Imperfections may improve graphene sensors

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Although they found that graphene makes very good chemical sensors, researchers at the University of Illinois at Urbana-Champaign have discovered an unexpected "twist"—that the sensors are better when the graphene is "worse"—more imperfections improved performance.

"This is quite the opposite of what you would want for transistors, for example," explained Eric Pop, an assistant professor of electrical and computer engineering and a member of the interdisciplinary research team. "Finding that the less perfect they were, the better they worked, was counter intuitive at first."

The research group, which includes researchers from both chemical engineering and electrical engineering, and from a startup company, Dioxide Materials, reported their results in the November 23, 2011 issue of *Advanced Materials*.

"The objective of this work was to understand what limits the sensitivity of simple, two-terminal graphene chemiresistors, and to study this in the context of inexpensive devices easily manufactured by chemical vapor deposition (CVD)," stated lead authors Amin Salehi-Khojin and David Estrada.

The researchers found that the response of graphene chemiresistors depends on the types and geometry of their defects.

"Nearly-pristine graphene chemiresistors are less sensitive to analyte molecules because adsorbates bind to point defects, which have low resistance pathways around them," noted Salehi-Khojin, a research scientist at Dioxide Materials and post-doctoral research associate in the Department of Chemical and Biomolecular Engineering (ChemE) at Illinois. "As a result, adsorption at point defects only has a small effect on the overall resistance of the device. On the other hand, micrometer-sized line defects or continuous lines of point defects are different because no easy conduction paths exist around such defects, so the resistance change after adsorption is significant."

"This can lead to better and cheaper gas sensors for a variety of applications such as energy, homeland security and medical diagnostics" said Estrada who is a doctoral candidate in the Department of Electrical and Computer Engineering.

According to the authors, the two-dimensional nature of defective, CVD-grown graphene chemiresistors causes them to behave differently than carbon nanotube chemiresistors. This sensitivity is further improved by cutting the graphene into ribbons of width comparable to the line defect dimensions, or micrometers in this study.

"What we determined is that the gases we were sensing tend to bind to the defects," Pop said. "Surface defects in graphene are either point-, wrinkle-, or line-like. We found that the points do not matter very much and the lines are most likely where the sensing happens."

"The graphene ribbons with line defects appear to offer superior performance as graphene sensors," said ChemE professor emeritus and Dioxide Materials CEO Richard Masel. "Going forward, we think we may be able engineer the line defects to maximize the material's sensitivity. This novel approach should allow us to produce inexpensive and sensitive chemical sensors with the performance better than that of carbon nanotube sensors."