

Abstract

Low-dimensional transition metal di-chalcogenides (TMDCs) consisting tri-atomic building blocks (X-M-X, M = Mo, W and X = S, Se) have drawn immense attention due to their thickness dependent tunable direct band gap energy. Indirect to direct band gap transition along with high absorption coefficient (exceeding 10^2 cm^{-1}) and high surface area of two dimensional TMDCs are very attractive for optical studies as well as multifunctional device applications. Recently, all-inorganic lead halide perovskite brings a new dimension in optoelectronics because of its tunable optical properties and better stability compared to organic-inorganic hybrid perovskite. However, there is still a lack of their large scale production methods, detail study of their exotic properties and suitable application strategies.

In this thesis, TMDC nanostructures growth by both top-down and bottom-up methods and their exotic optical properties are reported. As-synthesized TMDC nanostructure are employed in fabrication of optoelectronic device such as photodetector, light emitting diode (LED) and energy storage device (flexible solid state supercapacitor). Inorganic perovskite materials (CsPbX_3) of different morphologies and compositions are synthesized. Morphology and composition depended tunable optical properties and stability under ambient condition are studied to fabricate solar cell and photoconductor devices.

Low dimensional MoS_2 nanosheets and nanocrystals are synthesized by hydrothermal as well as liquid phase exfoliation process. At hydrothermal condition, sodium molybdate and MSCN (M= K, Na, NH_4) are used as precursors. Here, SCN^- acts as sulphur source and reductant for the reduction of Mo^{+6} to Mo^{+4} . As-synthesized MoS_2 shows broad absorption spectra in the visible region with direct band gap of 1.82 eV. Further, MoS_2 -Si heterojunction for visible light detection and MoS_2 and reduced graphene oxide hybrid for visible light induced photocatalysis are demonstrated. The fabricated photodetector shows $\sim 45 \text{ mA/W}$ responsivity at $\sim 630 \text{ nm}$ and broad photoresponse at -2 V bias. MoS_2 is also exfoliated by ethylenediamine, a chelating agent assisted liquid phase exfoliation. The method enables the formation of micrometer size MoS_2 flakes in organic solvent.

Next, lithium halides (LiX , X=Cl, Br, I) are used as a lithiating agent to exfoliate mono to few layers microns sized of WS_2 nanosheets in gram scale, replacing pyrophoric, and toxic n-butyllithium. The novelty of this method is the formation of semiconducting 2D WS_2 which is rare using n-butyllithium assisted exfoliation. Tunable optical properties of WS_2

nanosheets are studied with the variation of size. Fabricated WS₂/n-Si heterojunction photodetector shows maximum responsivity of 1.4 A/W at 635 nm and a broad photoresponse curve at bias of -1V. In continuation, WS₂ nanosheets are further fragmented to nanocrystals by prolonged sonication. A strong quantum confinement is observed when the sizes of WS₂ reach below 5 nm. Finally, LED device is fabricated using WS₂ QDs embedded in PEDOT PSS: ZnO heterojunction. The device shows a broadband white light emission from 400-800 nm with characteristic emission of WS₂ quantum dots and defect of ZnO.

Finally, inorganic perovskite (CsPbX₃) nanocrystals are synthesized by the hot injection method in olive oil. Then, optical properties and morphological evolution at different temperatures are studied. Interestingly, long nanorods are self assembled from nanocrystals at 150°C at ambient. CTAB is used as Br source for anion exchange of CsPbI₃ to obtain CsPbBr₃ nanowire (NW) at 60°C, CsPbBr₃ nanosheets at 80°C and degraded CsPbBr₃ nanocrystals at 100°C. CsPbI₃ NCs and CsPbI₃ NWs are employed to fabricate solar cell devices in ITO/PEDOT-PSS/CsPbI₃/BCP-C60/Al configuration to achieve an efficiency of 7.3% under 45-55% humid condition. A photoconductor device on top of ITO is fabricated using as-synthesized CsPbBr₃ NW by CTAB assisted anion exchange method in ITO/CsPbBr₃ NWs/Spiro-OMeTD/Al configuration. It shows a high responsivity of 0.28A/W at 520 nm at 1 V bias.