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Fabrication of MoS_2 layers on free-standing GaN for heterojunction photoresponsive device applications

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Abstract

Molybdenum sulfide (MoS_2) layers and gallium nitride (GaN) are well suited for heterojunction device fabrication due to their less lattice mismatch. In this study, we report on the synthesis of MoS_2 layers on free-standing GaN for fabrication of a heterojunction photoresponsive device. Rectifying diode characteristic and photovoltaic action with vertical current flow were obtained in the heterostructure. In the MoS_2-GaN heterojunction a suitable interface potential was observed by the photoelectron spectroscopy analysis. Our study revealed that the MoS_2-GaN heterojunction can be suitable for various optoelectronic devices with stable performance.

1. Introduction

Lattice mismatch of GaN and MoS_2 is only 0.8%, hence both these material can be used as substrate for growth on one another and could be used for development of novel heterostructure.[1-4] In the absence of dangling bond at the interface in layered heterostructures it provides ultra-fast charge transfer and thereby leading to fabrication of efficient devices.[5,6] The heterostructure of MoS_2 and GaN provides an opportunity to develop photoresponsive device beyond the ultraviolet (UV) wavelength.[7] The MoS_2-GaN heterojunction is practically applicable technology for optoelectronics devices such as photovoltaic devices, photodiode, and photocatalyst applications with broadband photoresponsivity.[8-10]

Previously, MoS_2 layers has been synthesized on various substrates by the chemical vapour deposition (CVD) technique.[11, 12] In this work, we studied the deposition of MoS_2 continuous film on GaN by sulfurization process of metal oxide precursor. The obtained MoS_2 layers on GaN surface was characterized and the current-voltage properties were analyzed.

2. Results and Discussions

Fig. 1a shows the ball and stick diagram of MoS_2 layers atop of GaN. Each molybdenum (Mo) atom is surrounded by six sulfur (S) atom forming a trigonal prismatic coordination sphere. The bulk MoS_2 consist of several layers like graphite, where the S-Mo-S configuration forms a monolayer. The GaN bulk single crystal has a wurtzite structure with one Ga atom has three nearest neighbors connected by a covalent bond.

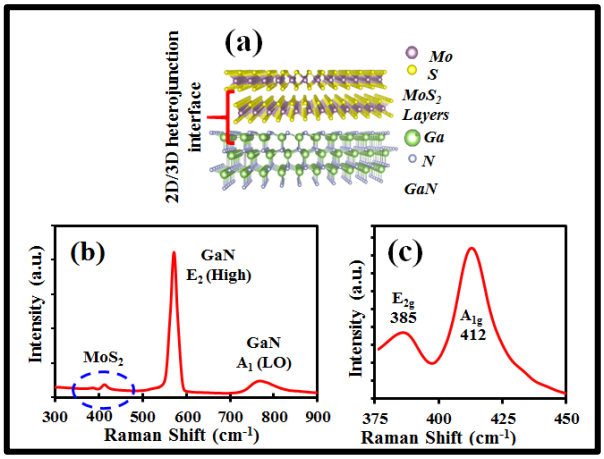

Fig 1. (a) Ball and stick diagram of MoS_2 and GaN (b) Raman spectra of MoS_2/GaN heterostructure (c) Raman spectra corresponding to MoS_2 peaks

The in-place lattice mismatch of MoS_2 and GaN is only 0.8%, signifying the possibility of epitaxial heterostructure growth. We carried out Raman spectroscopic analysis of the synthesized MoS_2 layers on GaN. Fig. 1b shows a Raman spectrum for the MoS_2-GaN heterostructure. The peaks corresponding to E_2(High) and A_1(LO) of GaN layer were observed at 570.2 and 749.2 cm^{-1}, respectively. Additional small intensity peaks were observed at lower wavenumber as shown in the fig. corresponding to the MoS_2 layer. Fig. 1c shows the E_{2g} and A_{1g} peaks of MoS_2 layer at 385 and 412 cm^{-1}, respectively.[43] The spectroscopy analysis confirmed the formation of MoS_2 layers on GaN and their heterostructure.

The heterostructure of MoS_2 and GaN was investigated by fabricating a two-terminal diode structure under dark and

monochromatic light illumination. Fig. 2a, 2b shows the J-V characteristics without and with light, respectively, and fig. 2c shows J-V characteristics under dark and illumination for a smaller voltage and current range, presenting the photovoltaic action on MoS_2 layers and GaN heterojunction device. The short circuit current (J_{sc}) and open circuit voltage (V_{oc}) were obtained as 0.35 mV and 0.22 μA/cm^2, respectively for the device under monochromatic light. Further, studies on the interface and heterojunction properties were under process to achieve higher device performance.

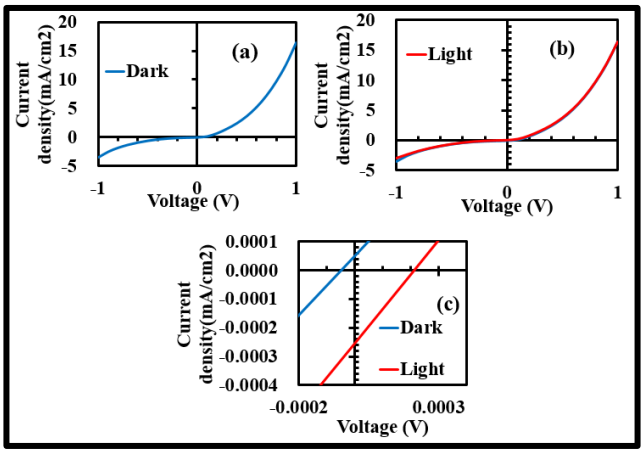

Fig 2. (a) J-V characteristics without light illumination presenting the rectification behavior (b) J-V characteristics with and without light illumination (c) J-V characteristics with and without light illumination for a smaller voltage range presenting the photovoltaic action.

3. Conclusion

In conclusion, we have demonstrated the fabrication of MoS_2 layers on free-standing GaN by the sulfurization technique for fabrication of a heterojunction photoresponsive device. Raman analysis showed the E_{2g} and A_{1g} peaks at 385 and 412 cm^{-1}, respectively confirming formation of MoS_2 layers. J-V analysis showed the rectifying diode characteristics and a photovoltaic action with monochromatic light illumination.

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