Preface

Transition-metal dichalcogenides (TMDCs) are relatively old materials. The structure of one of the best studied materials, MoS_2, was determined back in 1923. Being layered materials, they share similarities with graphite and, as graphite, MoS_2 was mainly used as a dry lubricant, although it also had some 'electronic' applications, e.g. as an anode in lithium-ion batteries. Group IV TMDCs were a platform to study charge-density waves in low-dimensional solids, which still remains a very challenging research topic.

The situation changed after the discovery of graphene, for which in 2010 K.S. Novoselov and A.K. Geim were awarded the Nobel Prize. The success of graphene generated explosive interest in other two-dimensional materials, where the use of different elements opens novel opportunities for the exciting new physics and ultimately thin devices. Among them, TMDCs, which can be easily produced as monolayers, moved to the forefront of solid-state research due to their unique band structure featuring a large bandgap with degenerate valleys and non-zero Berry curvature. Two-dimensional TMDCs are often referred to as 'next-generation graphene' and 'wonder materials', which clearly demonstrates their place in modern science and technology.

The field has been developing at a fascinating pace. While in 2010 only two papers were published with 'MoS_2' and 'monolayer' as key words, in 2014 the number of papers exceeded 600. The interest in two-dimensional TMDC, triggered by the observation of a direct gap in monolayer MoS_2, rapidly spread to other TMDCs, especially semiconducting materials. Numerous topical reviews were published in the past couple of years, but they cover specific aspects of TMDCs and so far there is no single source of reference for this class of materials.

The present monograph, which originated from the personal notes taken by one of the authors (AK), closes the existing gap by presenting under a single cover the current status of progress in two-dimensional graphene-like monolayer and few-layer structures of TMDCs. Semiconducting monolayer TMDCs, due to the presence of a direct gap, significantly extend the potential of low-dimensional nanomaterials for applications in nanoelectronics and nano-optoelectronics as well as flexible nanoelectronics with unprecedented possibilities to control the gap by external stimuli. Strong quantum confinement results in extremely high exciton binding energies, which forms an interesting platform for both fundamental studies and device applications. Breaking of spacial inversion symmetry in monolayers results in strong spin–valley coupling potentially leading to their use in valleytronics.

Starting with the basic chemistry of chalcogens and transition metals, the reader is introduced to the rich field of TMDCs. After a chapter on three-dimensional crystals and a description of top-down and bottom-up fabrication methods of few-layer and single-layer structures, the fascinating world of two-dimensional TMDCs structures is presented with their unique atomic, electronic, and magnetic properties. Particular features associated with decreased dimensionality such as the phase-stability of monolayers, the appearance of a direct gap, large binding energy of two-dimensional excitons and their dynamics, Raman scattering associated with decreased dimensionality, extraordinary strong light–matter interaction, layer-dependent photoluminescence properties, new physics associated with the destruction of the spatial inversion symmetry of the bulk phase, spin–orbit and spin–valley coupling are all covered in detail. The monograph is concluded by chapters on engineered heterostructures and device applications. It is richly illustrated with almost 400 figures, most of which are in colour, and contains a list of over 1000 references.

The authors did their best to make a complete coverage of the results available to date, but were limited by several factors. First, this book has been written by experimentalists and for experimentalists. As a consequence, some of the theoretical papers are covered in less detail. Second, considering the vastness of the field and the very fast pace with which it is developing, it is inevitable that some of the publications have not been included in this volume. Since the authors of different original papers use somewhat different terminology and notations, the present authors had to make a choice between preserving the original terminology and making the terminology unified throughout the volume; both approaches having their own advantages and drawbacks. We have adopted the former approach, i.e. preserved the original terminology, providing some comments where it was necessary. Finally, the results obtained by different groups are occasionally contradictory; we tried to add cross-references wherever possible.

Considering the explosive interest in physics and applications of two-dimensional materials, this book will be a valuable source of information for materials scientists and engineers working in the field as well as for the graduate students majoring in materials science.

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