Single photon emitters in exfoliated WSe_2 structures

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Crystal structure imperfections in solids often act as efficient carrier trapping centers which, when suitably isolated, act as sources of single photon emission. The best known examples of such attractive imperfections are well-width or composition fluctuations in semiconductor heterostructures (resulting in a formation of quantum dots) and colored centers in wide bandgap (e.g., diamond) materials. In the case of recently investigated thin films of layered compounds, the crystal imperfections may logically be expected to appear at the edges of commonly investigated few-layer flakes of these materials, exfoliated on alien substrates.

Here, we report on comprehensive optical microspectroscopy studies of thin layers of tungsten diselenide [1], WSe_2, a representative semiconducting dichalcogenide with a bandgap in the visible spectral range. At the edges of WSe_2 flakes, transferred onto Si/SiO_2 substrates, we discover centers which, at low temperatures, give rise to sharp emission lines [2] (down to 100 μeV). These narrow emission lines reveal the effect of photon antibunching, the unambiguous attribute of single photon emitters. The optical response of these emitters is inherently linked to two-dimensional properties of the WSe_2 monolayer, as they both give rise to luminescence in the same energy range, have nearly identical excitation spectra and very similar, characteristically large Zeeman effects. With advances in the structural control of edge imperfections, thin films of WSe_2 may provide added functionalities, relevant for the domain of quantum optoelectronics.

A firm identification of narrow line emission centers (NLECs) seen at the edges of the WSe_2 flakes is an obvious challenge. Our working hypothesis is that these NLECs consist of nano-sized, lateral fragments (nano-flakes) of a WSe_2 monolayer, which are apparently formed at the edges of exfoliated flakes of monolayers as well as WSe_2 multilayers. The appearance of such nanosized monolayer fragment (7 nm x 50 nm) at the edge of a thicker WSe_2 flake is demonstrated with scanning tunneling microscopy (STM) which we have performed on a WSe_2 flake exfoliated onto a graphene film grown on the silicon carbide substrate. Alternative hypotheses that our NLECs are due to some structural or other defects (though appearing in optical experiments as single objects) are to be tested in the future. Combined high resolution AFM or STM and optical experiments performed on the same edge locations is a possible route to shed more light on the origin of our NLECs.

[1] A. Arora, M. Koperski, K. Nogajewski, J. Marcus, C. Faugeras, M. Potemski, arXiv:1503.01682 (2015).
[2] M. Koperski, K. Nogajewski, A. Arora, J. Marcus, P. Kossacki, M. Potemski, arXiv:1411.2774 (2014).