Protection of the Optical Properties of Few Layer 2D Phosphane

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Over the past year, the discovery and development of 2D black phosphorous (2D Phosphane) has generated much excitement due to its high carrier mobility, strong anisotropy, and direct bandgap. 2D phosphane's bandgap exhibits a significant layer dependency allowing for tunability from 0.3 eV (bulk) to 2 eV (monolayer), making it a versatile material for optical applications. The primary issue preventing the integration and development of 2D phosphane is the material's ambient degradation. In the presence of light, water, and oxygen, black phosphorous undergoes a rapid photoassisted oxidation reaction resulting in the destruction of its electronic and optical properties. This project characterizes this ambient degradation by photoluminescence and goes on to demonstrate an effective method of protecting the crystal's optical properties with the use of thin layered hexagonal boron-nitride (h-BN). This project paves the way for the future use of 2D phosphane in a variety of different optical applications and devices.

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Introduction

Motive: Black Phosphorous (BP) is an exciting new 2D material with great promise due its extraordinary electrical and optical properties. Unfortunately, BP experiences severe degradation under ambient conditions.

Objective: Develop a method of protecting the crystal such that its photoluminescence is preserved, allowing it to be utilized in future optical projects.

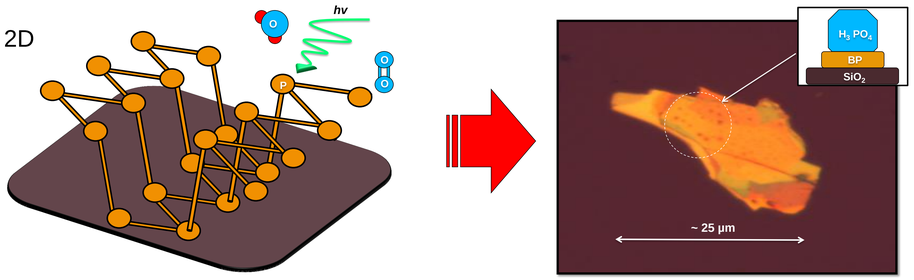


Fig.1. Light, water, and oxygen interact with phosphorous to form oxidized black phosphorous (P_xO_y) and eventually phosphoric acid (H_3PO_4)[1].

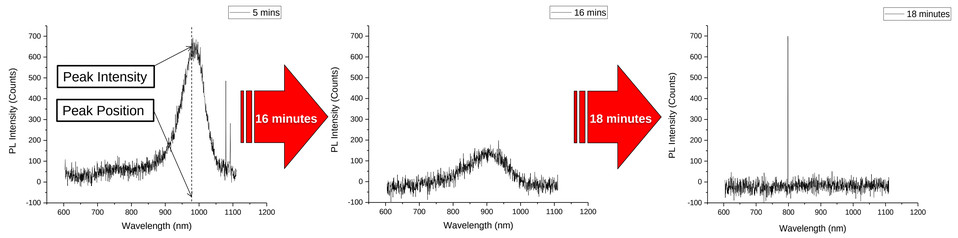
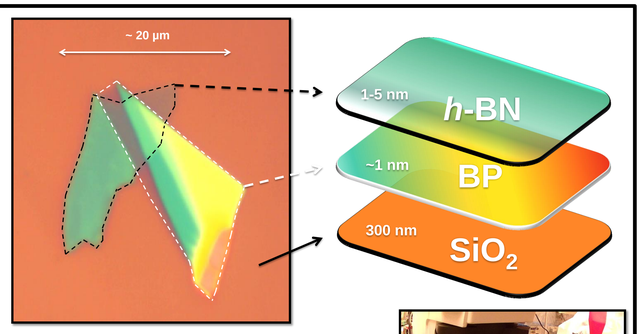
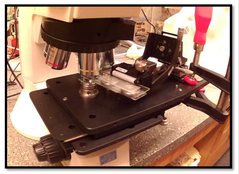


Fig. 2. Decaying PL intensity and peak blue shift indicate crystal degradation.

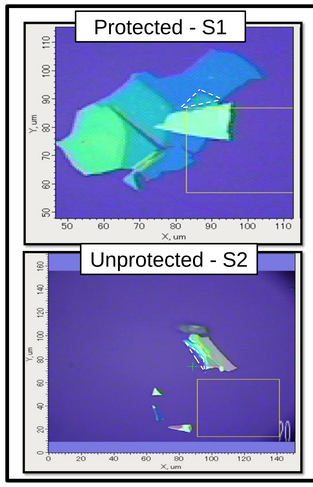
Protection Method



Method: Thin (1-5 nm) *h*-BN crystals are set on bi- and mono-layer BP using viscoelastic stamping and micromanipulator.



