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Structural, optical and magnetic properties of SnS_2 nanoparticles and photo response characteristics of p-Si/n-SnS_2 heterojunction diode

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ABSTRACT

As an emanating layered metal dichalcogenides (LMDs), tin disulfide (SnS_2) has immense potentials in next generation nanodevices considering their facile synthesis and versatile attributes. Here, we describe the hydrothermal synthesis of SnS_2 nanoparticles at different temperatures and growth times and discussed its structural, optical and magnetic characteristics in detail. The SnS_2 nanoparticles displayed growth time dependent structural, optical and magnetic properties. The structural analysis displayed hexagonal phase of SnS_2 nanoparticles whose thickness increase with duration of growth. The vibrational modes of SnS_2 nanoparticles in Raman spectra exhibited an increase in intensity with growth time, indicating an increased layer thickness with growth time. In addition, the optical properties were also affected by the growth time. Moreover, excitation dependent photoluminescence emission from these nanoparticles is observed, which is attributed to the polydispersity of nanoparticles. The realisation of room temperature ferromagnetism makes it a promising material for spintronic applications. Photocurrent properties of the spin coated n-SnS_2 on p-silicon were analysed by studying J-V relationships. Tunable optical, electrical and magnetic properties of SnS_2 layers could capacitate a great deal of freedom in modelling atomically thin optoelectronic and spintronic devices.

1. Introduction

The layered metal dichalcogenides (LMDs), consisting of single layers held together by weak van der Waals interactions represent a prominent group of two dimensional (2D) materials beyond graphene. Being the first discovered 2D layered material, graphene lacks a band gap, limiting its applications in optoelectronic devices [1]. LMDs have emanated as potential alternatives to graphene, satisfying the necessity of both semiconductivity and dimensionality [2,3]. The size and shape of LMDs play a major role in altering their electrical, optical, magnetic and catalytical attributes making them suitable in nanoelectronics and optoelectronic devices. Tin disulfide (SnS_2) is an emerging layered semiconductor among the LMDs with bulk band gap of 2.35 eV [4,5]. SnS_2 has gained interest since its constituent elements Sn and S are abundant in nature, relatively cheap and eco-friendly [6]. Both bulk and single layer SnS_2 possess an indirect band gap unlike other LMDs like WS_2 and MoS_2, where the bulk indirect band gap shifts to direct band gap when the thickness is reduced to single layer [7,8]. Being an n-type semiconductor, SnS_2 possess a layered CdI_2-type structure, where hexagonally ordered plane of Sn atoms are held between two hexagonally ordered planes of S atoms, and the adjacent sulphur layers are bonded through weak van der Waals interactions, facilitating easy isolation of layers through chemical or mechanical exfoliation [9,10]. SnS_2 serves as a potential candidate for applications in photodetectors, photocatalysts, solar cells, light emitting diodes, lithium/sodium ion batteries, field effect transistors and sensors etc [11–16].

SnS_2 is one of the most important sulfide compounds of tin such as SnS, Sn_2S_3 with more than 70 polytypes which are distinct from each other by stacking arrangements of the individual layers [17,18]. The most common polytype is 2H– SnS_2, whose structure is identical to that of 1T-MoS_2 in which the metal atom is octahedrally coordinated by sulphur atoms [19]. 2H polytype of bulk SnS_2 is formed by stacking individual layers of 2H– SnS_2 exactly above one another via weak van der Waals interactions. A clear difference between 2H and 4H-SnS_2 can be obtained from Raman spectroscopy in which 2H-SnS_2 shows only two prominent modes in contrast to 4H-SnS_2 where several other modes are present [20].

Due to rising curiosity for tin sulphides, its junction characteristics and response towards different illumination conditions are considered as an interesting research field for the fabrication of electronic and photovoltaic devices. Juarez *et al* [21] fabricated heterojunctions based on Sn-S compounds through PECVD process which shows a small

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