Free and localized excitonic complexes in atomically thin transition metal dichalcogenides

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Atomically thin semiconducting transition metal dichalcogenides (TMDCs) enable new insight into physics of many body effects mediated by Coulomb and electron-phonon interactions. In monolayers of TMDCs excitons, bound electron-hole pairs (X), exhibit very high binding energies of a few 100s of meV, leading to their stability at room temperature. In the presence of additional electrons charged excitons, trions (T), consisting of two electrons and one hole or two holes and one electron are observed in optical spectra of TMDCs MLs. In selenides, $MoSe_2$ and WSe_2 the PL intensity of a trion is high at low temperatures and negligible at high temperatures. In contrast, in sulfides, MoS_2 and WS_2 the emission spectra are dominated by the charged exciton at high temperatures. Moreover, in PL spectra of WSe_2 and WS_2, at low temperatures, at energies down to trion the group of intensive transitions are detected (L). They disappear from PL spectra above 80 K. Interestingly, the behavior of the highest energy peak is, however, different from that of the other low-energy features. This feature grows superlinearly as a function of excitation power. On this basis, this emission line was interpreted as arising from biexciton state.

In this talk, I will present complementary, optical spectroscopy studies of different TMDCs monolayers and their alloys. In the first part, I will give an overview of various excitonic complexes of different charge and degree of freedom (excitons, trions, biexcitons and localized excitons), that are observed in temperature dependent reflectivity contrast (RC) and PL spectra of WSe_2, WS_2, $MoSe_2$ and MoS_2 exfoliated on one SiO_2/Si substrate. In the second part, I will discuss robust high temperature trions emission in monolayers of $Mo(S_ySe_{1-y})_2$ alloys, which is attributed to the two effects: (i) strong increase of exciton-trion coupling mediated by the optical phonon, which is realized by tuning phonon energy through trion binding energy, and (ii) significant increase of two dimensional electron gas (2DEG) concentration.