Polarization control in few-layer MoS_2 by electric field induced symmetry breaking

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The recent discovery of truly two-dimensional direct band gap layered nanomaterials [1, 2] has paved the way for novel optoelectronic and quantum applications. Hexagonal transition metal dichalcogenides (TMDs) such as MoS_2, $MoSe_2$, WS_2 and WSe_2 exhibit a direct band gap in the monolayer limit and are very promising candidates for studying fundamental new physics. The inherent breaking of inversion symmetry accounts for a giant spin-orbit induced splitting of the valence band up to 463meV in WSe_2 [3]. Time-reversal symmetry paired with inversion symmetry breaking lifts the Kramer's spin degeneracy [4] at the corners of the hexagonal Brillouin zone (K-points) leading to coupled spin and valley pseudospin physics. Consequent valley optical selection rules provide access to these quantum degrees of freedom by employing circular polarized light.

Here, we present the electrical control of exciton emission energies and spin-valley photophysics in few-layer MoS_2 crystals embedded within electrically tunable micro-capacitor structures. By tuning the applied gate potential we induce a strong DC Stark shift up to ≈ 11 meV for monolayer crystals and $\approx$ 18 meV for five-layer MoS_2. We find effective dipole moments and exciton polarizabilities on the order of $p = 4 \times 10^{-6}$ meV/(kV/cm) and $\beta = 1 \times 10^{-9}$ meV/(kV/cm)^2, respectively.

In low-temperature polarization-resolved μ-photoluminescence studies, we observe a strong electric field tunability of the exciton spin-polarization in bilayer MoS_2 crystals. Due to the inversion symmetry breaking character of the perpendicular applied electric field, we are able to continuously tune the degree of circular polarization of the emission ranging from $\eta = 20$ % up to 65 %. Our results demonstrate the potential for emergent spin- and valleytronic devices based on two-dimensional atomically thin crystals.

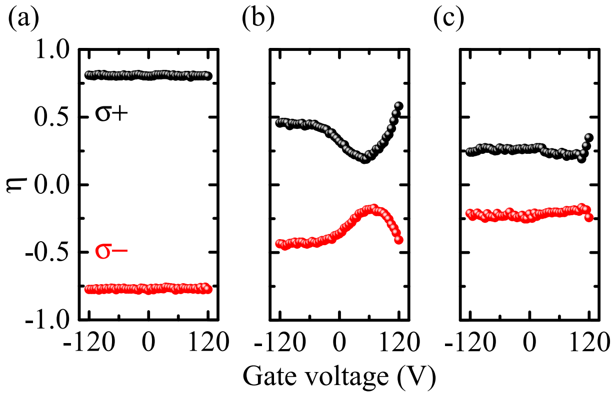

Fig. 1. (a-c) Layer-dependent degree of circular polarization η for (a) monolayer, (b) bilayer and (c) trilayer MoS_2 cystals as function of applied gate voltage obtained for $\sigma+$ (black) and $\sigma-$ (red) polarized laser excitation.

References

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