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Preparation And Study of Mos_2 Optoelectronic Devices

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ABSTRACT: Two-dimensional transition metal sulfides (TMDCs) have attracted the attention of many people for their unique optical and electrical properties. The existence of band gap structure makes up for the defect of graphene zero bandgap, which has shown a bright future in the field of electronics. As a member of TMDCs material, MoS_2 has many excellent properties, such as higher mobility, larger single layer photoluminescence properties and so on. We prepared a large area of high quality MoS_2 thin film by chemical vapor deposition method(CVD), prepared by the mask method of the MoS_2photodetector, the results show a good response to light. The effect of different lighting conditions on MoS_2 photodetector was studied to characterize it's response to light.

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I. INTRODUCTION

In recent years, two-dimensional material gradually into people's field of vision.As the preparation of single-layer graphene has matured, more and more peculiar properties have been discovered. Studies show that graphene materials have high conductivity, good heat conduction and very high carrier mobility, about $10000cm^2V^{-1}S^{-1}$[1, 2].These fine features make graphene widely used in various fields of research, such as gas detection, quantum hall effects, supercapacitors and spintronics[3-5].

However, the graphene band gap is zero, which is semi-metallic and cannot be electronic switch like a semiconductor.Therefore, the application of graphene has been limited in the field of electronic devices and integrated circuits. Later, people tried to solve this problem, some people put forward by chemical functionalization, micro-nano structured[6, 7] or the introduction of an external vertical electric field[8] to produce graphene band gap, but these methods are based on the cost of excellent characteristics of graphene, and the device produced by the high cost, complex stepis not better than the traditional silicon material devices. So people started to think about whether there was a material that had semiconductor property, and the two-dimensional structure of graphene. In the end, the new two-dimensional materials were found, such as boron nitride (h-BN), black phosphorus and transition metal sulfide (TMDCs).TMDCs is the most widely studied two-dimensional material, they keep the structure, properties and optical properties of graphene, but also because of its show the semiconductor properties and can be widely used in fields such as electronic components, integrated circuits, semiconductor sensor[9-11]. MoS_2 has been widely studied because of its simple and mature preparation process, unique and excellent optical and electrical characteristics, soft and uniform structure properties.

In this paper, MoS_2 films were prepared by chemical vapor deposition (CVD).Compared with mechanical dissection[12-19] and li-ion interlayer[20-23], CVD has controllable growth advantage, and the experiment is reproducible, the produced MoS_2films have a large area, uniform surface and good performance. Grow good MoS_2 films weretransferredby PMMA transfer way to a new silicon wafer, and then place the MoO_3 chip with a probe in MoS_2 film surface, the electrode was prepared by magnetron sputtering.After the electrode is prepared, we use a probe to pick out MoO_3 filmsand remove some unwanted electrodes.Through the above steps, the device channel is prepared.By studying the electrical and photoelectric characteristics of the prepared devices, we proved that the prepared films have excellent performance characteristics.

II. RESULTS AND DISCUSSION

We prepared MoS_2 films through CVD methods. We put 500 mg S powder in a quartz boat, and put a quartz tube across the furnace, the quartz boat is outside the heating furnace, 6 mg MoO_3 powder placed in corundum boat, buckle the Si/SiO_2 substrate on corundum boat, and corundum boat placed in a quartz tube, is located in the middle of the heating furnace. Heating furnace temperature to 760 ℃, rate of 15 ℃/ min, 30 min of the reaction time.In the whole heating process, maintain 200 sccm flow rate of argon, 10 min started earlier than furnace heats up to the highest temperature heating S powder, rose to 150 ℃within 3 minutes.

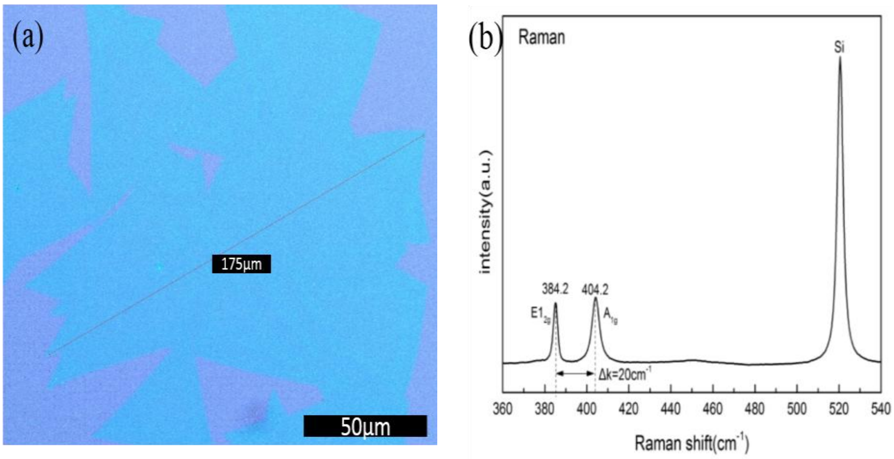

Figure 1. (a)Optical microscope images of MoS_2. (b) Raman spectra of multilayer MoS_2.

