PHYS.ORG

Black phosphorus reveals its secrets

June 2 2015

A team of researchers from Université de Montréal, Polytechnique Montréal and the Centre national de la recherche scientifique (CNRS) in France is the first to succeed in preventing two-dimensional layers of black phosphorus from oxidating. In so doing, they have opened the doors to exploiting their striking properties in a number of electronic and optoelectronic devices. The study's results were published in the prestigious journal *Nature Materials*.

Black phosphorus: future key player in new technologies

Black phosphorus, a stable allotrope of phosphorus that presents a lamellar structure similar to that of graphite, has recently begun to capture the attention of physicists and materials researchers. It is possible to obtain single atomic layers from it, which researchers call 2D phosphane. A cousin of the widely publicized graphene, 2D phosphane brings together two very sought-after properties for device design.

First, 2D phosphane is a semiconductor material that provides the necessary characteristics for making transistors and processors. With its high-mobility, it is estimated that 2D phosphane could form the basis for electronics that is both high-performance and low-cost.

Furthermore, this new material features a second, even more distinctive, characteristic: its interaction with light depends on the number of atomic layers used. One monolayer will emit red light, whereas a thicker sample will emit into the infrared. This variation makes it possible to manufacture a wide range of optoelectronic devices, such as lasers or detectors, in a strategic fraction of the electromagnetic spectrum.

A scientific first: preserving single-atom layers of 2D phosphane from degrading

Until now, the study of 2D phosphane's properties was slowed by a major problem: in ambient conditions, very thin layers of the material would degrade, to the point of compromising its future in the industry despite its promising potential.

As such, the research team has made a major step forward by succeeding in determining the physical mechanisms at play in this degradation, and in identifying the key elements that lead to the layers' oxidation.

"We have demonstrated that 2D phosphane undergoes oxidation under ambient conditions, caused jointly by the presence of oxygen, water and light. We have also characterized the phenomenon's evolution over time by using electron beam spectroscopy and Raman spectroscopy," reports Professor Richard Martel of Université de Montréal's Department of Chemistry.

Next, the researchers developed an efficient procedure for producing these very fragile single-atom layers and keeping them intact.

"We were able to study the vibration modes of the atoms in this new material. Since earlier studies had been carried out on heavily degraded materials, we revealed the as-yet-unsuspected effects of quantum confinement on atoms' vibration modes," notes Professor Sébastien Francoeur of Polytechnique's Department of Engineering Physics.

The study's results will help the world scientific community develop 2D phosphane's very special properties with the aim of developing new nanotechnologies that could give rise to high-performance microprocessors, lasers, solar cells and more.

More information: "Photooxidation and quantum confinement effects in exfoliated black phosphorus." *Nature Materials* (2015) DOI: 10.1038/nmat4299

Provided by University of Montreal