Carrier control of defective few-layer MoS_2 by thiol molecule chemisorption

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The discovery of graphene has promoted significant interest in other two-dimensional (2D) materials, especially transition metal dichalcogenides (TMDs) in recent years. Although graphene shows a high mobility up to 106 cm2/Vs, its absence of a bandgap seriously limits its application for an active channel material in electronic devices. Alternatively, molybdenum disulfide (MoS_2), one of the most widely studied semiconducting TMDs, shows a thickness-dependent energy bandgap and band structure: indirect bandgap of 1.2eV in a bulk MoS_2 and direct bandgap of 1.8eV in a monolayer form [1].

Mechanical exfoliation can produce high quality MoS_2 sheet, and thus field effect transistors (FET) based on a ultrathin MoS_2 exfoliated from its layered bulk material shows high on/off current ratio up to 10¬8, steep sub-threshold swing of 70 mV/dec and a large in plane carrier mobility of 200~500 cm2/Vs [2]. Nevertheless mechanical exfoliation is not compatible with the fabrication of highly integrated electronic devices such as large-scale FET arrays. Instead, chemical and physical vapor deposition (CVD and PVD) are more suitable for the large scale and high-quality production of MoS_2. However, CVD or PVD-grown MoS_2 presents plenty of native short-range disordered structural defects such as vacancies, point defects, and grain boundaries. These defects are the major scattering center of carrier; therefore, CVD or PVD-grown MoS_2 based FETs show a relatively low mobility. On the other hand, these defects can provide us new possibility of tailoring physical and chemical properties of the defective MoS_2. Moreover, few-layer MoS_2 may not be doped via traditional methods such as ion implantation due to ultrathin body nature.

In this work, we demonstrate the facile chemical doping method for modulating carrier concentration and electrical properties of FETs based on defect-containing MoS_2 using thiol chemistry. For example, sulfur vacancy of MoS_2 can act as useful sites for hydrodesulfurization. Thus, thiol molecules with various functional groups which can act as a surface charge transfer donor can be easily absorbed and tightly bound to defect sites of MoS_2. We therefore chose thiol molecules containing an NH_2 group, which has lone electron pairs and can donate electrons to MoS_2. As a result, the carrier density increased 3 fold (from 6.65×10^{12} /cm^2 to 1.86×10^{12} /cm^2) and field effect mobility also increased from 0.59 cm^2/Vs to 1.64 cm^2/Vs after doping in Figure 1. This method can be used to effectively modulate the conductivity, carrier mobility, and carrier density in few-layer MoS_2.

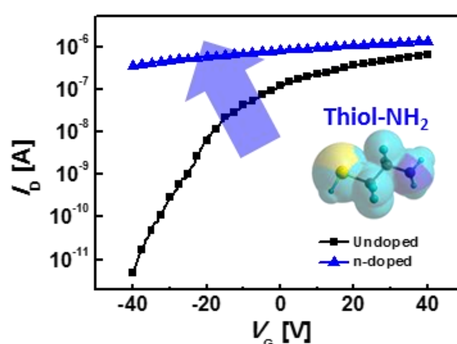

Fig. 1. Transfer characteristic curve of undoped and n-doped (NH_2 group) MoS_2 FET

References

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