprobe Technology and Appl., Spier Estate, South Africa, 11-16/10/ 1998, and to be pub. in Nucl. Instr. and Meth. in Phys. Res. B

[8] E.Vittone, F.Fizzotti, A.Lo Giudice, P.Polesello and C.Manfredotti, Presented at the "Workshop on Room Temp. Semiconductor Detectors for remote, portable and in situ radiation meas. systems", Jerusalem, Israel, 27-28/7/1998, to be pub. in Nucl. Instr. and Meth. in Phys. Res. B

[9] C. Manfredotti, F. Fizzotti, E.Gargioni, R. Lu, P. Polesello, A. Lo Giudice, E. Vittone, S.Galassini, M.Jaksic, Submitted at 6th Int. Conf. on Nucl. Microprobe Techn. and Appl., Spier Estate, South Africa, 11-16/10/1998, to be pub. in Nucl. Instr. and Meth. in Phys. Res. B

[10] C. Manfredotti, F. Fizzotti, A.LoGiudice, P. Polesello and E. Vittone, Presented at

the "15th Int. Conf. on the Appl. of Accelerators in Res. and Industry, 4-7/11/1998, Denton, Texas.