Various approaches to transfer of epitaxial transition metal dichalcogenides and II-VI semiconductors to a transparent substrate

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Molecular beam epitaxy (MBE) provides an excellent way to produce layers of monocrystalline materials on dissimiliar substrates . The choice of the substrate is typically determined by the lattice constant and the crystalline order of the designed structure. However physical properties of substrates may significantly affect the experiments performed on epitaxial layers, e.g. opaque substrate limits the light transmission and contributes to the absorption. One way to solve this issue is to free the structure from the substrate by dissolving a sacrificial buffer layer and then lift-off and transfer the structure onto another transparent substrate. Here we present this approach applied for various systems such as layers of different materials and thicknesses, quantum wells, quantum dots containing single Mn ions [1] and semiconductor microcavities [2]. In each case the MgTe sacrificial buffer was deposited on the GaAs substrate prior to the growth of the final structure. To separate the structure from the substrate, the sample is glued to a quartz glass and immersed in deionized water for 2 hours. After rinsing, MgTe layer is removed by water and the glass plate with structure is lifted-off from the substrate. For all those structures we have examined their optical properties and none of them have not been quenched by the lift-off process. Even for such complicated structure as microcavity the optical experiments involving exciton polaritons were successfully carried out in a transmission regime.

In order to perform transmission electron microscope (TEM) investigations it is necessary to transfer the sample to a TEM grid. The method used by us is based on leveraging the penetration of water between hydrophobic $MoSe_2$ films and hydrophilic growth substrate [3]. Then we are able to lift off the film and dry transfer them to the TEM grid. The realization of this concept has been performed for 10 ML $MoSe_2$ sample grown by MBE on a sapphire substrate; it can possibly be applied for other systems.

Another method of transferring a layer from one substrate to another enables achieving large scale single monolayer of semiconducting material. The relevant procedure involves crack propagation in a layer-resolved splitting (LRS). We have grown 12 ML of 2H-$MoTe_2$ layer on the GaAs substrate, followed by several nanometers of nickel layer. Ni assists the top layer and prevents from propagating lateral splits. During lift-off of the stack of Ni/$MoTe_2$ the crack propagates in a way that most of a material remains attached to the Ni layer and the process can be repeated to obtain single layer of $MoTe_2$ [4]. The effective transfer was confirmed by Raman Spectroscopy studies revealing a proper position of a corresponding $MoTe_2$ peak.

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