二硫化モリブデン FET への分子ドーピング

Molecule Doping on MoS_2-FET

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BACKGROUND

Atomic scale layer of transition dichalcogenide including MoS_2 has attracted attentions for the field emission transistor material due to its genuine semiconductor nature. In such a limited dimension in the thickness, the strategy for the doping should be different from the conventional Si MOSFET fabrication and adsorption of molecules can be one of techniques to place dopants. Even though preliminary investigations revealed that there is a doping effect in FET characteristics if the channel is exposed to gas molecules, there is no systematic study how the doping is achieved with such a condition. In this report we fabricate MoS_2 FET which is placed in ultra-high vacuum (UHV) condition to measure the effect of Cl_2 molecule adsorption on the FET properties without exposing the channel to the air.

EXPERIMENTAL & RESULTS

The atom layer MoS_2 FET was fabricated using the scotch tape method onto 285 nm SiO2/ p++ Si substrate which was used as the back gate electrode. The device is then placed in a UHV chamber in which well shielded cables are bridging the UHV chamber and outside electrodes so as precise measurements of FET parameters with using Keithley 2600 are enabled.

The fabricated MoS_2 FET shows a typical n-type FET characteristic. With dosing Cl_2 gas molecule, drain current (Id) vs gate voltage (Vg) curve shifts toward the positive Vg direction, meaning hole doping with Cl_2 dosing. The threshold gate voltage (Vth) deduced from the Id-Vg curve shows a sensitivity as good as 1 Langmuir ($1L=10^{-6}$ Torr sec). However with an apparent weak bonding energy, the Vth gradually shifts to the negative side with time when the device is kept at room temperature.

From the time dependent Vth changes, the binding energy of Cl_2 molecule on MoS_2 substrate is estimated to be ~ 1eV for a molecule, whose value was further confirmed with using a standard surface scientific technique of thermal desorption spectroscopy (TDS). The small binding energy of Cl_2 on MoS_2, ~1 eV, is usually categorized to physisorption or very weak chemisorption, in which no large charge transfer between the molecule and substrate is assumed, while a constant Vth shift is observed. We discuss the doping mechanism of Cl_2 with employing a density functional theory calculation.