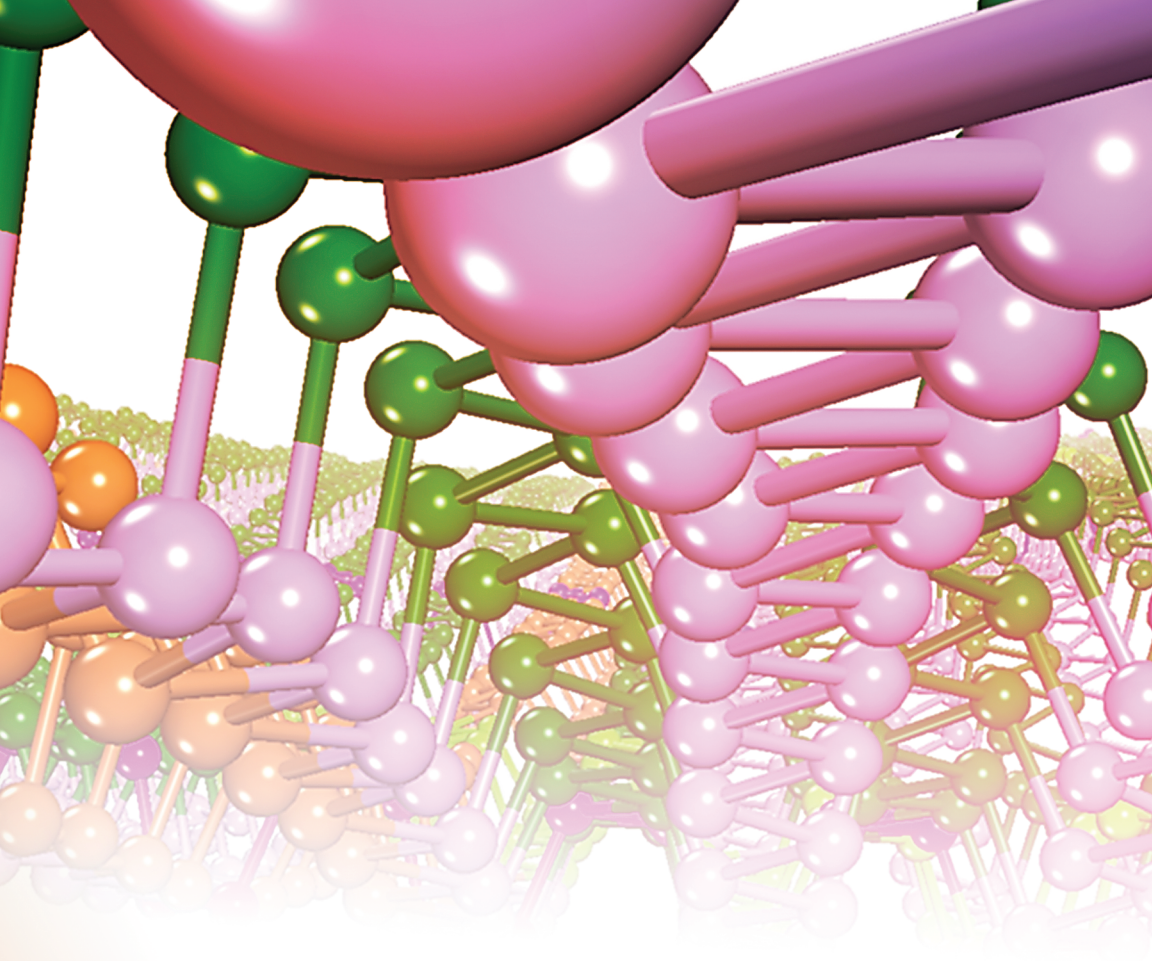

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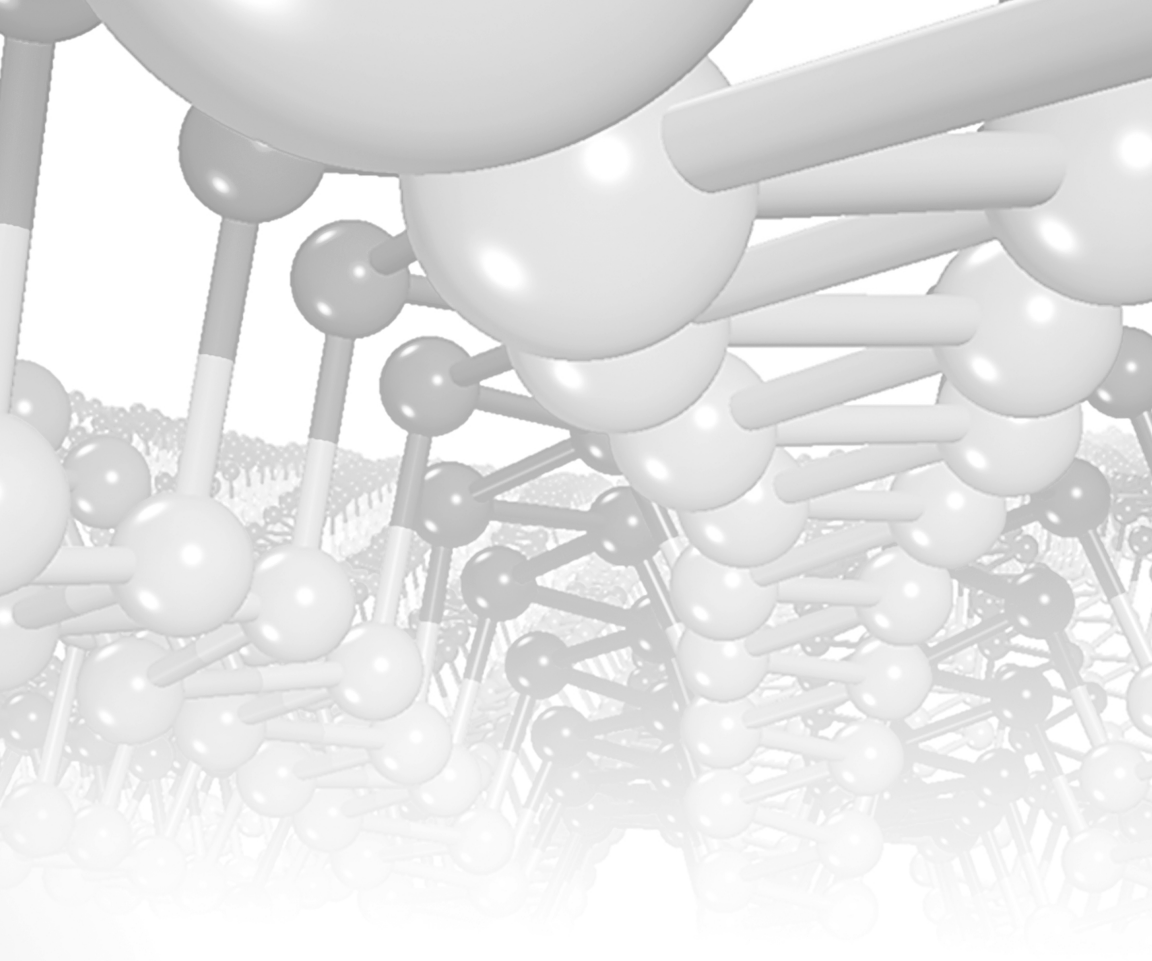

