Adding hydrogen to graphene

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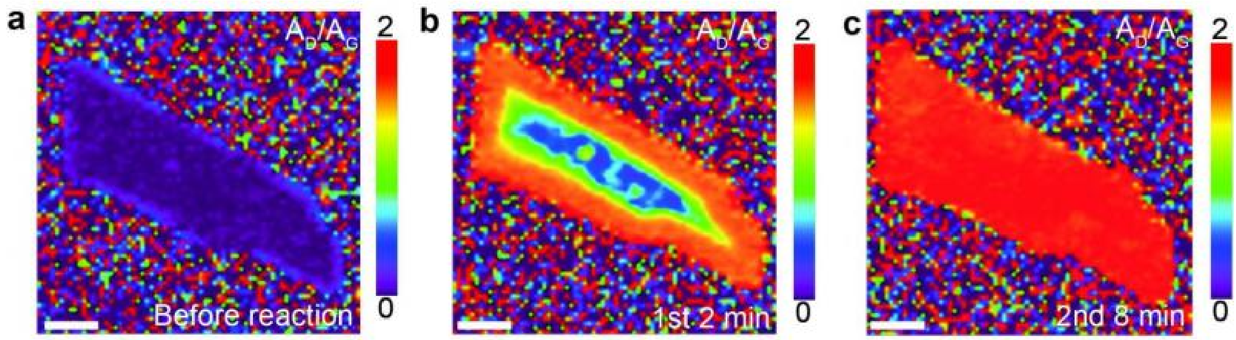

Hydrogenation (in red) of bilayer graphene via Birch-type reaction begins from the edges. The images show a graphene flake before (a), two minutes (b), and eight minutes (c), after exposure to a solution of lithium and liquid ammonia (Birch-type reaction). Graphene gets gradually hydrogenated starting from the edges. Credit: Zhang X et al, JACS, Copyright 2016 American Chemical Society

Adding hydrogen to graphene could improve its future applicability in the semiconductor industry, when silicon leaves off. Researchers at the Center for Multidimensional Carbon Materials (CMCM), within the Institute for Basic Science (IBS) have recently gained further insight into this chemical reaction. Published in *Journal of the American Chemical Society*, these findings extend the knowledge of the fundamental chemistry of graphene and bring scientists perhaps closer to realizing new graphene-based materials.

Understanding how graphene can chemically react with a variety of chemicals will increase its utility. Indeed, graphene has superior conductivity properties, but it cannot be directly used as an alternative to silicon in semiconductor electronics because it does not have a bandgap, that is, its electrons can move without climbing any energy barrier. Hydrogenation of graphene opens a bandgap in graphene, so that it might serve as a semiconductor component in new devices.

While other reports describe the hydrogenation of bulk materials, this study focuses on hydrogenation of single and few-layers thick graphene. IBS scientists used a reaction based on lithium dissolved in ammonia, called the "Birch-type reaction", to introduce hydrogen onto graphene through the formation of C-H bonds.

The research team discovered that hydrogenation proceeds rapidly over the entire surface of single-layer graphene, while it proceeds slowly and from the edges in few-layer graphene. They also showed that defects or edges are actually necessary for the reaction to occur under the conditions used, because pristine graphene with the edges covered in gold does not undergo hydrogenation.

Using bilayer and trilayer graphene, IBS scientists also discovered that the reagents can pass between the layers, and hydrogenate each layer equally well. Finally, the scientists found that the hydrogenation significantly changed the optical and electric properties of the graphene.

"A primary goal of our Center is to undertake fundamental studies about reactions involving carbon materials. By building a deep understanding of the chemistry of single-layer graphene and a few layer graphene, I am confident that many new applications of chemically functionalized graphenes could be possible, in electronics, photonics, optoelectronics, sensors, composites, and other areas," notes Rodney Ruoff, corresponding author of this paper, CMCM director, and UNIST Distinguished Professor at the Ulsan National Institute of Science and

Technology (UNIST).

More information: Xu Zhang et al. Birch-Type Hydrogenation of Few-Layer Graphenes: Products and Mechanistic Implications, *Journal of the American Chemical Society* (2016). DOI: 10.1021/jacs.6b08625

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