

# Black phosphorus has good application prospects in energy storage

Can black phosphorus be used for energy storage?

Black phosphorus is a potential candidate material for next-generation energy storage devices and has attracted tremendous interest because of its advantageous structural and electrochemical properties, including its large theoretical capacity, high carrier mobility, and low redox potential.

What are the advantages of black phosphorus?

Some of the great advantages of black phosphorus are the special structure with puckered layers, high theoretical capacity, enhanced charge carrier mobility and anisotropic in-plane properties. BP is expected to significantly improve the specific capacity without changing the basic performance of the batteries.

What is single- or few-layered black phosphorus?

Recently, a new two-dimensional material, single- or few-layered black phosphorus (BP), has attracted considerable attention for applications in electronics, optoelectronics, and batteries due to its unique properties, including large specific surface area, anisotropy, and tunable and direct band gaps.

What is black phosphorus?

Black phosphorus (BP) is a type of relatively novel and promising material with some outstanding properties, such as its theoretical specific capacity (2596 mAh/g) being approximately seven times larger than that of graphite as a negative material for batteries. Phosphorene, a one-layer or several-layer BP, is a type of two-dimensional material.

What is the specific capacity of black phosphorus?

In particular, black phosphorus has a folded structure, and each P atom can react with three Li or Na atoms to form  $\text{Li}_3\text{P}$  and  $\text{Na}_3\text{P}$ , giving it a very high theoretical specific capacity of 2596 mAh/g [31], which is far more than the graphite negative electrode (372 mAh/g) with its excellent energy storage properties.

Could black phosphorus open a new chapter for energy materials?

All in all, with persistent attempts by researchers around the world, it is out of question that black phosphorus would not only open a new chapter for a new generation of energy materials but also provide a remarkable market potential in the foreseeable future. There are no conflicts to declare.

Black phosphorus with a long history of ~100 years has recently attracted extraordinary attention and has become a promising candidate for energy storage and conversion owing to its unique layered structure, impressive carrier ...

This review has comprehensively presented the current progress of 2D BP materials with their synthesis, properties, and energy storage applications. In summary, the attractive properties (e.g., high mechanical strength, good ion conductivity) of thin-layer 2D BP allow it to be further studied for future energy storage

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applications.

Since phosphorene was mechanically exfoliated from bulk black phosphorus (BP) crystal in early 2014 [1,2], BP has been rediscovered from the perspective of a two-dimensional (2D) layered material, which has drawn considerable attention both in terms of fundamental research and in exciting potential applications, such as energy storage and conversion, ...

Black phosphorus with a long history of ~100 years has recently attracted extraordinary attention and has become a promising candidate for energy storage and conversion owing to its unique layered structure, impressive carrier mobility, remarkable in-plane anisotropic properties, and tunable bandgap from 0.3 eV in the bulk to 2.0 eV in the monolayer.

Beyond their exceptional structure, black phosphorus (BP) and phosphorene exhibit remarkable potential in various applications. Their favourable electrochemical properties and high theoretical specific capacity make them promising candidates for advanced lithium-ion batteries and efficient photovoltaic devices [32]. Notably, their sensitivity to chemical and physical stimuli ...

and the energy gap of 10-layer black phosphorus is very close to that of bulk material, and the energy band cleavage due to the interaction between layers is the direct cause of the decrease of ...

Two-dimensional black phosphorus: Properties, fabrication and application for flexible supercapacitors Author links open overlay panel Yaopeng Wu a, Wei Yuan a, Ming Xu a, Shigen Bai a, Yu Chen b, Zhenghua Tang b, Chun Wang a, Yang Yang a, Xiaoqing Zhang a, Yuhang Yuan a, Mingyue Chen a, Xing Zhang a, Bin Liu c, Lelun Jiang c

Recently, research on and the application of nanomaterials such as graphene, carbon nanotubes, and metal-organic frameworks has become increasingly popular in tissue engineering. In 2014, a two-dimensional sheet of ...

The energy densities of lithium/sodium ion batteries only reach ~ 260 W h kg<sup>-1</sup> or less when they are used for electric vehicles at present, which is insufficient to satisfy the urgent demand of high energy density and high ...

2.1.2. Fundamental properties. Among all the other 2D materials explored over the past few years like graphene, hexagonal- boron nitride (h-BN), MoS<sub>2</sub>, and WSe<sub>2</sub>, phosphorene has been considered as one of the best 2-D materials ...

Black phosphorus (BP), as a typical two-dimensional material, exhibits excellent lithium ion lithiation/delithiation properties when used in lithium-ion battery energy storage processes, primarily relying on the intercalation mechanism [6]. This intercalation mechanism provides a high specific capacity for

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lithium-ion batteries but does not meet the demand of high ...

