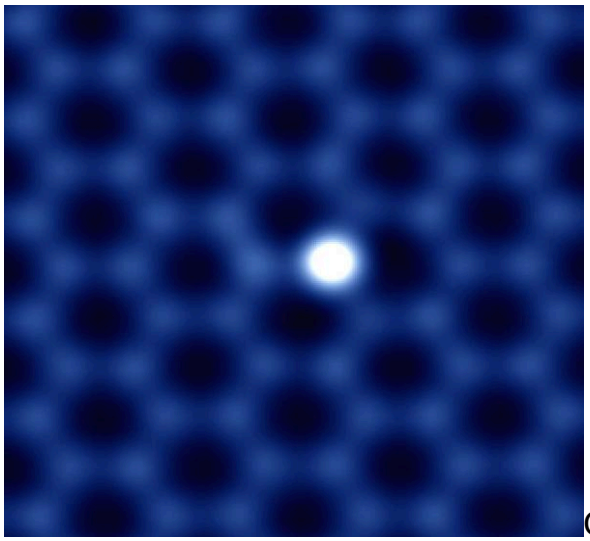
ORNL pushes the boundaries of electron microscopy to unlock the potential of graphene

Oak Ridge National Laboratory



OAK RIDGE, Tenn., Nov. 15, 2012 — Electron microscopy at the Department of Energy's Oak Ridge National Laboratory is providing unprecedented views of the individual atoms in graphene, offering scientists a chance to unlock the material's full potential for uses from engine combustion to consumer electronics.

Graphene crystals were first isolated in 2004. They are two-dimensional (one-atom in thickness), harder than diamonds and far stronger than steel, providing unprecedented stiffness, electrical and thermal properties. By viewing the atomic and bonding configurations of individual graphene atoms, scientists are able to suggest ways to optimize materials so they are better suited for specific applications.

In a paper published in Physical Review Letters, a team of researchers from Oak Ridge National Laboratory and Vanderbilt University used aberration-corrected scanning transmission electron microscopy to study the atomic and electronic structure of silicon impurities in graphene.

"We have used new experimental and computational tools to reveal the bonding characteristics of individual impurities in graphene. For instance, we can now differentiate between a non-carbon atom that is two-dimensionally or three-dimensionally bonded in graphene. In fact, we were finally able to directly visualize a bonding configuration that was predicted in the 1930s but has never been observed experimentally," said ORNL researcher Juan-Carlos Idrobo. Electrons in orbit around an atom fall into four broad categories - s, p, d and f - based on factors including symmetry and energy levels.

"We observed that silicon d-states participate in the bonding only when the silicon is two-dimensionally coordinated," Idrobo said. "There are many elements such as

chromium, iron, and copper where the d-states or d-electrons play a dominant role in determining how the element bonds in a material."

By studying the atomic and electronic structure of graphene and identifying any impurities, researchers can better predict which elemental additions will improve the material's performance.

Slightly altering the chemical makeup of graphene could customize the material, making it more suitable for a variety of applications. For example, one elemental addition may make the material a better replacement for the platinum catalytic converters in cars, while another may allow it to function better in electronic devices or as a membrane.

Graphene has the potential to replace the inner workings of electronic gadgets people use every day because of its ability to conduct heat and electricity and its optical transparency. It offers a cheaper and more abundant alternative to indium, a limited resource that is widely used in the transparent conducting coating present in almost all electronic display devices such as digital displays in cars, TVs, laptops and handheld gadgets like cell phones, tablets and music players.

Researchers expect the imaging techniques demonstrated at ORNL to be used to understand the atomic structures and bonding characteristics of atoms in other two-dimensional materials, too.

The authors of the paper are Wu Zhou, Myron Kapetanakis, Micah Prange, Sokrates Pantelides, Stephen Pennycook and Idrobo.

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