SRI2024

Contribution ID: **694** Type: **Contributed talk**

Coupling X-ray Beam Induced Current ToF-XBIC with high time resolution to characterize semiconductor-based detectors

Recently the demand for accurate characterization of the electronic properties of semiconductor-based detectors is steadily increasing. In this context, at the beamline BM05of the EU synchrotron, we have developed an X-Ray Beam Induced Current (XBIC) [1] and a Time of Flight X-Ray Beam Induced Current (ToF XBIC) experiment setup. These two methods involve recording two-dimensional current maps (XBIC) and/or time resolution (ToF-XBIC) to assess the homogeneity of the crystal's response of local electrical property. Furthermore, by leveraging Bragg diffraction imaging technique [3] on the same beamline, we have demonstrated correlations between these techniques, revealing insights into charge collection attenuation, intrinsic time resolution, and structural defects at a percent level accuracy [1].
Achieving precise mapping of the crystal's intrinsic temporal resolution with local precision necessitates superior electronics to minimize measurement interference, along with high-intensity X-ray beams to enhance the signal-to-noise ratio and enable large-scale resolution (30 um). This beam intensity can be attained using a multilayer monochromator which can gain 102 time the flux of a Si(111) monochromatic. Control over the amount of signal generated within the semiconductor is crucial to have a good signal to noise ratio. Slits placed just in front of the sample can select the fraction of the transmitted beam down to 10 um2, although this approach also dictates the resolution of the map. Alternatively, adjusting the beam energy within the range of 5 to 60 keV can influence the fraction of absorbed radiation. This provides sufficient signal for straightforward reading electronics comprising a preamplifier and an oscilloscope. Synchronizing measurements with the synchrotron frequency can compensate for smaller signals in large-gap semiconductors.
Our studies with XBIC and ToF-XBIC have shown the effects of the irradiation on single crystal diamond (sCVD) with a 68 MeV proton beam at ARRONAX, resulting in a notable decrease in charge collection and an increase in intrinsic time resolution dependent on the received fluence, as depicted in Figure 1 (attached document).
These integrated quantitative imaging techniques (XBIC, ToF XBIC, and X-ray diffraction imaging) offer valuable insights for optimizing not only for diamond crystals but also for all semiconductor: from bulk materials, thin overgrown layer to final devices in the order to understand better the success or failure of the electronic devices.
[1] Gallin-Martel, M.-L. et al. Diamond and Related Materials 112 108236 (2021).
[2] Lafont, F et al., Diamond & Related Materials 140 110454 (2023)
[3] T-N TranThi et al., J. Appl. Cryst. 50, 561-569 (2017).

I plan to submit also conference proceedings

Yes

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Session Classification: Mikrosymposium MS 12/1: Time Resolved Techniques

Track Classification: 12. Time resolved techniques