Synthesis and Fabrication of MoS2 QDS Thin Films for Novel Optoelectronic Devices with Cost-Efficient Technique

Maymunah A. Alwehaibi, Princess Nourah bint Abdulrahman University, +966580560676, 439000991@pnu.edu.sa
Yasmeen A. Khoja, Princess Nourah bint Abdulrahman University, +966500027898, 439000892@pnu.edu.sa
Reem S. Alghamdi, Princess Nourah bint Abdulrahman University, +96657459053, 439004167@pnu.edu.sa
Fahdah A. Alsuhaibani, Princess Nourah bint Abdulrahman University, +966535388926, 439004478@pnu.edu.sa
Norah M. Alwadi, Princess Nourah bint Abdulrahman University, +966566616128, nmalwadai@pnu.edu.sa
Manar S. Alshatwi, Princess Nourah bint Abdulrahman University, +9665381226268, msalshatwi@pnu.edu.sa

Overview

The impact of the COVID-19 pandemic on the semiconductors manufacturing industry leads to a necessity for typical research work. For this reason, our work chose molybdenum disulfide (MoS_2), an organic semiconductor with high neutral abundance, low cost, high carrier mobility, unique optical properties, fixable bandgap, and very low toxicity that make MoS_2 a very safe and sustainable material. This work successfully synthesizes MoS_2 quantum dots (MoS_2 QDs) by liquid exfoliation to fabricate MoS_2 QDs thin film by spray technique. The extract MoS_2 QDs were characterized using scanning electron microscopy (SEM), Fluorescence emission spectra (FES), UV-VIS spectroscopy, and Energy-dispersive X-Ray (EDX). The SEM images have shown the MoS_2 QDs with sizes ranging from (~ 4-11 nm), a spherical shape with a homogenous distribution. With strong UV absorption and bandgap=4.49eV corresponding to UV-VIIS spectroscopy result. Moreover, the MoS_2 QDs show a fluorescence spectrum under excitation of 340 nm. The MoS_2 QDs are spray-coated onto a substrate to fabricate thin film. The Photoluminescence (PL) results show an expansion in emission with high sensitivity covering the whole visible light region (380-700 nm), which makes MoS_2 QDs thin films promising for optoelectronic devices such as solar cells and photodetectors.

Methods

1. **Synthesis of n-MoS2 QDs**
   We successfully synthesized n-MoS_2 QDs through the liquid phase exfoliation method, as shown in Fig.1

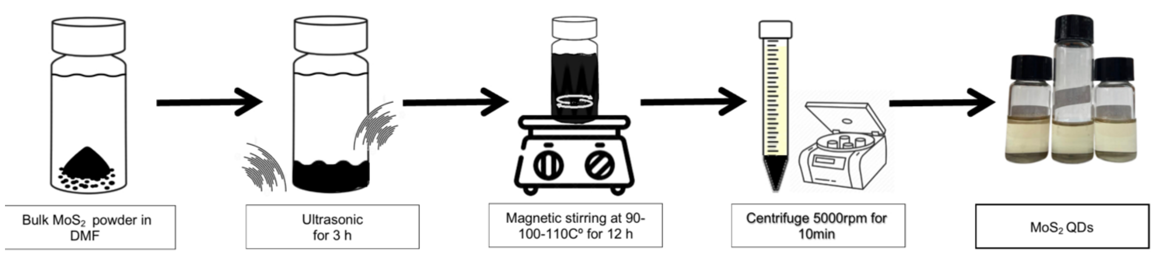

Fig. 1 Process of synthesizing n-MoS_2 QDs

2. **Thin film deposition**
   The device fabrication was achieved, and the Fabrication process illustrate in details in Fig.2

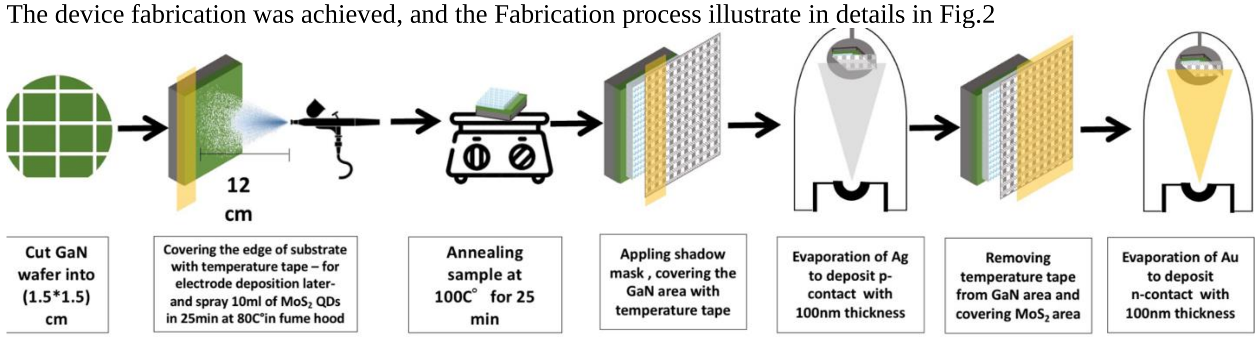

Figure.2 Process of p-GaN/N-MoS_2 device fabrication

Results

- The SEM images have shown the MoS_2 QDs with sizes ranging from (~ 4-11 nm), a spherical shape with a homogenous distribution shown in fig.3

