Metal Oxide Nanostructures & Composites for Ionizing Radiation Detection and Measurement

A Thesis submitted by

Ram Milan Sahani

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Department of Physics
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Chapter 9 Conclusion and Scope of Future Work

The work presented in the thesis mainly aimed to develop metal oxide-based sensor material and devices to detect and measure alpha, neutron and gamma radiations. Our objective was to create a cost-effective sensor such as ZnO:Ga nanorods, ZnO/Polystyrene composite for alpha radiation detection, ZnO-^{6}LiF/Polystyrene composite for neutron detection and TiO_2 nanorods for gamma radiation measurement. The significant developments of the thesis are as follows;

We developed a highly textured ZnO:Ga nanorod scintillator on FTO substrate using low-temperature hydrothermal method and investigated structural, optical and luminescence properties. A set-up was designed and developed for studying the alpha radiation response of ZnO:Ga nanorods. Alpha radiation measurements on the developed ZnO:Ga scintillator showed a good response to alpha radiation with a minimum detectable activity ~1.7 Bq with good repeatability and acceptable sample to sample response variations. These nanorods can be used to detect alpha particles in case of radioactive contamination and high-temperature application as these nanorods can sustain temperatures ~ 400 ^{0}C.

Another scintillator we worked on is a zinc oxide/polystyrene composite scintillator developed using a cost-effective solution mixing method. Optical, photoluminescence and radioluminescence properties of 5-50% w/w ZnO loaded in polystyrene investigated. Alpha radiation measurement on these composite shows increased different scintillation pulse height due to ZnO loading. These responses for 50% ZnO-loaded polystyrene show a maximum response to alpha radiation with MDA~0.4 Bq, thus measuring small activity. Alpha radiation response was found linear for al samples and optimized detector thickness for maximum response ~35 μm. The flexibility of polystyrene makes the composite scintillator suitable for fabrication in various sizes and shapes as per the requirement.

We also developed a composite scintillator to detect and measure thermal neutrons by adding a converter material ^{6}LiF (95% enriched ^{6}Li) in ZnO/Polystyrene composite. ZnO-^{6}LiF/polystyrene scintillator response to thermal neutron radiation shows high scintillation pulse height as compared with natural LiF due to increased (n, α) reaction. ZnO-LiF (1:1)/Polystyrene composite scintillator shows the maximum response to thermal neutrons. The net counts obtained at different counting times are linear when plotted vs. measured dose by neutron dosimeter for the same time duration. The sensitivity of the scintillator is obtained as 206 counts/μSv. The net count variation with source to detector distance has a nearly similar trend as the neutron dosimeter. The developed ZnO-^{6}LiF/Polystyrene composite scintillator can be used as a promising sensor material for the detection of thermal neutrons.

TiO_2 nanorods developed using the hydrothermal method over FTO substrate. Structural and Optical properties investigated showed the c-axis oriented nanorods and of rutile phase. Gamma radiation measurement was performed by analyzing the change in I-V characteristics. Leakage current increases linearly with increasing gamma dose from 375 to 3000 mGy. This study suggests that TiO_2 nanorods can be used for gamma radiation measurement applications

The above work on developing scintillator/dosimeter sensor material showed a good response to different ionizing radiations. Further scopes of work in ZnO nanorod detector are preparation of nanorods of different diameters/length and to study the variation of detection efficiency. It will be interesting to grow $^{10}B_2O_3$ nanorods over ZnO:Ga nanorods to explore neutron detection using n,α reaction. Also imaging applications of ZnO:Ga nanorods detector can be explored by coupling the ZnO:Ga detector with position sensitive PMT. Enhancement of detection efficiency of ZnO/PS composite by altering the size of ZnO particles or doping can be another area of work. ^{10}B based ZnO-$^{10}B_2O_3$/PS detectors can be explored for neutron detection as cross-section of ^{10}B is high as compared to ^{6}Li and limited availability of ^{6}LiF. Effect of TiO_2 nanorod's diameter on response to gamma radiation can be interesting area to explore.