L.5: X-ray absorption edges of transition metals and their alloy measured by an indigenously developed GaAs detector

The gallium arsenide (GaAs) is among the best-suited materials for X-ray photon detection and 3D imaging under direct photon counting mode over a broad energy range. This is because of its high quantum efficiency, excellent signal-to-noise ratio at room temperature, and the matured processing technology. The comparative graphs of the theoretical quantum efficiency of 4 µm thick GaAs and Si up to 20 keV energy of the X-ray photon are shown in Figure L.5.1(a). The theoretical curves indicate that the GaAs detector should show a superior response over Si for the energy greater than 10 keV. This is mainly because silicon (Z=14) has low stopping power as compared to GaAs (Z=31/33). In addition, GaAs being the direct wide bandgap material with high charge carrier mobility allows the detector operation at room temperature with the low dark current. GaAs p-i-n device structures are grown by using metal organic vapour phase epitaxy (MOVPE) technique at RRCAT. Thickness of SiO_2 layer was kept as 20 nm, which is just sufficient to passivate the surface states and transfer a maximum number of X-ray photons to the intrinsic region of the device. The developed detectors are mounted on a TO5 header supported by a Teflon holder. The stray light is blocked using a thin aluminum cover on the detector mount while allowing the X-ray to pass through. The response of the developed GaAs detector is used to detect x-ray signals generated by a lab-based Cu K_α X-ray source and at BL-16 beamline of Indus-2. Inset in Figure L.5.1(a) shows the measurement setup. X-ray response of the device up to 20 keV is shown in Figure L.5.1(a), where a 4-fold rise of signal varying from 287 nA (10 keV) to 1190 nA (12 keV) is seen. It is associated with the *K*-edge absorption of Ga and As at ~10.4 keV and 11.9 keV, respectively and closely matches with the theoretical absorption curve. It confirms a high charge conversion efficiency of the developed device for x-ray photons. The dynamic range of the detector ~10^6(at 12 keV) is also estimated by measuring the X-ray photon flux received after the double crystal monochromator. The minimum signal observed at energy of 6 keV is 61 nA and it is 10^4times higher than the background dark current of the detector (~5 pA). Finally, the developed detector has been used to measure the characteristic lines (*K*-edge) of various transition metals and their alloys. The characteristic lines (*K*-edge) of Mn, Fe, Ni, Cu, and Zr at 6.5 keV, 7.1 keV, 8.3 keV, 8.9 keV and 17.9 keV, respectively are measured in the reflection geometry as shown in Figure L.5.1(b). The Fe-Ni alloy is identified by measuring their *K*-edge, which is also verified by the commercial X-ray florescence setup. Further, the detection of Zr *K*-edge confirms that the GaAs detectors can be used to detect high Z elements more efficiently than Si in which the response decays drastically above 10 keV energy. Due to the above advantages, GaAs detectors are considered for grating-based phase-contrast computed tomography required for advanced safety and medical applications.

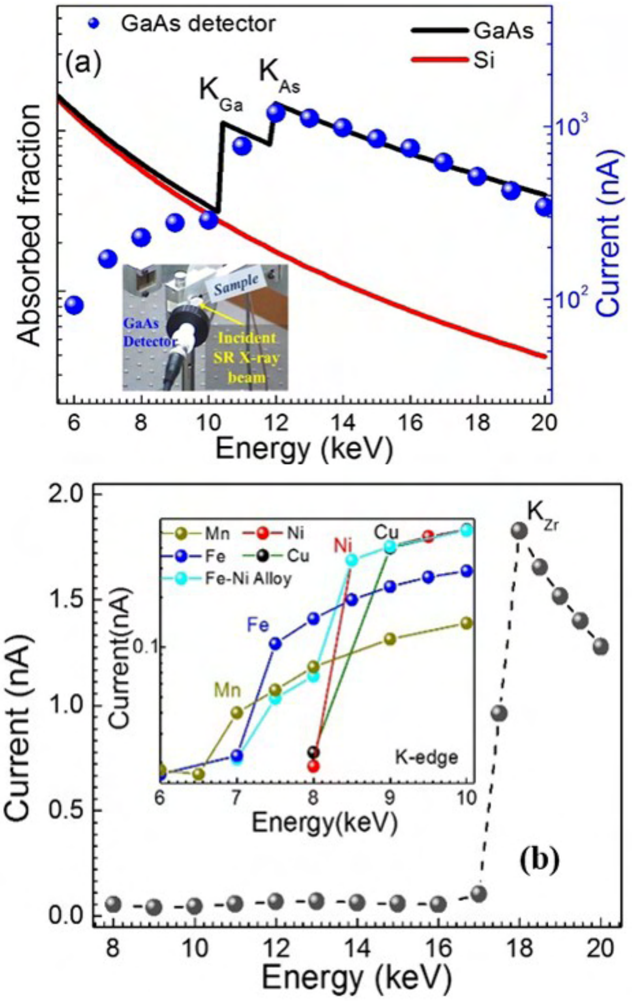

Fig L.5.1: (a) Theoretical X-ray absorption fraction curves of Si and GaAs along with experimental response of GaAs detector, and the inset shows experimental setup and (b) the characteristic X-ray edge of various elements like Mn, Fe, Ni, Cu, Zr and Fe-Ni alloy measured by indigenously developed GaAs detector.

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