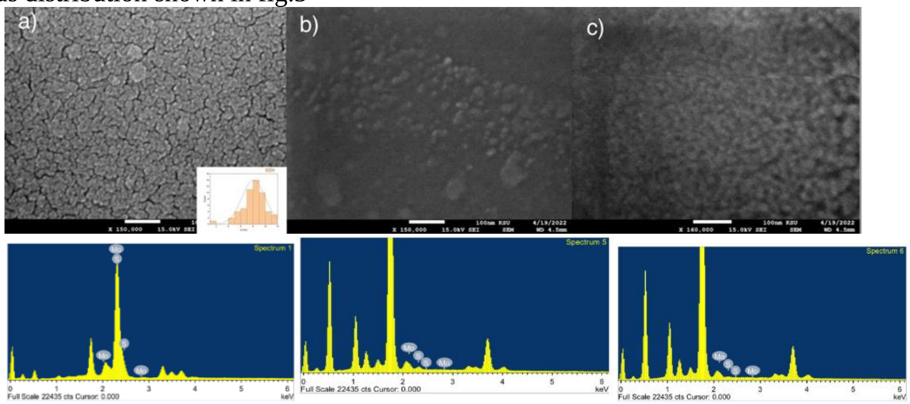

Figure.3 SEM image and EDX result of prepaed sample at (a) 90 ºC (b) 100 ºC (C) 110 ºC

- Strong UV absorption and bandgap 4.49eV corresponding to UV- VIS spectroscopy result as shown in Fig. 4a. Moreover, the MoS_2 QDs show a fluorescence spectrum under excitation of 340 nm as shown in Fig. 4b and under UV light in Fig. 4c. while the PL peak of n-MoS_2 QDs laying in the range of nm the prepared sample was excited under different wavelengths $\lambda_{excitation}$ from 270nm to 450nm where maximum peak found at 408 nm corresponding to $\lambda_{excitation}$ = 350nm as shown in Fig. 4d.

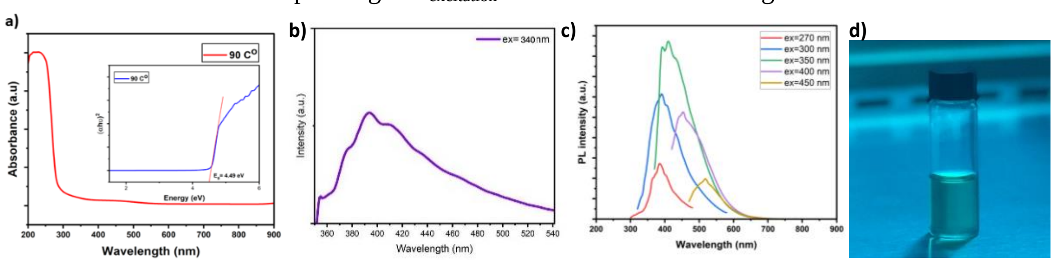

Figure.4 (a) UV-Vis absorption and Tauc plot of n-MoS2 QDs prepared at 90 ºC (b) Fluorescence spectra of n- MoS_2 QDs under $\lambda_{excitation}$ = 340nm (C) Photoluminescence spectra of n- MoS_2 QDs under different $\lambda_{excitation}$ ºC (d) n-MoS_2 QDs under UV lamps

- The result shows a promising thin film for optoelectronic devices. For this reason, the p-GaN/n-MoS_2 QDs photodetector was fabricated and characterized. The PL results in Fig. 5a show expansion in the emission spectrum to cover the visible region, while the I-V characteristic in Fig. 5b shows photodiode behavior.

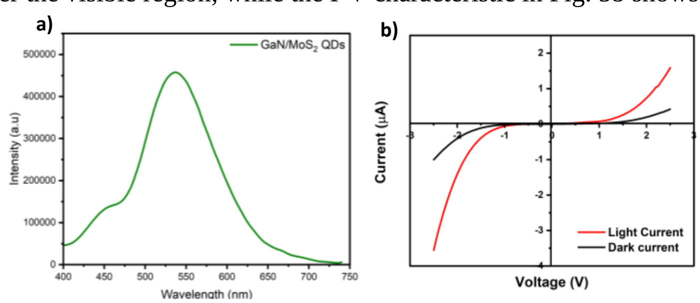

Figure.5 (a) p-GaN N-MoS_2 QDs with the maximum intensity at the peak of 537nm (b) Current as a function of voltage for p-GaN/N-MoS_2 heterojunction photodetector

Conclusions

This work successfully synthesis n-MoS_2 QDs from bulk MoS_2 powder by liquid phase exfoliation in DMF. The samples were prepared at various temperatures where 90C exhibited the best result with strong quantum confinement, Eg4.49 eV, expanding absorbance, and fluorescence behavior at $\lambda_{excitation}$ = 340nm. p-GaN/n-MoS_2 QDs photodetector was fabricated and characterized at [-2.5-2.5]; the device showed high performance with a responsivity of 7.069 mA/W and detectivity of 1.24×10^{10} Jones at visible light region.