Charge and spin transport in 2D Rashba system

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Abstract

The microelectronics revolution is driven by the motto ‘the smaller the better’, as it aims to miniaturize electronic components and improve performances. Nowadays silicon transistors are approaching the scaling limit. Recently, the MoS_2 transistor with an atomically thin channel and a gate length of sub-1-nm has been fabricated successfully [1], illustrating the potential of 2D materials for applications in electronic devices. In addition to the electron, spin is another degree of freedom to manipulate the logic operations, and the spintronic devices have high-density, low-power, and non-volatile advantages [2]. Using *ab initio* calculations, we demonstrate the superior charge and spin transport properties in 2D buckled III-V semiconductors. Due to the broken inversion symmetry, Rashba splitting is revealed in the conduction bands, where high electron mobilities over 1400 $cm^2/(V{\cdot}s)$ are predicted [Fig. 1(a)]. This can be explained by the negligible scattering on the single Γ valley [Fig. 1(c)]. In contrast, the hole mobility [Fig. 1(b)] is lower due to the strong scattering on multiple K valleys [Fig. 1(d)]. Fig. 2(a) presents the spin Hall conductivity (SHC), and the universal SHC are identified in Rashba systems. More significantly, via heavy hole doping, the semiconductors are turned to be metallic systems, where efficient spin-charge conversions are discovered [Fig. 2(d)], which can reduce the writing power in spin-orbit torque devices. This work highlights the promising application for 2D Rashba systems in electronic and spintronic devices.

References

[1] Wu *et al.*, *Nature* **603**, (2022) 259–264.
[2] Liu *et al.*, *Nature* **606**, (2022) 663–673.

Figures

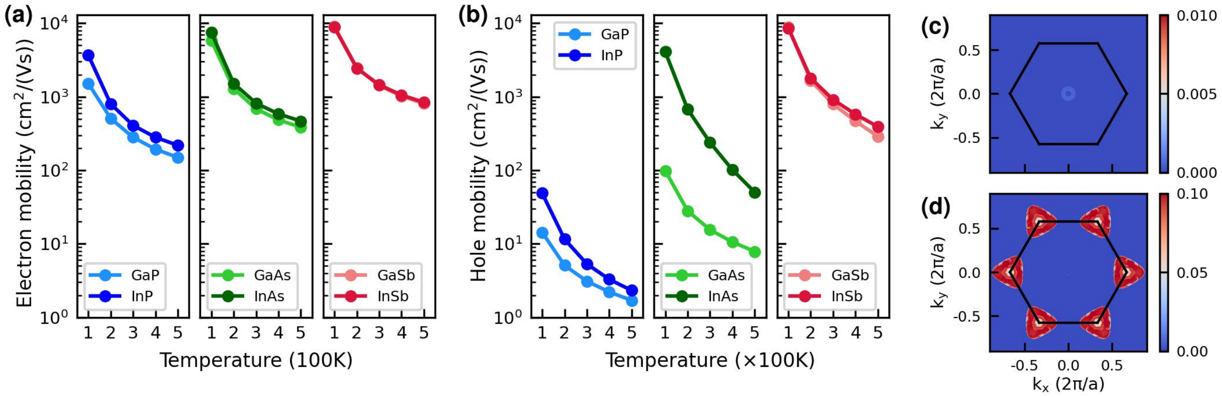

Figure 1: (a)-(b) Temperature-dependent electron and hole mobilities of 6 III-V monolayers. (c)-(d) **k**-resolved scattering rate of InSb electron transport and GaP hole transport, respectively.

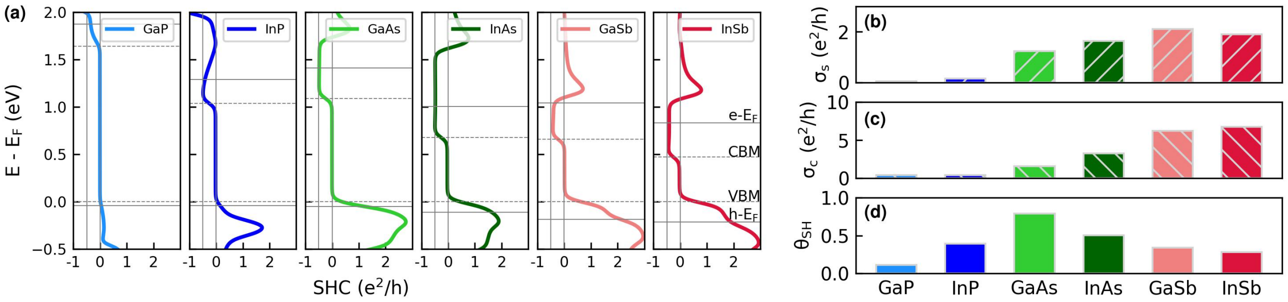

Figure 2: (a) Spin Hall conductivities of 6 III-V monolayers. The dashed lines denote the conduction band minimum and valence band maximum of intrinsic semiconductors, and the solid lines indicate the position of Fermi energy after electron doping and hole doping, respectively. (b)-(d) The spin Hall conductivity, charge conductivity, and spin-charge-conversion efficiency after hole doping of $2{\times}10^{13}$ cm^{-2}.