Transition metal dichalcogenides and topological semimetals grown by molecular beam epitaxy – challenges and opportunities

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Molecular beam epitaxy (MBE) - an established method of growing thin crystalline layers and heterostructures embracing low dimensional structures of variety of materials can also be used for the growth of transition metal dichalcogenides (TMD) and topological semimetals, extensively investigated over the last decade. Investigations of both classes of materials have initially been based on specimens acquired from bulk crystals. The use of MBE opens a range of new opportunities related to the advantages of this growth technique, such as in-situ control of the growth regarding the thickness of deposited material, its crystalline perfection, surface smoothness, composition of multinary alloys, etc. Moreover formation of heterostructures combining different materials, even dissimilar in terms of crystallographic and electronic structure, magnetic properties, is quite straightforward with use of the MBE growth method.

I will review selected results of the efforts to grow by MBE thin layers of TMD Van der Waals materials: $MoTe_2$, $MoSe_2$, $NiTe_2$; and TaAs - the first experimentally realized topological Weyl semimetal (WSM). MBE growth of both groups of materials faces different challenges. In case of TMD the deposition of exactly one monolayer (ML) providing direct bandgap of semiconducting TMD has to be achieved. Moreover the effective protection of such an extremely thin layer is an issue, to prevent its degradation on exposure to ambient conditions after the growth in ultra-high vacuum MBE environment. This can be resolved by deposition of a suitable (transparent) capping layer.

Some TMD materials can occur in distinct crystalline phases (e.g. $MoTe_2$ with semiconducting 2H phase and metallic 1T' one). The occurrence of selected phase requires a fine tuning of the MBE growth conditions, in many cases the mixture of both phases can arise in the MBE-grown TMD layer.

For WSM (e.g,. TaAs) grown by MBE the key issue is the crystalline perfection and lateral uniformity of the grown film; indispensable for revealing unique WSM features related to topologically protected Weyl fermions.

The successful application of the MBE technique for deposition of TMD, WSM (and other topological materials not mentioned here) opens new research perspectives, hardly possible with use of specimens derived from bulk crystals. It also opens a way for applications of these materials in novel devices, since device technology is based on thin films rather than bulk crystals or crystalline flakes obtained by exfoliation.

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