Blake Kasper

The material that could ignite a technological revolution

We are all familiar with *graphite* – the material used to make your pencil lead. You may even be aware that graphite can be pulled apart to obtain a single layer, one atom, thick known as *graphene*. In 2004 graphene was isolated for the first time. Since then, it has been much touted due to its unique properties and the technological advancements these properties could deliver. This is not without good reason due to a myriad of unique properties; it could revolutionize batteries, construction materials, and much more. Despite all its remarkable properties, graphene cannot do it all.

Graphene is a conductor; however, the basis for electronic and optoelectronic devices are semiconductors. Semiconductors are a class of materials that are circumstantially conductive. Each semiconductor has what is known as a band gap. If enough energy is applied to overcome the band gap, it will behave like a conductor.

The band gap can be used as a switch for electronics - an applied voltage larger than the band gap can turn a device on or off. It can also convert light to electricity as with solar cells or from electricity to light as with a laser.

Fortunately, in 2014, *phosphorene* – a single layer of black phosphorus – was isolated. Phosphorene has many of the properties that make graphene attractive, but it is a semiconductor. Furthermore, it is a semiconductor with a tunable *bandgap*. That is, the amount of energy required to make it conductive can be varied. This is a very exciting feature for design purposes. One of the primary factors determining phosphorene's bandgap is the number of phosphorene layers stacked on top of one another.

The number of layers has other important design implications as the number of layers also determines the heat conductivity of the black phosphorus. The heat conductivity must be known to understand how to design components that do not overheat during operation. This brings us to the purpose of this study - to determine the thickness of black phosphorus samples.

The thickness cannot be determined by regular means as there is no ruler small enough; rather than measurements on the scale of centimeters or even millimeters, the scale involved here is nanometers - one billionth of a meter. In this case, we will measure the thickness with a laser. A black phosphorus sample will be placed on a silicon wafer; the reflected light will be observed using an array of charged coupled devices - the same basic building blocks of a digital camera. The sample will be moved so that the laser is for one measurement incident on just the silicon substrate and for another will pass through the black phosphorus. Because the sample will block some of the reflected light, dependent on its thickness, the amount of light blocked can be used to determine the thickness.

This is an essential step in commercializing black phosphorus, which promises many new and exciting advances in electronics, communication, energy, and much more.

Supervisors: Jörgen Larsson and Eric Nilsson
Degree project 30 credits in Master of Science 2021
Department of Physics, Division of Atomic Physics, Lund University