Abstract

The doctoral dissertation concerns the research on the fundamental properties of various types of two-dimensional crystals of transition metal dichalcogenides (TMDs) belonging to group 6. (MoS_2, $MoSe_2$, WS_2 and WSe_2) and crystals of different thickness belonging to group 7. (ReS_2). Mastering the method of preparation of the monolayer TMDs and its development with the possibility of conducting a transfer in a deterministic manner resulted in the production of high-quality structures. This enabled the study of subtle effects, in particular electron-electron and electron-phonon interactions in these materials resulting from the strong spatial confinement of excitons and reduced dielectric screening.

Studies of the electron-electron interaction were carried out in measurements of photoluminescence, photoluminescence excitation and reflectance contrast spectra in a wide temperature range. On the basis of the obtained results a comparative analysis of the observed exciton complexes was performed, which were interpreted in terms of binding energy, degree of spatial location and spin-valley configuration of the carriers included in the complex. Differences resulting from the opposite signs of splitting of the bottom of conduction band between molybdenum and tungsten compounds are presented and an explanation of the nature of the low energy lines observed in photoluminescence spectra of tungsten compounds is proposed. In the case of monolayer WS_2 a detailed analysis of the reflectance contrast spectra allowed to propose a diagram of the fine structure of the trion. Furthermore, it was observed that strong exciton-phonon coupling in TMDs leads to multiphonon photoluminescence up-conversion process. It was shown that this process strongly depends on the concentration of two-dimensional electron gas (2DEG). In the case of bulk crystal of ReS_2, a group of optical transitions was observed, which on the basis of polarization-resolved measurements were interpreted as two series of Rydberg excitons associated with the same energy gap. The energy dependence of ground states of both excitons as a function of the number of layers was analyzed.

The impact of the 2DEG concentration on the electron-phonon interaction was investigated in measurements of Raman scattering spectra of monolayers MoS_2. Under resonant excitation corresponding to the energy of the ground state of the A exciton, the *'b'*-mode resulting from the second order scattering process related to the successive emissions of the LA and TA phonons at K point of the two-dimensional Brillouin zone was observed. Based on the analysis of obtained Raman spectra, a strong dependence of the *'b'*-mode dispersion on 2DEG concentration was presented, which was tuned by change of the environmental conditions. In addition, by measuring photoluminescence and Raman scattering spectra on various substrates, the significant effect of the target substrate on 2DEG concentration in the two-dimensional structure was demonstrated.