Electrical Tuning Of Exciton Lifetime In Monolayer MoS_2

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The recent studies of low-dimensional semiconductors and their hybrid structure have led to discovering of many fascinating properties that are absent in their bulk counterparts. [1] Here, we studied the dynamics of excitons, which have high binding energy at room temperature using steady-state photoluminescence (PL) and time-resolved photoluminescence (TRPL) by systematically controlling the carrier density. We observed neutral and charged exciton(trions) dominant regimes in some specific carrier density.[2] In pristine MoS_2 devices, we observed an exciton dominant regime with an exciton lifetime of 3 ns, when we doped electrostatically with holes. Interestingly, we observe a sharp decrease in exciton lifetime with an increase of the electron density by electrostatic doping, with a corresponding increase in negative trion population, as shown in Fig. 1(a). This indicates the formation of negative trion. With increased hole doping by a chemical method, the exciton lifetime decreases, but it remains almost constant with electrostatic doping, which is visible in Fig. 1(b). This might be due to the exciton-exciton annihilation mechanism. Further hole doping by a chemical method leads to a transition to a positive trion dominated regime, as shown in Fig(c). Our observations suggest that when calculating the lifetime of excitons, the exciton-to-trions formation and exciton-exciton annihilation mechanisms should be considered.

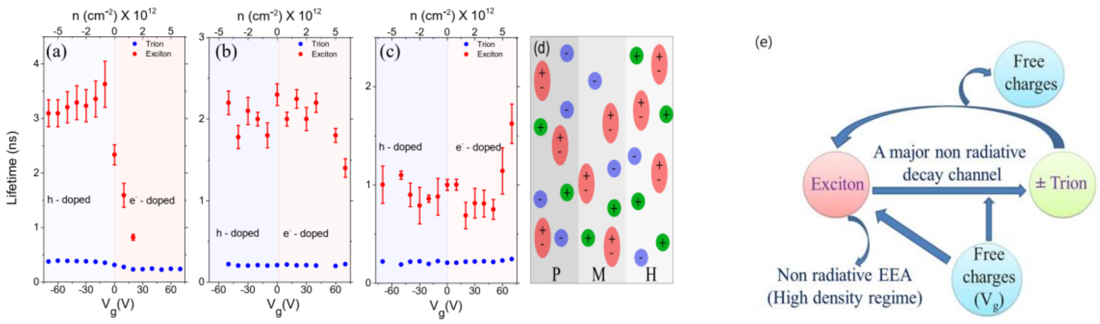

Fig.1. Lifetime of A-exciton (red circles) and trions (blue circles) at different doping levels achieved via chemical treatment and electrostatic doping: (a) pristine sample(P); (b) medium-hole-doped sample(M); (c) high-hole-doped sample(H). The lifetime of the A-exciton depends strongly on doping level. (d) Schematic of the exciton interaction at different regimes. (e) Schematic showing the various channels available for excitons and trions.

[1] Wang, Gang et al. Colloquium: Excitons in atomically thin transition metal dichalcogenides. *Reviews of Modern Physics*, 90, 2, 021001, 2018.
[2] H L Pradeepa et al. Electrical and Chemical Tuning of Exciton Lifetime in Monolayer MoS_2 for Field-Effect Transistors. *ACS Applied Nano Materials,* 3, 1, 641-647, 2020.