Field-Effect Transistors Based on Few-Layered WSe_2 Displaying Room Temperature Hole-Mobilities Comparable to *p*-Doped Si

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Introduction

Transition metal dichalcogenides are emerging as a major research frontier due to their unique properties. Here, we present a systematic comparison between field-effect and Hall-mobilities in field-effect transistors (FET) based on multilayered WSe_2 mechanically exfoliated onto SiO_2. We focus on single-crystals displaying ohmic, non-hysteretic hole conduction as a function of gate voltage V_{bg} observing a pronounced increase in both the Hall (μ_H) and the field-effect (μ_{FE}) hole mobilities, when V_{bg} is increased beyond a threshold value Vtbg. Both mobilities display maximum values approaching or surpassing 300 cm^2/Vs at T = 300 K, but (as in graphene) they tend to decrease as the number of carriers increase. We observe μ_H values in excess of 650 cm^2/Vs as the T is lowered below T = 150 K. Therefore, WSe_2-based FETs display the largest μ_H among TMDs, particularly at T = 300 K.

Experimental

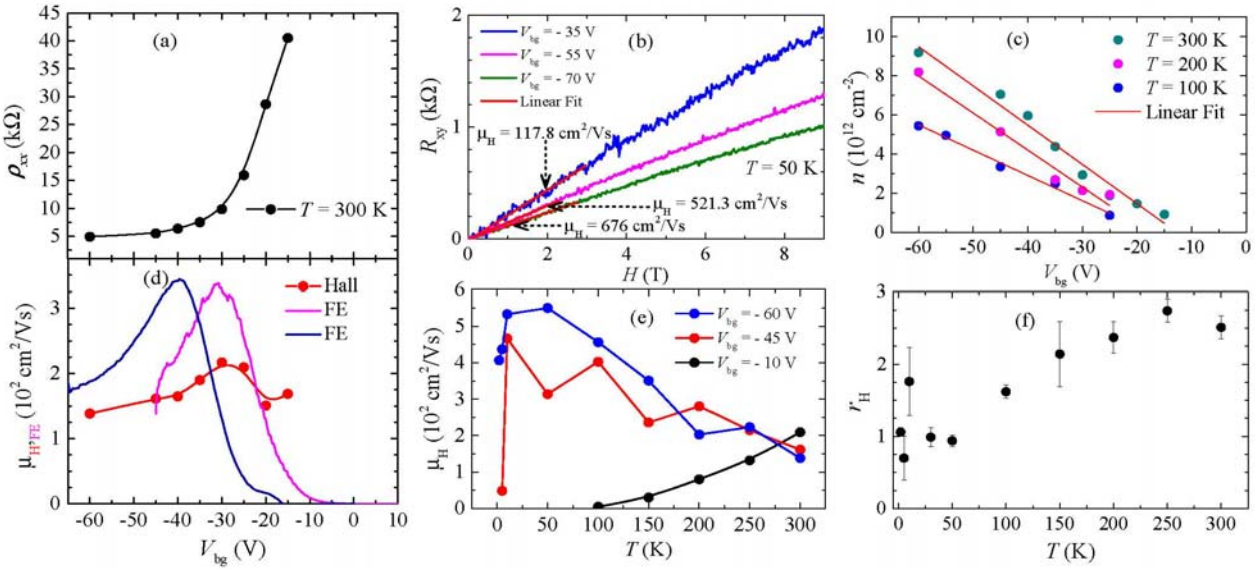

Fig. 1 **a** Sheet resistance R_{xx} measured at a temperature of T = 300 K and as a function of V_{bg} for a second multilayered WSe2 FET after annealing it under vacuum for 24 h. **b** Hall response R_{xy} = VH(H)=Ids as a function of the external magnetic field H, and for several values of the gate voltage V_{bg}. Red lines are linear fits from whose slope we extract the values of the Hall constant R_H(= V_H/HI_{ds}). **c** Density of carriers $n_H = 1/(eR_H)$ induced by the back gate voltage as a function of V_{bg}. Red lines are linear fits from which, by comparing the resulting slope s with $n/V_{bg} = c/e$ (c is the gate capacitance) as expected for an ideal device, we extract the Hall factor $r_H = se/c$. **d** Field-effect □$_{FE}$ (magenta and blue lines) and Hall □$_H$ = R_H =□$_{xx}$ (red markers) mobilities (where □$_{xx}$ = $R_{xx}w/l$, w and l are the width and the length of the channel, respectively) as functions of V_{bg} at T = 300 K. Both Hall and field-effect mobilities show relatively similar behavior and maximum values. Thermally cycling the samples increases the gate voltage required to overcome the mobility edge, i.e. magenta and blue traces were measured respectively, before and after cooling the sample down to low temperatures. **e** Extracted Hall mobility as a function of the temperature for several values of Vbg. □$_H$ increases as T is lowered, but subsequently it is seen to decrease below a gate voltage dependent temperature. **f** Hall factor r_H as a function of T. Notice that the resulting drift mobility □$_d$ = r_H□$_H$ has a weaker T-dependence than □$_H$.

Conclusions

The extracted Hall factors indicate that WSe_2-based FET should have room temperature drift mobilities in excess of 500 cm^2/Vs, thus surpassing *p*-doped Si. Improvement in fabrication protocols, could make WSe_2 an ideal candidate for high performance, flexible opto-electronics.

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