Photo Enhanced Electrical Properties of Organic Dye Doped MoS_2 FET Sensor

Md Iftekharul Alam[1], Tsuyoshi Takaoka[2], Hiroki Waizumi[1], M. Shamim Al Mamun[1], Yudai Tanaka[1], Kosei Takahashi[1], Tadahiro Komeda[2], Atsushi Ando[3]

Dept. of Chemistry, Tohoku University[1], IMRAM, Tohoku University[2] and Nanoelectronics Research Institute, AIST

The molybdenum disulfide (MoS_2) is a proclaimed candidate for a channel material of the field effect transistor (FET) sensor due to its significant electrical and optoelectrical properties like as the high on-off ratio and carrier mobility, in addition to the high sensitivity to the light injection. It is expected that π-conjugated organic dye molecules like methylene blue (MB) enhance such a photo-response when adsorbed on the MoS_2-FET. In this report, we investigate the variation of the electrical behavior of the MoS_2-FET with the injection of the monochromatized UV-Vis light to explore its sensor behavior.

Experimentally, a few-layer MoS_2 flake was transferred onto the p++ Si- substrate covered with 300 nm SiO_2 by the mechanical exfoliation. The FET devices were fabricated using the electron beam lithography method. In addition, the doping of the MB molecule was carried out in an ultra-high vacuum (UHV) chamber at a good vacuum pressure (10^{-6} Pa) and photo enhanced electrical properties were observed using source meter (Keithley 2634B) in dry nitrogen environment by injecting light from a monochromatic light source.

We focus on how the electrical property of the MoS_2 FET doped with the MB molecule changes with the UV-Vis light illumination. Figure 1 indicates the transfer characteristics of the pristine and MB adsorbed MoS_2-FET under dark conditions (V_D = 50mV). Threshold voltage (V_{th}) shifts to the left-hand-side for both 0.1Å and 0.2Å MB deposited surface as compared to pristine FET reveals n-doping of MB in contact with MoS_2. Such n-doping behaviors can be explained by the charge transfer in between MB and MoS_2 originated from the S-π interaction between the two. However, the photocurrent vs wavelength curves (Figure 2) show a strong enhancement of the drain current with the light injection at a constant V_D of 50mV. Two maximum photocurrent peaks are observed in between 600 nm and 670 nm (II & III) both for the pristine and MB doped device. An additional shoulder appears at around 500 nm wavelength that is absent for the pristine case (I). That maximum photocurrent enhancement is due to the effective charge transfer from the LUMO of MB to the conduction band (CB) of MoS_2 while the additional shoulder can be attributed by the formation of S−S or S−Mo coordination interactions with MoS_2.

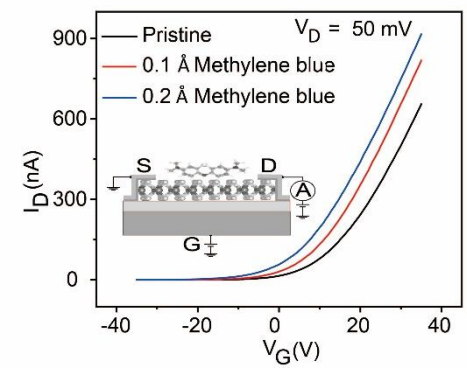

Figure 1: Transfer characteristics of pristine and MB/MoS_2 FET

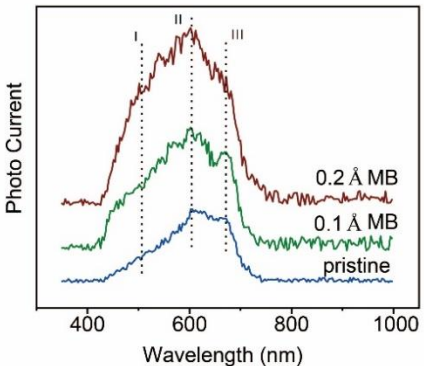

Figure 2: Photocurrent-wavelength curves of pristine and MB/MoS_2