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Raman scattering and photoluminescence studies of Bi_2Te_3/MoS_2 heterostructures

We report simultaneous study of optical phonons and excitons in Bi_2Te_3/MoS_2 heterostructures using Raman spectroscopy and photoluminescence (PL). Monolayer MoS_2 was grown on a SiO_2/Si substrate using chemical vapor deposition. Subsequently, topological insulator Bi_2Te_3 was directly fabricated on the monolayer MoS_2. Monolayer MoS_2 covered by the 40-nm-thick Bi_2Te_3 film was not seen under an optical microscope. In addition, Raman spectrum from the sample surface showed only the optical phonons of Bi_2Te_3 at 102 and 133 cm^{-1}, corresponding to the E_g^2 and A_{1g}^2 phonon modes, respectively. Interestingly, however, when the as-grown sample surface was exposed at moderate laser power density, optical phonons of monolayer MoS_2 were observed at 384 and 405 cm^{-1}, corresponding to the E_{2g}^1 and A_{1g} phonon modes, respectively. The observation of the optical phonons of MoS_2 was mainly due to a structural modification in Bi_2Te_3 under laser irradiation. With increasing the laser power density, a systematic change in the peak energy of the A_{1g} phonon mode was observed. In contrast, the E_{2g}^1 phonon mode did not show any noticeable changes in its peak energy. It is noted that the in-plane E_{2g}^1 phonon mode is sensitive to strain, while the out-of-plane A_{1g} phonon mode is affected by doping. Therefore, the optical phonon behaviors of MoS_2 indicate the variation in carrier density without structural deformation. To study the influence of the laser irradiation on the excitons in the Bi_2Te_3/MoS_2 heterostructures, laser-power dependent PL measurements were performed. The peak energies of the A and B excitons in MoS_2 varied systematically as a function of the laser power density, indicating that a band gap renormalization was occurred owing to the variation in carrier density. As a result, the correlated PL and Raman spectroscopy suggested that charge transfer might occur between Bi_2Te_3 and MoS_2. Our results demonstrated that laser irradiation could be utilized to modify structural and optical properties in Bi_2Te_3/MoS_2 heterostructures.

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