Enhanced Hole Mobility of CVD Transition Metal Dichalcogenide Monolayer by Metal Nanoparticles

Chang-Hsiao Chen

Department of Automatic Control Engineering, Feng Chia University, Taichung, 40724, Taiwan.
chsiaoc@fcu.edu.tw

Abstract

Tungsten diselenide (WSe_2) is an attractive transition metal dichalcogenide material, since its Fermi energy close to the mid gap makes it an excellent candidate for realizing p–n junction devices and complementary digital logic applications. Doping is one of the most important technologies for controlling the Fermi energy in semiconductors, including 2D materials. Moreover, the Fermi level engineering or doping in monolayer WSe_2 is still relatively unexplored. Recently, Fang et al have reported transistors based on WSe_2 using high-k materials as the gate dielectrics, where the chemically doped source/drain contacts exhibit low contact resistances. Selective treatment with potassium is able to form degenerately doped n+ contacts for electron injection while NO_2 treatment forms p+ contacts [1–3]. Liu et al have demonstrated the n-type WSe_2 FET by using indium as a contact metal [4]. Chuang et al have revealed that graphene can be a work-function-tunable electrode material for few-nanometre WSe_2 FETs [5]. It is noted that the small molecules adsorbed on the 2D materials tend to desorb from the surfaces and the alkali metals are known to be sensitive to moisture and oxygen. Here we present a simple, stable and controllable p-doping technique on a WSe_2 monolayer, where a more p-typed WSe_2 field effect transistor is realized by electron transfer from the WSe_2 to the gold (Au) decorated on the WSe_2 surfaces. Related changes in Raman spectroscopy are also reported. The p-doping caused by Au on WSe_2 monolayers lowers the channel resistance by orders of magnitude. The effective hole mobility is ~ 100 (cm^2/Vs) and the near ideal subthreshold swing of ~ 60 mV/decade and high on/off current ratio of >10^6 are observed. The Au deposited on the WSe_2 also serves as a protection layer to prevent a reaction between the WSe_2 and the environment, making the doping stable and promising for future scalable fabrication.

References

[1] Tosun M, Chuang S, Fang H, Sachid A B, Hettick M, Lin Y, Zeng Y and Javey A, ACS Nano, **8** (2014) pp. 4948–53.
[2] Fang H, Tosun M, Seol G, Chang C T, Takei K, Guo J and Javey A, Nano Letters, **13** (2013) pp.1991–5.
[3] Fang H, Chuang S, Chang C T, Takei K, Takahashi T and Javey A, Nano Letters, **12** (2012) pp. 3788–92.
[4] Liu W, Kang J, Sarkar D, Khatami Y, Jena D and Banerjee K, Nano Letters, **13** (2013) pp.1983–90.
[5] Chuang H J, Tan X, Ghimire N J, Perera M M, Chamlagain B, Cheng M M C, Yan J, Mandrus D, Tománek D and Zhou Z, Nano Letters, **14** (2014) pp.3594–601.

Figures