High Electron Mobility Few Layer MoS_2 Grown by Chemical Vapor Deposition

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MoS_2 has recently attracted significant research interests for next generation nanoelectronics, flexible and transparent electronics. Unlike graphene, as a 2D semiconductor, MoS_2 is a great candidate for highly scaled MOSFETs with a high current on/off ratio. However, the reported electron mobility of thin films (either mechanically exfoliated or grown by chemical vapor deposition (CVD)) is still very low, which hinders the device performance. Here we report high electron mobility few layer MoS_2 thin films grown by CVD.

Few layer MoS_2 films were grown on sapphire by CVD[1,2]. TLM patterns were fabricated for transport study. The I-V characteristics in Fig. 1 show that at the low voltage region, the relationship between current and voltage is linear while the relationship becomes square dependence at high biases, suggesting that the electron transport is space-charge limited. According to the space charge model, for thin film semiconductor materials, the relationship between space charge limited current density and voltage is $J = 2\mu\varepsilon_o\varepsilon_r\frac{V^2}{\pi L^2}$. Considering the Drude mechanism at a low electrical field, the total current density can be expressed as $J = q\mu n\frac{\mathrm{V}}{\mathrm{L}} + 2\mu\varepsilon_o\varepsilon_r\frac{V^2}{\pi L^2}$. Electron mobility and sheet carrier concentration are extracted based on this model. A high mobility of 118 cm^2/Vs is obtained. The doping concentration is in the range of 10^{10} to 10^{11} cm^{-2}. However, the extracted mobility values are not uniformly distributed as shown in Fig. 2. Detailed TEM studies suggest that the non-uniformity is attributed to the grain boundaries (Fig. 3). This is confirmed by Raman spectra taken at different regions. The ratio changes of E^1_{2g} and A_{1g} peaks in Raman spectra taken at different regions shown in Fig. 4 indicate the crystal structural variation of MoS_2 film on the same sample. Current efforts are directed to development of MOSFETs on these high mobility CVD growth few layer MoS_2 thin films.

1. Masihhur R. Laskar et al., "Large area single crystal (0001) oriented MoS_2", Appl. Phys. Lett., 102, 252108 (2013).
2. Lu Ma et al., "Epitaxial Growth of Large Area Single-Crystalline Few-Layer MoS_2", ACS Nano (submitted).

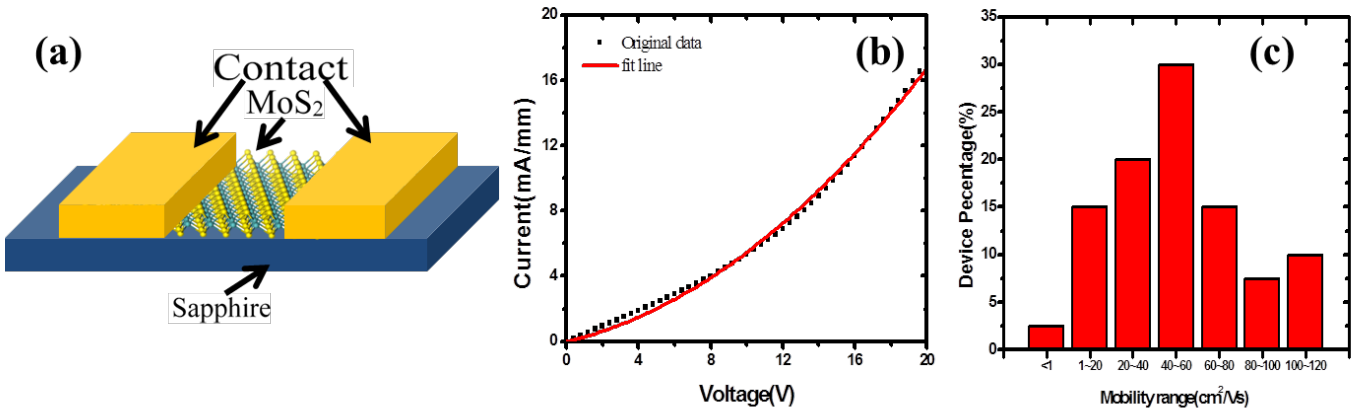

Figure 1. (a) Device structure with variable spacings; (b) Current-voltage characteristics and fitting based on space-charge limited transport model; (3) Distribution of extracted electron mobility values of devices across the sample.

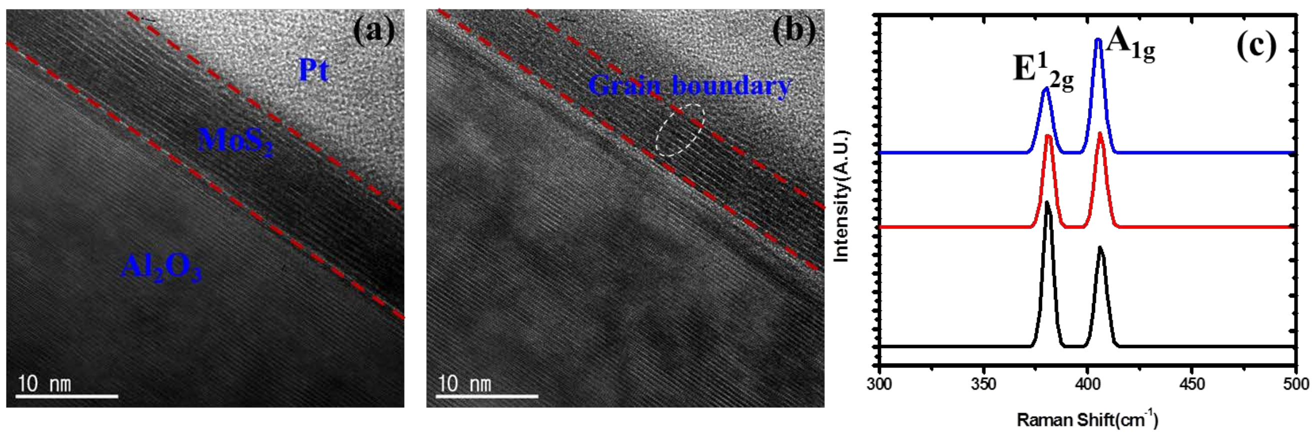

Figure 2. (a) TEM micrograph showing single crystalline quality in large area; (b) TEM micrograph showing grain boundaries at a different region on the same sample; (c) Raman spectra taken at different regions showing intensity ratio changes of E^1_{2g} and A_{1g} peaks.