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Optical Along with Magnetic Properties of Doped Nano-Structured Mos_2 Nano-Films by Spin Coating

Rashmi Singh[1],*

Abstract

The supernatant containing 2D nano-flakes of Molybdenum di-sulphide (MoS_2) are synthesized and collected using wet chemical synthesis process. The dispersed MoS_2 nano-flakes solution is having strong absorbance values at 627 nm and 690 nm conforming to an energy band gap BG of 1.79 eV and 1.98 eV. Thereafter, MoS_2 thin films with and without magnetic doping (cobalt) are deposited on n type silicon by spin coating technique. These samples are placed in the quartz boat then and annealed in a thermal furnace at 260°C for 40 min in Nitrogen gas environment. The AFM imaging of these samples revealed average lateral dimensions of nano-flakes to be from 100 to 200 nm. The magnetization curves with respect to the applied field for both samples are studied using Vibrating Sample Magnetometer (VSM). The VSM measurements, conducted at room temperature, verified the presence of the magnetic property that was introduced, as well as the hysteresis loop, in the thin films of Cobalt-doped MoS_2.

Keywords: MoS_2, wet chemical synthesis, thin film deposition, spin coating, optical properties, magnetic properties

INTRODUCTION

Molybdenum di-chalcogenides are semiconductors that have a wide range of uses in several fields, such as solar energy-based cells, rechargeable batteries, gas and light-detecting sensors, surface catalytic devices, and many more [1- 7]. Among these di-chalcogenides, MoS_2 Molybdenum di-sulphides are materials of interest as they exhibit very interesting properties. It is stratified, with van der Waals forces existing between layers that are one above the other [8, 9]. In this layered structure, molybdenum monolayers are placed in-between sulphur monolayers. MoS_2 exists in two phases, determined by the crystal's structure and the configurations of the sulphur atoms in each layer [10]. The bulky 1-T metastable phase is metallic in nature, but the bulky 2-H phase is a n type indirect band-gap semiconductor. [11- 13]. Variations of such features make MoS_2 flexible, with strong charge mobility and high optical transmittance, making it suitable for optoelectronics devices. $MoS_{2,}$ being a transition metal dichalcogenides is extremely hydrophobic and it also exhibit extremely least friction while growing 2-D nanostructures. Many decades have been spent to explore the production as well as the application of complex form of nanostructured molybdenum disulphide like nano-particles and nano-flakes. Owing to the strong chemical activity of sulphur that is an oxygen family element, as well as the transition character of molybdenum, the base element; it has numerous desirable properties. The deep knowledge of the mechanisms behind the number of properties along with catalytic activity of nanostructured MoS_2, as well as the progressions involved in its nucleation, growth, structuring, has progressed pointedly. MoS_2 nanostructures are a bio-compatible with least-toxicity, besides tremendously stable substitute to hefty toxic metals having a high binding affinity. Introducing magnetism in two-dimensional 2-d materials like MoS_2 is contributing novel dimensions in the

***Author for Correspondence**
Rashmi Singh

[1]Assistant Professor, Department. of Physics, Institute of Applied Sciences & Humanities IAH, GLA University, Mathura, Uttar Pradesh, India

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magnetic materials domain. A diamagnetism nature is exhibited by MoS_2 usually but one may observe ferromagnetic nature in other forms of MoS_2 2-d nanomaterials like thin films, nano sheets, nano flakes etc. [14, 15]. Such kind of magnetism in 2-d MoS_2 is explained on the basis of various defects that may include vacancies, structural deformities or reconstruction of structures. In order to produce MoS_2 films, there are a few different approaches. The limited scalability and cost criteria that lead to limitations in industry applications are the primary obstacles that must be overcome in order to generate uniform two-dimensional MoS_2. For the purpose of this study, a low-cost and effective wet chemical synthesis is utilised to create two-dimensional nano-flakes of MoS_2. Subsequently, thin films are obtained by the spin coat process. After that, a variety of characterization techniques are utilised in order to investigate the optical, morphological, and magnetic properties [16, 17].

