World Academy of Science, Engineering and Technology
International Journal of Materials and Metallurgical Engineering
Vol:12, No:12, 2018

Lead Chalcogenide Quantum Dots for Use in Radiation Detectors

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Abstract : Lead chalcogenide-based (PbS, PbSe, and PbTe) quantum dots (QDs) were synthesized for the purpose of implementing them in radiation detectors. Pb based materials have long been of interest for gamma and x-ray detection due to its high absorption cross section and Z number. The emphasis of the studies was on exploring how to control charge carrier transport within thin films containing the QDs. The properties of QDs itself can be altered by changing the size, shape, composition, and surface chemistry of the dots, while the properties of carrier transport within QD films are affected by post-deposition treatment of the films. The QDs were synthesized using colloidal synthesis methods and films were grown using multiple film coating techniques, such as spin coating and doctor blading. Current QD radiation detectors are based on the QD acting as fluorophores in a scintillation detector. Here the viability of using QDs in solid-state radiation detectors, for which the incident detectable radiation causes a direct electronic response within the QD film is explored. Achieving high sensitivity and accurate energy quantification in QD radiation detectors requires a large carrier mobility and diffusion lengths in the QD films. Pb chalcogenides-based QDs were synthesized with both traditional oleic acid ligands as well as more weakly binding oleylamine ligands, allowing for in-solution ligand exchange making the deposition of thick films in a single step possible. The PbS and PbSe QDs showed better air stability than PbTe. After precipitation the QDs passivated with the shorter ligand are dispersed in 2,6-difloupyridine resulting in colloidal solutions with concentrations anywhere from 10-100 mg/mL for film processing applications, More concentrated colloidal solutions produce thicker films during spin-coating, while an extremely concentrated solution (100 mg/mL) can be used to produce several micrometer thick films using doctor blading. Film thicknesses of micrometer or even millimeters are needed for radiation detector for high-energy gamma rays, which are of interest for astrophysics or nuclear security, in order to provide sufficient stopping power.

Keywords : colloidal synthesis, lead chalcogenide, radiation detectors, quantum dots
Conference Title : ICQD 2018 : International Conference on Quantum Dots
Conference Location : Paris, France
Conference Dates : December 27-28, 2018