Results



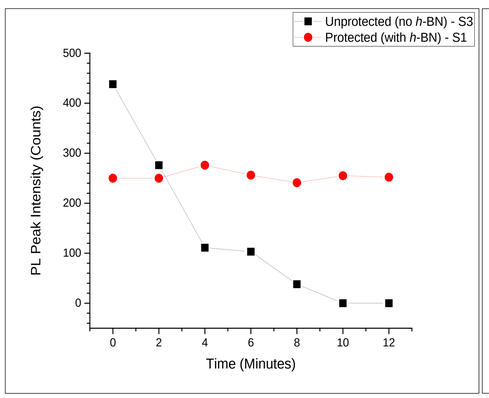


Fig. 3. The unprotected sample (black) exhibits rapidly decaying photoluminescence intensity.

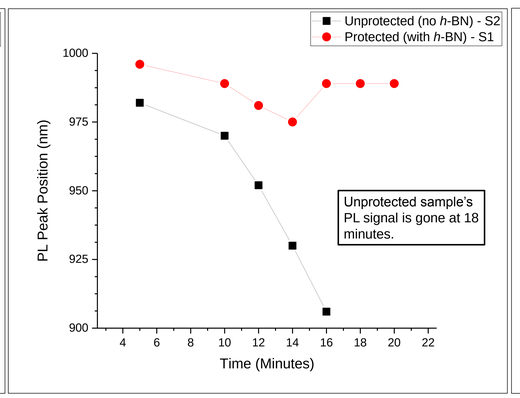


Fig. 4. The unprotected sample (black) exhibits degradation indicated by blue shift.

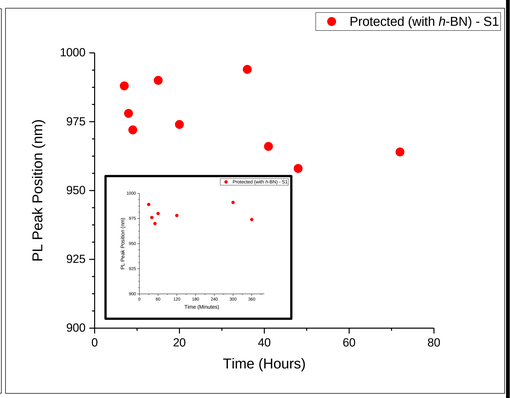
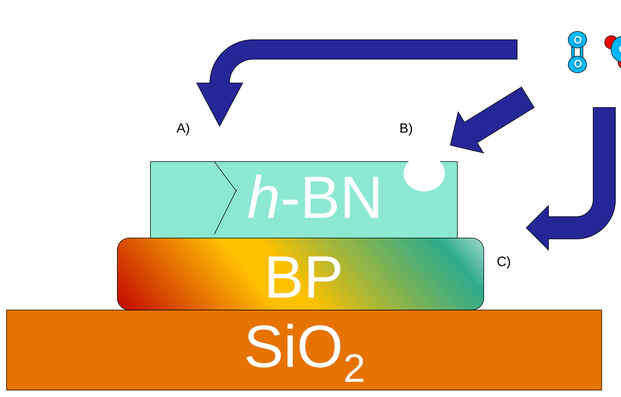


Fig. 5. Long term PL peak position (nm) stability of the *h*-BN protected sample up to 72 hours. Inset is first 6 hours.

Future Studies



A) Structural Defects

B) Nitrogen Vacancies

C) Lack of Full Coverage

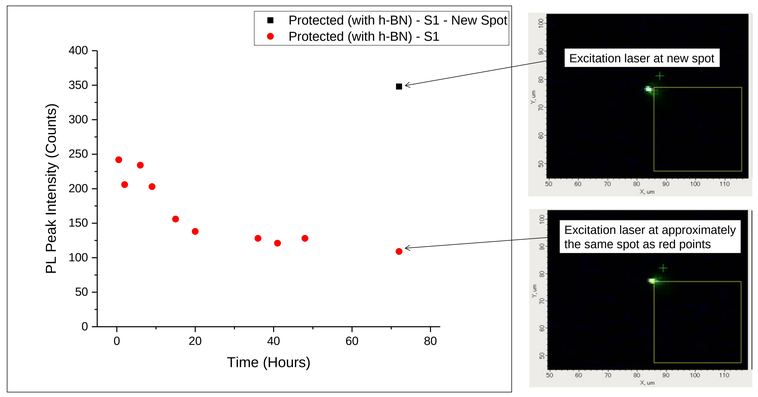


Fig. 6. Laser induced degradation and different crystal excitation points

Conclusion

In this work, bi-layer black phosphorus crystals have been successfully protected for 24 hr+ by implementing protective layers of *h*-BN. Photoluminescence was measured from samples for up to 72 hours. This work will enable future optical measurements and applications of few layer black phosphorus.

Acknowledgments

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