Fig.1a is a microscopic image of a grown MoS_2 film. It can be seen from the figure that the side length of the film is about 175 micrometers and the surface has a good uniformity. The color of the film is similar to the color of the substrate, and it can be inferred that the thickness of the film is thinner. Fig.1b shows the Raman spectrum of MoS_2. As can be seen from the figure two obvious peak $E^1{}_{2g}$ and A_{2g}, $E^1{}_{2g}$ value of 384.2cm^{-1}, peak A1g value of 404.2cm^{-1}, the difference between the two is 20cm^{-1}, you can determine the thickness of the film is approximately double.

After preparing a complete, high quality MoS_2 film, we spin-coated the PMMA solution onto the substrate. Then the substrate was dried and heated 40min, The substrate was placed in a mass fraction of 30% NaOH solution for etching operation, After 24 hours, the PMMA film detached from the surface of the substrate and was suspended on the surface of the solution. At this moment, the PMMA film adhered to the MoS_2 film which we have grown, as shown in Fig.2a.]

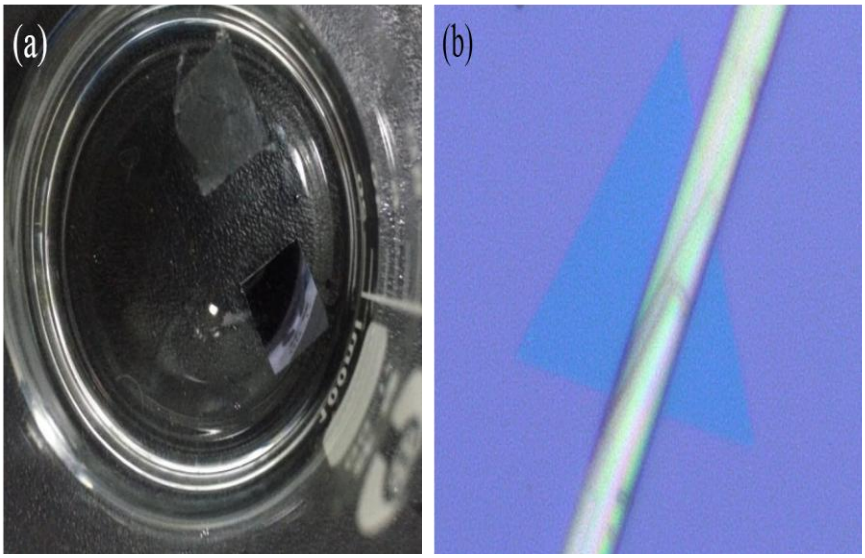

Figure 2.(a) The PMMA film was transferred. (b) MoO_3 sheet for masking.

The detached PMMA film was transferred to a new clean Si / SiO_2 substrate, Due to the impurity film PMMA on the MoS_2 film, we placed the new substrate carrying the PMMA film in an acetone solution to remove PMMA impurities for 12 hours. After removing the PMMA impurities, we got a clean MoS_2 film. A MoO_3 wafer was placed over the MoS_2 film with a probe to form a masking structure as shown in Figure 2b. The covered MoS_2 film was magnetron sputter coated Ag electrode, and then pick up the MoO_3 sheet, Through the probe sliding extension of the boundary line to the edge of the substrate, you can create a complete channel, and the entire process shown in Fig.3a.

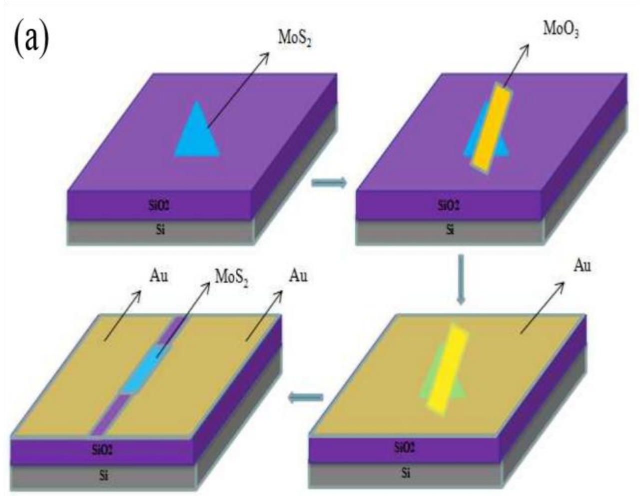

Figure 3. (a)MoS_2 device preparation process.

