OPTICAL PROPERTIES OF MOLECULAR BEAM EPITAXY GROWN (Mo,Mn)Se_2 , $MoSe_2$, AND MnSe

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Doping non-magnetic semiconductors with magnetic ions such as Mn leads to formation of diluted magnetic semiconductors (DMS) e.g. (Cd,Mn)Te or (Ga,Mn)As. DMS exhibit enhanced magnetooptical properties and fascinating magnetic phenomena as for example carrier mediated ferromagnetism. Aim of this work is to answer if above concept can be applied to layered graphene-like two dimensinal (2D) materials, such as tranistion matal dichalcogenides (TMD). To study imapct of Mn ions on properties of TMD we have grown in the same conditions: undoped molybdenum diselenide ($MoSe_2$), molybdenum diselenide doped with manganese ((Mo,Mn)Se_2), and manganese selenide (MnSe) - as a reference. We used molecular beam epitaxy and two kinds of substrates: Si with polycrystalline SiO_2 buffer and Al_2O_3.

On Si/SiO_2 substrate we have grown a series of samples with various amount of deposited Mn, while amount of Mo and Se were kept constant (optimized for 1 monolayer of $MoSe_2$). Next, we investigated all samples using room temperature optical spectroscopy: Raman scattering and photoluminescence. We observe that characteristic Raman line of $MoSe_2$ at 241 cm^{-1} only weakly evolved with increasing amount of Mn, but other spectral lines appears in the Raman spectrum of (Mo,Mn)Se_2. Also, we found that the addition of manganese have not significantly altered the result of photoluminescence. There are only very weak effects of photoluminescence quenching. It is in contrary to most of diluted magnetic semiconductors, where Mn ions are known to induce effect of total photoluminescence quenching. What is new, for high amount of Mn, new photoluminescence bands appears. We have found that Si substrate with 90 nm thick SiO_2 buffer is very convenient for optical study of (Mo,Mn)Se_2, because of constructive optical interferences. On the other hand, such kind of polycrystalline buffer gives no hope for growth of large monocrystalline layers. This is why we decided to start work on Al_2O_3 substrates also.

Samples grown on c-plane Al_2O_3 were analyzed in situ using Reflection High Energy Electron Diffraction (RHEED). This technique confirmed that in particular conditions growth of well oriented crystals is possible. Further optical microscopy analysis showed that crystals have typical sizes of 1 micrometer, so structure is not a monocrystal. Thanks to transparency of Al_2O_3, transmittance measurements were performed on obtained layers.