Smart devices, Flexible devices, High-performance batteries

Development of chemically synthesized boron monolayer (chemical borophene)

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Researchmap https://researchmap.jp/kambe?lang=en

Abstract

In this study, a two-dimensional material composed of a monolayered boron network (chemical borophene) was synthesized in a solution phase. This material represents an entirely new class of monolayer materials that contain neither transition metals nor carbon. X-ray diffraction and spectroscopic analyses revealed its structure and bonding states, demonstrating that it possesses anisotropic electronic properties that are metallic only within the plane. Furthermore, by inducing chemical reactions at the terminal sites of the chemical borophene, the emergence of liquid crystal functionality was confirmed. In addition, by controlling the migration of ions present between the layers, we successfully achieved a remarkable enhancement in capacitance performance.

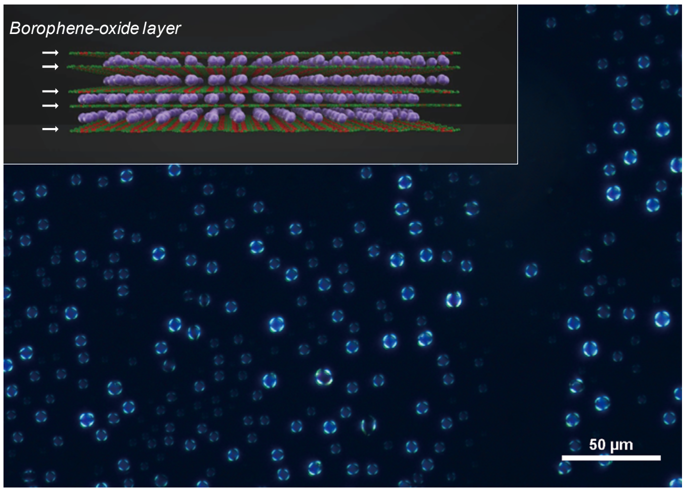
Background & Results

Inorganic materials generally have the superior thermal and chemical stability compared with organic liquid crystals, and they have been extensively studied for potential applications in various electronic devices. Among them, inorganic nanosheets have attracted considerable attention owing to their large surface area and ease of integration into device architectures. The synthesis of such inorganic nanosheets is well known through exfoliation from layered compounds, a method that has been actively investigated. In this study, we investigated the synthesis, structure, and properties of a boron-based monolayer material (chemical borophene). The feature of this material lies in its two-dimensional structure with a true monolayer thickness, making it more analogous to atomically thin materials such as graphene than to conventional inorganic nanosheets.

The borophene-like layered structure was synthesized through a controlled partial oxidation reaction of potassium borohydride, in which the reaction rate and crystallization kinetics were precisely regulated to form a layered crystalline structure. When the crystal was heated, it changed from crystal to liquid crystal. An electrically driven optical device was fabricated using this chemical borophene liquid crystal, and its performance was evaluated. Upon applying a voltage of more than 1 V to the liquid crystal, a dynamic scattering behavior emerged, enabling the construction of an optical device based on this phenomenon. Furthermore, when the liquid crystal was introduced between electrodes, the capacitance was found to increase by more than 10^5 times, demonstrating an extraordinary enhancement of electrostatic storage capability.

Significance of the research and Future perspective

Two-dimensional materials of main-group elements have attracted considerable attention as post-graphene materials, however, they have suffered from stability issues. The chemical borophene developed in this study can be synthesized under ambient pressure, and its composition can be tuned by substituting constituent elements. These advantages suggest significant potential for further material development. Moreover, this is the first inorganic material known to exhibit liquid-crystalline behavior in the absence of any solvent, opening up possibilities for liquid-crystal devices capable of operating under harsh conditions. In addition, the capacitance enhancement feature points toward future applications, including high-performance capacitors and responsive electronic components.



The structure of the chemical borophene and the polarized optical microscope image of its liquid crystal

Patent	Japanese Unexamined Patent Publication No.2022-151934, Japanese Patent No.6829920, 6656564, PCT/JP2019/003380, Japanese Patent No.6656563
Treatise	Kambe, Tetsuya et al. Capacitance enhancement by ion-laminated borophene-like layered materials. Nature Communications. 2025, 16, 1073. doi: 10.1038/s41467-024-55307-6 Kambe,Tetsuya et al. Liquid crystalline 2D borophene oxide for inorganic optical devices. Nature Communications. 2022, 13, 1037. doi: 10.1038/s41467-022-28625-w
URL	http://www.chem.eng.osaka-u.ac.jp/masaoka_lab/english/index.html
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