Nanoscale materials for electronics and optoelectronics

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We explore nanoscale semiconducting materials (transition metal oxides, dichalcogenides and elemental 2D Materials) through understanding fundamentals, engineering defects and deploying them in various electronic and optoelectronic applications.

We have had an emphasis on Black-phosphorus (BP) that has emerged as a material of interest owing to its high carrier mobility and the presence of an intrinsic direct bandgap. However, the ambient instability of BP remains the biggest hurdle in its progress. Here, we present a systematic investigation of the origins of oxidative degradation in few-layer black phosphorus (BP). Subsequently, we also propose an ionic liquid-based approach to prevent ambient degradation of BP.

First, we conducted an in-depth investigation into the origins of degradation revealing that oxidation due to light causes degradation whereas humidity on its own does not cause any material and acts merely as a facilitator of photo-oxidation.

Subsequently, we determine the influence of discrete wavelengths ranging from UV to infrared on the degradation of BP. It is shown that the UV component of the spectrum is primarily responsible for the deterioration of BP in ambient conditions. Based on these results, new insights into the degradation mechanism have been generated which will enable the handling and operating of BP in standard laboratory environments.

Finally, we designed an approach that allows this sensitive material to remain stable without requiring its isolation from the ambient environment. We employ imidazolium-based ionic liquids (ILs) as quenchers of damaging oxidative species on the BP surface. This chemical sequestration strategy allows BP to remain stable for over thirteen weeks, while retaining its key electronic characteristics.

Besides, fundamental studies on the degradation of BP, we have explored plasma thinning and defect engineering of BP layers to reveal exciting optoelectronic properties governed by defects which we have exploited to create all-optical synapses and perform logic operations.

References

1. T. Ahmed et al “Optically stimulated artificial synapse based on layered black phosphorus” Accepted 2019 smll.201900966
2. T. Ahmed, et al “Degradation of black phosphorus is contingent on UV–blue light exposure,” Nature Partner Journal: 2D Materials and Applications 18 (2017)