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Full Length Article

Near-infrared photodetector achieved by chemically-exfoliated multilayered MoS_2 flakes

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ABSTRACT

A near-infrared (NIR) photodetector built from chemically exfoliated multilayer MoS_2 films was investigated. Devices that are photoresponsive to wavelengths up to 1550 nm were fabricated using 25-nm-thick MoS_2 films. To the best of our knowledge, this is the first time such a detector was produced using chemical exfoliation. As the thickness was increased to 25 nm, the MoS_2 flakes formed a nearly or fully continuous film with a 2H-dominant phase, and also exhibited enhanced NIR absorption up to 1550 nm. We conjecture that the defects formed during chemical exfoliation affect the intrinsic bandgap of MoS_2, extending its spectral absorption range into the NIR range. Moreover, the responsivity of the device was enhanced by introducing plasmonic Ag nanocrystals.

1. Introduction

Photodetectors that can change light into electrical signals are important components various technologies, such as those used in biomedical imaging, optical communication, video imaging, motion monitoring, night vision, and remote sensing [1,2]. Currently, Si-based photodetectors capable of excellent detection performance are used widely and commercially, but their detection range is limited to wavelengths shorter than 1100 nm due to the intrinsic electronic bandgap of Si. Thus, semiconductor materials based on InGaAs, HgCdTe, InSb, and their related heterostructures have been used for detecting near-infrared (NIR) light with wavelengths longer than 1100 nm [3,4]. However, these inorganic semiconductor-based photodetectors usually suffer from severe drawbacks, including the necessity to use thicker materials, expensive fabrication methods, the need for strictly controlled fabrication conditions, and rigorous operational demands. These materials in bulk form are also very fragile, making such detectors unsuitable for use in novel devices requiring properties such as flexibility, transparency, and bendability. Therefore, there is an increasing demand for new materials that can support high absorption efficiencies at broader wavelengths, have high flexibility and transparency, and can be processed using cost-effective techniques with simplified device geometries to overcome the limitations of photodetectors based on bulk Si [1–4].

Two-dimensional (2D) materials are newly emerging because of their attractive optical, electrical and physical properties such as good flexibility, strong light-matter interactions, high transparency and simple processablility [1]. They remedy some of the drawbacks of current Si-based technologies and are promising for development of high-performance photodetectors [5–12]. In particular, among 2D materials, molybdenum disulfide (MoS_2) is a layered transition-metal dichalcogenide crystal, which is composed of atomic layers vertically stacked by van der Waals forces. Each layer consists of S-Mo-S′ atomic planes that are bounded strongly in-plane [1,2]. The optical and electrical properties of MoS_2-layered semiconductors are strongly affected by the number of layers due to out-of-plane quantum confinement effects and changes in symmetry [1,2]. Another quantum confinement effect is increased absorption efficiency, which results from strongly bound excitons owing to reduced thickness of MoS_2 film [5,6,13–15]. MoS_2 appears with two distinct symmetries of 2H and 1T phases with differing electronic structures. In the semiconducting 2H phase, each Mo has trigonal prismatic coordination with neighboring S atoms, while in the metallic 1T phase, each Mo octahedrally coordinates with S atoms [16–18].

Recently, multiple methods have been developed for synthesizing layered MoS_2 materials, such as chemical exfoliation, chemical vapor deposition and van der Waals epitaxial growth [1,2]. To fabricate NIR photodetectors, we synthesized layered MoS_2 films with a few layers of various thicknesses via chemical exfoliation [19–21]. In a typical process, the interlayers of a bulk-layered material are intercalated with small ions such as lithium, which

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