Black phosphorus-based materials for energy storage and electrocatalytic applications, Xiong-Xiong Xue, Haiyu Meng, Zongyu Huang, Yexin Feng, Xiang Qi ... The latest recent advances of BP-based functional ...

The successful isolation of phosphorene (atomic layer thick black phosphorus) in 2014 has currently aroused the interest of 2D material researchers. In this review, first, the fundamentals of phosphorus allotropes, phosphorene, and black ...

Black magic: Recent advances in black phosphorus applications in energy conversion and storage are comprehensively reviewed. Black phosphorus possesses advantages such as tunable band gap, high carri...

Two-dimensional black phosphorus (2D BP) possesses huge potential in electrochemical energy storage field owing to its unique electronic structure, high charge carrier mobility, and large ...

Abstract: As a novel fine phosphorus chemical product, black phosphorus has a promising application prospect in energy storage due to its high theoretical specific capacity, high carrier mobility, and good conductivity. In recent years, many new technologies, methods, and strategies have been emerged for the preparation and energy storage application of black ...

As an emerging energy storage material, phosphorus has been attracting extensive attentions in recent years due to its fascinating electrochemical properties and favorable thermal stability. In this review article, its allotropes and their synthesis are introduced specifically.

Among them, black phosphorus has attracted attention because of its large theoretical specific capacity (2596 mA h/g). However, the moderate conductivity of black phosphorus itself makes it less effective. The addition of graphite to form P-C and P-O-C bonds with black phosphorus enhances the performance of the battery cell.

Biomedical applications of black phosphorus. ... and energy storage. There are two main approaches for the synthesis of BP: top-down and bottom-up approaches [69], ... Black phosphorus has emerged as a promising 2D material in the field of optoelectronics due to its unique electronic and optical properties. BP possesses a direct bandgap, which ...

Two-dimensional (2D) crystals have emerged as a class of materials that can impact future electronics (Li et al., 2014), with excellent electrochemical properties and a high specific surface area, which are ...

As a rising star in the family of two-dimensional (2D) materials, black phosphorus (BP) has recently attracted tremendous attention all over the world and demonstrated great potential in energy applications owing to its direct and narrow bandgap, high carrier mobility ...

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Black phosphorus with a long history of ~100 years has recently attracted extraordinary attention and has become a promising candidate for energy storage and conversion owing to its...

The article highlights the potential applications of these materials in energy storage (e.g., high-capacity batteries), flexible electronics (e.g., bendable displays), environmental sensing, and ...

Black phosphorus (BP) is rediscovered as a 2D layered material. The experimental and theoretical progress of 2D BP on the basis of its preparation methods is presented. ... The good lithium-storage performance ...

Red phosphorus also has high theoretical specific capacity, similar to BP, but red phosphorus is non-conducting so that it cannot be used directly for energy storage. Distinct from red phosphorus, BP or phosphorene is a fairly good conductor of electricity, which exhibits mobility on the order of  $\sim 1000 \text{ cm}^2/\text{V/s}$  [19, 46, 47].

The atomic structure of layered BP as seen from different sides is shown in Fig. 2. Based on first-principles calculations, the  $sp^3$ -hybridized P atoms bond covalently and form the distinctive structure of BP (Fig. 2 a) [43]. The angle between two adjacent P atoms on the same atomic plane of a layer is  $98.15^\circ$ ; while that between two adjacent P atoms on adjacent planes ...

**The Mechanism of Lithium/Sodium Storage.** Red phosphorus and black phosphorus anodes have very similar lithiation/sodiation reaction mechanism, both of which can form  $\text{Li}_3\text{P}/\text{Na}_3\text{P}$  in a fully discharged state, thus having a high theoretical specific capacity of  $2596 \text{ mAh/g}$  [59,60,61]. Unlike lithiation in red phosphorus, which only involves a one-step ...

Few-layer black phosphorus (BP) is a two-dimensional material that has attracted intensive attention for application in energy storage and catalysis due to its large surface area, and good ...

Black phosphorus with a long history of ~100 years has recently attracted extraordinary attention and has become a promising candidate for energy ...

Catalysts 2022, 12, 1403 3 of 13 et al. takes black phosphorus as its active ingredient, and has the highest weight capacity among all known potassium ion anode materials [77].

Notably, black phosphorus quantum dots for solar cells the energy conversion efficiency could approach 20%, but not long-term thermal stability limits its wide application [109]. Lithium ion batteries (LIBs) have high energy storage, no memory effect, long cycle life and low

BP, phosphorene or their composite materials can significantly improve the performance of energy storage devices, e.g., mainly lithium ion batteries, sodium ion batteries ...

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