Controllable Ozone Oxidation on N-type MoS_2 to Make Ambipolar or P-type MoO_x/MoS_2 Transistors

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The discovery of single layer graphene helps to establish experimental techniques to process layered materials. Recently, semiconducting layered materials such as MoS_2 and WSe_2 attract much attention because these materials show prominent potential to replace Si or Si/Ge bodies as channel materials. As the body width of fin field-effect transistors (FETs) is continually downsized to several nanometer, the three-dimensional nature of the Si lattice structure hinder further thinner manufacture due to dangling bonds at surface. In contrast, the semiconducting layered materials are natively saturated without dangling bonds thus paving the way to the atomic thin FETs. The MoS_2 single layer usually shows n-type features, limiting its application in FETs. Here, we show controllable oxidation to convert MoS_2 with thickness of few-tens of nanometers to either ambipolar or p-type FETs.

The MoS_2 flakes are heated at 150^oC or 270^oC under ozone exposure for several hours. The surface of oxidized MoS_2 was examined by scanning tunneling microscope and scanning tunneling spectroscopy. Further, we made FET devices on MoS_2 flakes with a thickness of few-tens of nanometers. Before ozone oxidation, the FET devices presented n-type features that are consistent with others' reports. After the MoS_2 FETs were oxidized, the devices showed Schottky contact properties which were inspected at different source-drain bias voltages and different back-gating voltages. The MoS_2 FETs after minor oxidation treatments showed an ambipolar feature and electron transport in channels was studied. On the other hand, the MoS_2 FETs under stronger oxidation treatments presented p-type FET behaviors. The electron transport and transfer characteristics in the p-type FETs were explored. From experimental data, we propose a band diagram to explain the oxidation, the formation of MoO_x/MoS_2 heterostructure, and the variation of electron transport manners.