EXPERIMENTAL DETAILS

One gram MoS_2 powder was added to 0.8 mL of IPA and then ground for at least 02 hours. After grinding for 02 hours, thermal furnace was used to dry the mixture under vacuum for 02 hours at 60°C. At that time, it was collected to re-disperse into an IPA 10 mL solvent to make a solution. The dispersed solution was then ultra-sonicated for 02 hours. After that, this solution was centrifuged at 4000 rpm for 01 hour. The supernatant was collected together as it contains 2D nano-flakes of MoS_2. The n type silicon substrate was cleaned by piranha solution such as to make it hydrophilic and then by DI water. Then the substrate is dried on the hot plate for 15 min. The dried substrate is covered with the supernatant solution and left for 01 min. Then it is spin coated at 1000 rpm for 01 min. This process is repeated 03 times. This spin coated substrates are again dried for 15 min on hot plate. For magnetic doped films, 02 drops of Cobalt oxide nanoparticles dispersed in ethanol were mixed in MoS_2 nano-flakes dispersed in IPA and ultra- sonicated for 01 hour. Then the whole process of spin coating was carried out. The S1 is the sample name for the undoped MoS_2 thin films and S2 is the sample name for magnetic doped MoS_2 thin film. These samples were placed in the quartz boat and annealed in a thermal furnace at 260°C for 40 min in Nitrogen gas environment. The furnace was then allowed to slowly and undisturbed cool down up to RT room temperature.

RESULTS AND DISCUSSION

Optical Property

The supernatant having dispersed MoS_2 nano-flakes after centrifugation looked like transparent dark greenish in colour, as shown in the inset of Figure 1. These dispersed nano-flakes stayed stable for several weeks. The optical related characteristics of these MoS_2 nano-flakes were studied and explained by measurement of UV-visible absorption spectra using U V Spectroscopy (Shimadzu U V-3600 Plus). The optical absorption spectra were recorded.

Figure 1. Dispersed MoS_2 nano-flakes.

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In the spectrum in Figure 2, the dispersed MoS_2 nano-flakes solution has strong absorbance values at 627 nm and 690 nm agreeing to an energy band gap BG of 1.79 eV and 1.98 eV. These two absorptions at 627 nm in addition to 690 nm are accredited to B and also A excitonic peaks correspondingly. It rises due to the splitting of energy from valence band VB spin-orbital (S-O) coupling in two dimensional MoS_2 with big lateral size [18, 19]. Two peaks at 364 nm and 462 nm were observed which may be ascribed because of the absorption from MoS_2 nano-flakes with small lateral dimensions [20].

Band-Gap BG Energy $E = h * C / \lambda = 1.8$ eV

here, h = Planck's const. = 6.6×10^{-34} J-s

c = velocity of light = 3.0×10^{8} m/s

λ = Cut-off wave length = 690×10^{-9} m

here 1 eV = 1.6×10^{-19} J (conversion factor)

Morphological Study By AFM

Figure 3 displays the AFM picture of MoS_2 nano-flakes deposited by spin coat on an n type silicon substrate. Average lateral dimensions of nano-flakes were observed to be from 100 to 200 nm. A step (height) of ∼20 nm was seen for nano-flakes of Sample S1 while a step of ~5 nm was seen for nano-flakes of Sample S2. There were some a number of nano-flakes deposited on the substrates [21].

