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## Study of semiconductors by Ion Beam Induced Charge (IBIC) microscopy

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# ACCELERATORS FOR RESEARCH AND SUSTAINABLE DEVELOPMENT

From good practices towards socioeconomic impact



#### The RBI accelerator facility





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and Sustainable Development

23-27 May 2022 IAEA, Vienna, Austria

#### The Ion Beam Induced Charge – IBIC technique



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Slide 4/11 Spe

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#### The Ion Beam Induced Charge – IBIC technique



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Frontal / Lateral IBIC



#### IBIC applications – Study of detectors and electronic devices

300

250

200

100

50

50

100

150

x (µm)

200

250 300

**E** 150

>







Characterization of 3D contact devices

Diamond detector with laser-formed buried graphitic electrodes: micron-scale mapping of stress and charge collection efficiency

> S. Salvatori, Member, IEEE, M.C. Rossi, G. Conte, T.V. Kononenko, M.S. Komlenok, A.A. Khomich, V.G. Ralchenko, V.I. Konov, G. Provatas, and M. Jaksic





(b)

50

100

x (µm)

150

200

**E**<sup>150</sup>

>100

50

TIIIIII

M. Pezzarossa<sup>a</sup>, E. Cepparrone<sup>b</sup>, D. Cosic<sup>d</sup>, M. Jakšić<sup>d</sup>, G. Provatas<sup>d</sup>, M. Vićentijević<sup>d</sup>, E. Vittone<sup>b, c, \*</sup>

Experimental methodology based on IBIC.

Characterization of electronic features of power diodes using 1.2 - 2.0 MeV protons, angles of incidence and applied voltage



rators for Research

100

80

60

40

20

RAC

200

250

**↑***p*+

CCE



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#### IBIC applications – Study of detectors under extreme conditions



- For 100% ion impact detection efficiency, IBIC can be used to monitor the irradiation fluence
- Irradiation of arbitrary shapes
- **IBIC probing**, on-line monitoring of CCE degradation / radiation hardness studies



A scCVD exposed to high temperature and high radiation







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Slide 7/11

### IBIC applications – Deterministic single ion implantation / Imaging of electric fields in micromachined detectors

**Quantum centers in diamond**, such as NV centers, can serve as information

E 500

250 500 750



A XGLab CUBE PRE031 high signal/noise preamp was used.

M. Vićentijević PhD Thesis

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600 7

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#### In air IBIC experiments



Large detector structures which cannot be tested in vacuum chambers can be studied with in-air microbeams. However, in such case, degradation of the beam spot is resulted.

Solution: A 100 nm thick  $Si_3N_4$  exit foil can be used. For protons > 6 MeV and 2 mm working distance.





Testing the HVCMOS RD50 MPW2 monolithic pixel sensor matrix at the RBI new microprobe



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Slide 9/11

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#### Summary



- IBIC is a powerful tool for quantitative characterization of semiconductor detectors and devices (minority carrier diffusion lengths, depletion layer widths etc)
- CCE 2D/3D maps obtained with IBIC technique show evidence of the performance and electronic properties within the whole volume of the materials
- Detectors and devices can be studied under different radiation and physical conditions, using the microprobe setups
- \* The availability of the **dual microbeam** setup will enable **real time monitoring of radiation damage** / annealing
- Moreover, with two microbeams, simultaneous IBIC probing and irradiation in channeling and non-channeling mode will enhance the possibilities for studies of effects in the crystals structure

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Slide 10/11

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# Thank you !

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