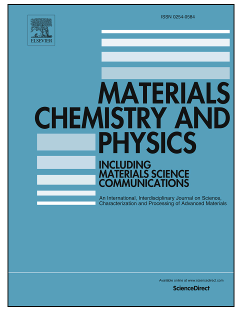
Accepted Manuscript



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PII: S0254-0584(16)30916-6

DOI: 10.1016/j.matchemphys.2016.12.014

Reference: MAC 19345

To appear in: *Materials Chemistry and Physics*

Received Date: 15 July 2016

Revised Date: 27 November 2016

Accepted Date: 11 December 2016

Recent advance in black phosphorus: properties and applications

Yun Zhao*[,a], Yong Chen[a], Ye-Hua Zhang[a], Shu-Feng Liu[a]

[a]School of Chemical and Environmental Engineering, Shanghai Institute of Technology, Shanghai 201418, China. Tel: +86-21-60873241; E-mail: zhaoyun@sit.edu.cn

Abstract: Black phosphorus (BP) atomic layers, also called phosphorene, has triggered a recent renaissance of interest owing to its unique structure as well as fascinating optical and electronic properties. Several good reviews have been published in the past two years either concerning its physical and mechanical properties or electronic and optoelectronic applications. Herein, we offer our opinions from chemists' viewpoints on this emerging two-dimensional (2D) nano-material. A relatively comprehensive summarization for the recent advances of phosphorene is given, including the basic properties, fabrication features and promising applications especially the applications in chemical and biochemical analysis which have not been so widely mentioned in the past works. We also briefly discuss the drawbacks and limitations of phosphorene, and give a short outlook on the future directions. This tutorial review will be a desirable enlightenment for the new coming researchers and also inspire the fellow researchers to explore more appealing chemical characteristics and potentials of phosphorene especially toward chemical sensing and biochemical applications.

Key Words: phosphorene, synthesis, application

1 Introduction

Two-dimensional nanomaterials have always been one of the hottest research topics for their outstanding potential applications in many fields such as flexible electronics,[1] sensing,[2, 3] and optics,[4] due to their desirable physical and structural properties.[5-7] Among those 2D materials, graphene, which was first peeled off with a clear tape from a chunk of graphite by Andre Geim and Konstantin in 2004,[8] is no doubt the most shining one. Last year, more than 10,460 papers focusing on graphene were published around the world, a number that has grown exponentially since its birth. Although graphene bears the highest charge carrier mobility,[9] it fails to act as a semiconductor for lack of a bandgap in its electronic structure.[10] This deficiency further hinder its practice in many applications, especially toward optoelectronic devices, thus urging scientists to move beyond graphene and seek new 2D materials with an intrinsic bandgap.[11]

Transition metal dichalcogenides (TMDCs), another major part in 2D material family, have also attracted warm attention. The monolayer structures of TMDCs typically consist of a plane of metal atoms sandwiched by two planes of chalcogens.[12, 13] Molybdenum disulfide (MoS_2), the most typical one originally synthesized in 2008,[14] possesses a noticeable