Magnetic Property By VSM

The magnetization curves with respect to the applied field for Samples S1 and S2 are displayed in the Figure 4. Sample S2 demonstrates a hysteresis loop with a maximum saturation magnetization Ms of 11.2 emu/cc and Sample S1 demonstrates a hysteresis loop with a maximum Ms saturation magnetization of 3 emu/cc on a n-Si substrate. These saturation magnetizations were attained on applying a field of 10000 Oe where 1Oe = 10^{-4} Tesla [22, 23]. The shapes of the hysteresis loop for both Samples S1 MoS_2 thin film and Sample S2 magnetic doped MoS_2 thin film, spin coated on n - Si substrate is similar. Here, these results illustrate the nano-structured form of the MoS_2 can reveal poor and weak magnetism [24, 25]. It is important to note that the magnetism that originates from a variety of structural flaws is responsible for this magnetic performance in the undoped MoS_2 sample S1. In most cases, the strength of this type of magnetism is insignificant, and it is also temperature independent. In addition, when the structure is reassembled, this type of magnetism becomes unstable. [26]. Due to the fact that the carriers were not found to be interacting with the local moment, the magnetism in the material was not discovered to be of any value in spintronics. As a result, the magnetism in the undoped film cannot be controlled [27-29].

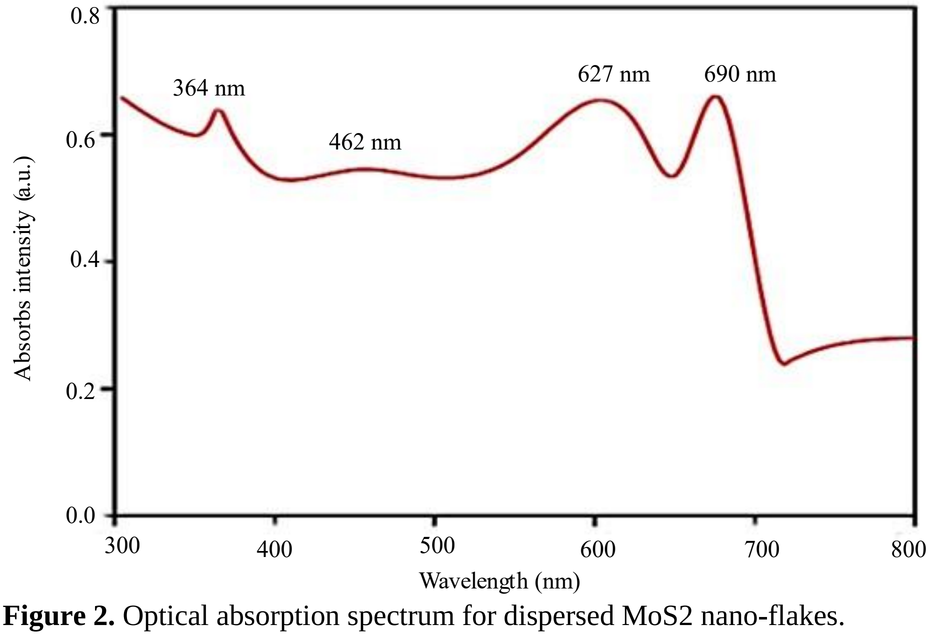

Figure 2. Optical absorption spectrum for dispersed MoS2 nano-flakes.

