L.9: Development of CsI(Tl) coupled GaAs γ-ray detector

The gamma-ray and x-ray detectors are widely used in synchrotron facilities, medical and space applications. The performance of such detectors mainly depends on the semiconductor material properties. Germanium is the most matured high-Z semiconductor and is widely preferred for such applications, but it has several limitations for room temperature operations. In the last few decades, III-V compound semiconductors like GaAs, CdTe, and GaN have emerged as promising materials for such applications due to their superior radiation tolerance as compared to their elemental semiconductor counterparts. Improvements in epitaxial growth and device processing of GaAs-based materials led to the development of room temperature high responsivity γ-ray and x-ray detectors. At RRCAT, we have developed prototype scintillator CsI(Tl) coupled GaAs PIN junction-based radiation detectors and used them for γ-ray detection at room temperature. In this detector configuration, initially, the gamma photon interacts with matter, by the most dominant interactions like photoelectric absorption, Compton scattering, and pair production. The high-energy photon interacts with the scintillator lattice resulting in the creation of electron-hole pairs. This is followed by the transport of the carriers to the luminescence center and consequently leading to radiative recombination (Figure L.9.1(a)). Thus, the single crystal scintillator facilitates the conversion of high-energy γ-photons into visible photons. These photons generate electrical signal in the GaAs PIN junction device, which is measured as a function of photon flux. In such detection application, one of the foremost requirements is the spectral overlap of the scintillator's emission band with the spectral photo-sensitivity of the detector material.

Here, we present the experimental results of the developed detector. Initially, the GaAs-based multilayer structures with reduced *p*-layer thickness are grown by metal-organic vapor phase epitaxy. Thereafter, several device processing steps viz. photolithography, surface passivation, electrode formation, etc. are employed for the development of semiconductor GaAs PIN detector. Subsequently, a CsI(Tl) single crystal scintillator is coupled to a GaAs PIN detector. The single-crystal scintillator was obtained from Technical Physics Division, BARC. The photograph of the completely fabricated scintillator-detector assembly mounted on indigenously designed special headers is shown in Figure L.9.1(b). Figure L.9.1(c) depicts emission spectra of the CsI (Tl) scintillator when excited with 266 nm diode pumped solid-state laser (DPSSL) along with the spectral response of the GaAs detector.

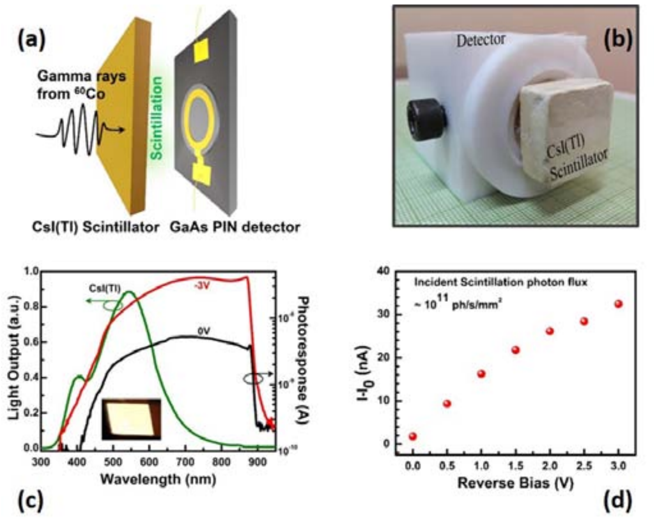

Fig. L.9.1: (a) Schematic diagram of the gamma ray detection process in combined Scintillator-GaAs semiconductor detector, (b) photograph of the scintillator-detector assembly, (c) spectral overlap of scintillator's emission profile with the photo-response of the GaAs detector, inset shows photograph of the scintillator emission upon interaction with high energy photons, and (d) response of the scintillator coupled GaAs detector upon exposure to 9 Curie Cobalt-60 source.

The scintillation spectrum of CsI(Tl) crystal peaks at 545 nm and photo-sensitivity of the detector is significant in the range of 450-870 nm. A significant spectral overlap of the scintillator's emission band with the spectral photo-sensitivity of the detector material confirms their suitability for the measurement of γ-radiation.

The scintillator-detector assembly was irradiated by γ-rays originating from a ^{60}Co source with an activity of 9 Curie in the Radiation Instrument Calibration Facility at RRCAT. For an incident flux of the order of 10^7 ph/s/mm^2 and CsI(Tl) crystal with scintillation yield of 65 ph/keV, 10^{11} visible photons of 2.27 eV are generated per second. These photons are then optically coupled to the GaAs detector, producing an output current of 32.44 nA at an applied reverse bias of 3 V. The bias-dependent gamma-ray response of the developed detector is shown in Figure L.9.1(d), where I_0 denotes the dark current. In conclusion, room temperature coupled scintillator-semiconductor detectors are ingeniously developed and used for the detection of γ-rays. The developed detector along with custom made preamplifier can also be used in γ-ray and x-ray spectroscopy and also for the detection of high-energy charged particles.

Reported by:
Payal Taya (payaltaya@rrcat.gov.in)