After preparing a complete MoS_2 device, we used Keithly-2612A for electrical characterization. The measured circuit model is shown in Fig.4a. The measured transfer curve and output curve are shown in Figure 4b and 4c. It can be clearly seen from the figure that the gate voltage can adjust the source-drain current to a certain extent, and the device has obvious MOS tube characteristics.

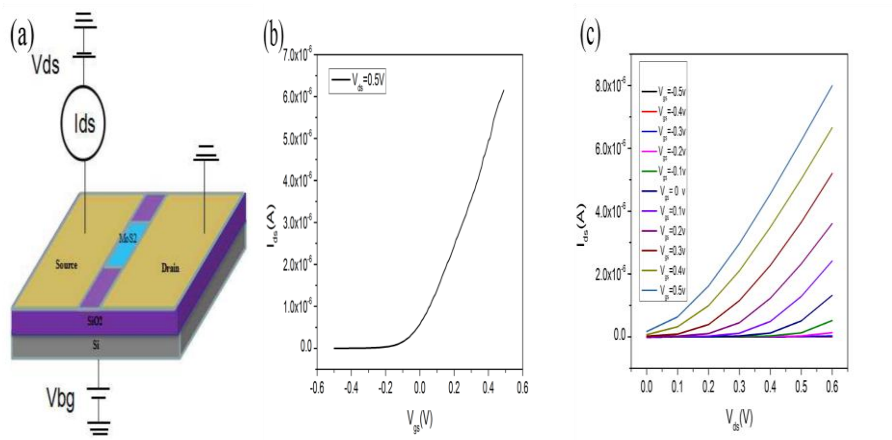

Figure 4. (a) MoS_2 voltage measurement route. (b) MoS_2 device transfer curve and output curve.

Due to the Si semiconductor has significant photoelectric properties.In order to prevent the defect of SiO_2 to make the photoelectric current produced by Si affect the result of MoS_2 photoelectric experiment, we use glass instead of Si / SiO_2 as the device substrate, the experimental circuit structure shown in Fig.5a.

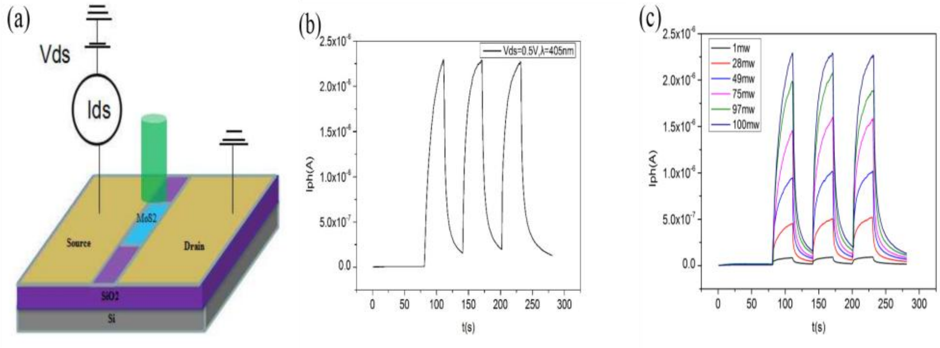

Figure 5. (a) MoS_2 measurements from photo sensor. (b)Photocurrent of MoS_2 at 405 nmwavelength. (c) The photocurrent of MoS_2 at different powers at 405 nm wavelength.

The width of the bandgap of the MoS_2 thin film we prepared is about 1.7eV, So we choose 405nm laser to irradiate MoS_2 thin film can stimulate valence band electronic transition. T The power of the laser is 100 mW and the resulting current response is shown in Figure 5b. It can be seen that the MoS_2 film has significant photoresponsiveness. When there is no light, due to the existence of a slight bias across the device will produce a small dark current, However, as the illumination increases, the photocurrent increases rapidly and gradually approaches a maximum value, When the light disappears again, the photocurrent immediately reduced to near the original value, Device response time is very fast, we can see that there is greater sensitivity. After the light disappears, the dark current does not immediately return to the original value because at the end of the light, the device also has light inside the holes excited by the electron is not recombined in time, so the dark current will be slightly larger than the original value. We also conducted experiments at different powers of the same wavelength, the result shown in Figure 5c. It is obvious that as the incident light power increases, under the premise of certain photon energy, the number of photons will also be a corresponding increase, resulting in a corresponding increase in the number of excited electrons, and ultimately affect the excitation current, so that it also becomes larger.

III. CONCLUSION

We prepared by CVD method of large area, uniform surface layer of MoS_2 thin film, The MoS_2 film was transferred to a new substrate by the PMMA transfer method, At the same time, the device fabrication process of the MoS_2 thin film is simplified, avoiding the complicated steps and high costs caused by the lithography. The final device is tested and found to have better voltage and current regulation characteristics and more sensitive photoelectric characteristics.

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