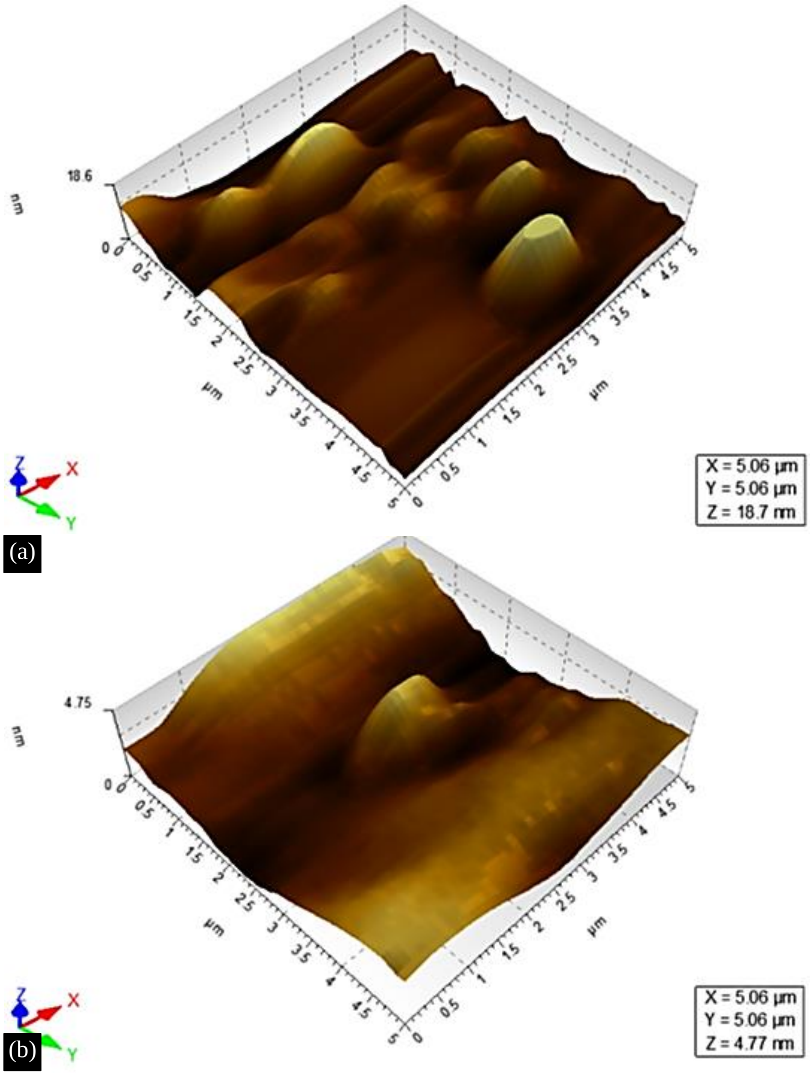

Figure 3. AFM of MoS_2 thin films on n-Si substrate (a) Sample S 1 (b) Sample S 2.

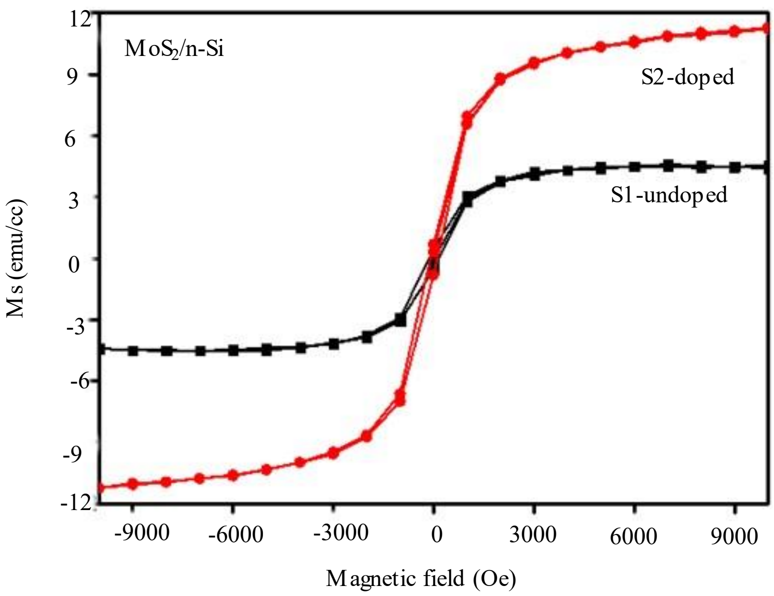

Figure 4. VSM of MoS_2 thin films on n-Si substrate (a) Sample S1(b) Sample S2.

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CONCLUSION

MoS_2 thin films and doped with magnetic material are deposited using a wet chemical synthesis. First of all, 2D nano-flakes of MoS_2 were made by using exfoliation method. Thereafter, spin coating method was used to deposit thin films of solution having MoS_2 nano-flakes. Different characterizations were done to confirm the deposition. Then optical and magnetic properties were also studied. AFM images of both the samples confirm the deposited film consisting of nano-flakes of MoS_2. The hysteresis curve showing magnetization with respect to the applied field confirms the presence of ferromagnetism in the magnetic doped thin films of MoS_2 nano-flakes.

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