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Contents

Preface

A lot of efforts have been devoted to the growth, integration, and application of layered two-dimensional (2D) structures beyond graphene in the last ten years. Improvement in the technique for obtaining the high-quality flake has led to a variety of good-quality sheets and multilayer heterostructures, which are a prerequisite for device fabrication. After several years of intensive research on graphene, interests have gradually shifted toward other 2D materials, notably black phosphorus and molybdenum disulfide. In particular, phosphorene, a 2D form of black phosphorus, has attracted increasing attention due to its high carrier mobility (intrinsic p-type) up to 1000 $cm^2\ V^{-1}\ s^{-1}$ at room temperature and a sizable bandgap which is appropriate for a high ON–OFF ratio in transistors. As a cousin of graphene, phosphorene has a similar honeycomb structure, which is strongly puckered with ridge and accordion structures. The unique structure of phosphorene leads to intriguing electronic and optical properties.

This volume, written by theoretical and experimental experts in the field, is the first book devoted to a systematic discussion of the properties (including electronic, optical, and thermal behaviors), synthesis, and integration of phosphorene. We hope that researchers from various academic backgrounds will benefit from this volume. All the chapters in the book are self-contained, and each concerns a specific issue of the updated progress in the field of phosphorene. In what follows, we limit ourselves to a few general remarks.

The growth, exfoliation, and synthesis of phosphorene are given in Chapter 1. The synthesis of black phosphorus via a physical method (applying high pressure on white and red phosphorus) and chemical catalysis under low-pressure conditions are introduced in this chapter. The bottom-up and top-down methods for the

growth the phosphorene flakes are also discussed, followed by mechanical and liquid exfoliations. We also discuss the preparation of nanostructured phosphorene like quantum dots from bulk black phosphorus.

Chapter 2 discusses the methods of characterization, including the approaches for determining the number of layers by using Raman and photoluminescence spectroscopies. We introduce the characterization of few-layer phosphorene, including its layer number identification with phase-shifting interferometry (PSI) method, temperature- and angle-dependent Raman spectroscopy to detect their fine structure and crystalline orientation, layer- and power-dependent PL measurements to determine the band structure, and exciton and trion dynamics of thin-layer phosphorene.

Chapter 3 deals with some basic properties, including the structural, phononic, and defective characteristics of phosphorene. This chapter presents a good summary of the comparison of phosphorene with some other phosphorus polymorphs. The phononic vibrational modes of monolayer phosphorene and the rigid-layer modes of multilayer phosphorene are fully discussed, together with some experimental setups of Raman measurement. We also discuss the mechanical properties of phosphorene, and its structural transformation under high pressure. Lastly, the feature of point defect atomic vacancies of phosphorene is given.

Chapter 4 describes the recent advances in the study of thermal properties of monolayer and few-layer phosphorene. We first discuss some of the interesting features in the thermal conduction of monolayer and multilayer phosphorene and their underlying mechanisms. Next, we present recent understandings in developing phosphorene phononic crystal. Finally, we examine recent experimental works on the thermal conductivity of few-layer phosphorene.

Chapter 5 discusses the electronic and optical properties of phosphorene. The evolution of the bandgaps, and band alignment with the number of layers, electron–phonon coupling, and strain engineering of the electronic structures, renormalized electronic properties due to defects and dopant are presented. In addition, the effects of structural rippling, environmental small molecules, and passivating graphene/BN layers on the bandgap and carrier density

of the sheets are also discussed. Lastly, the intriguing excitonic and linear dichroism of phosphorene are introduced.

Chapter 6 deals with the electronic transport properties (mainly transistors) of phosphorene for device applications.

Chapter 7 discusses the promising applications of black phosphorus in energy storage. It also reviews oxygen productions, together with the structural degradation problems of phosphorene and potential strategies on the protection of phosphorene.

Yongqing Cai
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