Gate-tunable recombination pathways in MoS_2 and MoS_2/graphene heterostructures

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Transition metal dichalcogenides (TMDs), which are direct gap semiconductors in the monolayer limit [1], are characterized by radiative emission from a variety of excitonic quasi particles [1]. Understanding the interplay between such quasi-particles is paramount for fundamental science and technology. For instance, the ratio between excitons and trions in TMDs ultimately defines the photoluminescence (PL) quantum yield, which in turn affects the efficiency of TMD based opto-electronic devices [2]. Tuning between neutral exciton and trions can be achieved by chemical [3] and electro-static doping [4], or by active filtering in combination with graphene [5]. Here, we further investigate the interplay between neutral exciton and trions by studying the electrical tunability of light emission arising from A excitons, B excitons and trions in a monolayer MoS_2, both in its pristine form and combined into a heterostructure with monolayer graphene (Figure1a). We show gate-tunable quenching of the PL intensity from the A exciton in MoS_2 and MoS_2/graphene by two orders of magnitude and a factor of two, respectively (Figure 1b). This stark difference is ascribed to the fact that MoS_2/graphene remains undoped at any value of the external gate voltage due to ultrafast and efficient charge transfer. Second, we investigate the impact of doping on the PL power dependence and find that in pristine MoS_2 under positive gate voltage, A excitons show a super-linear behaviour at low values of excitation power. This behaviour is due to a nonlinear reduction of the A exciton to trion conversion rate [6]. In contrast, this super-linear power-dependence disappears at any value of excitation power in MoS_2/graphene, once again indicating that the sample remains basically undoped due to efficient charge-transfer. Our work provides a detailed description of the interplay between neutral excitons and trions as a function of gate voltage and exciton/charge density, thus offering new insights for the optimization of tailored opto-electronic such as light emitting diodes.

References

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Figures

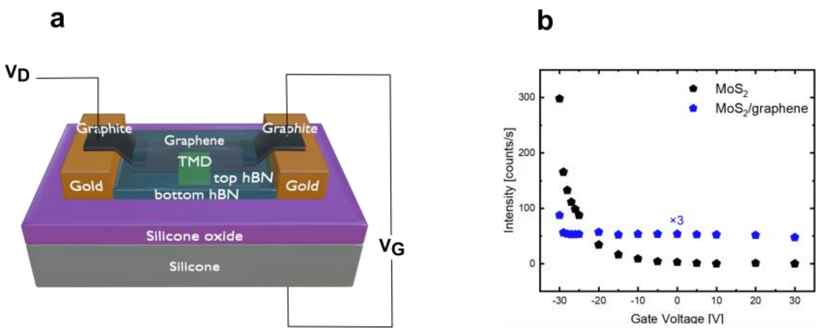

Figure 1: a). Schematic of the device. V_D and V_G represent the drain and gate voltages, respectively. b) A exciton PL intensity as a function of gate voltage in MoS_2 (black dots) and MoS_2/graphene (blue dots).