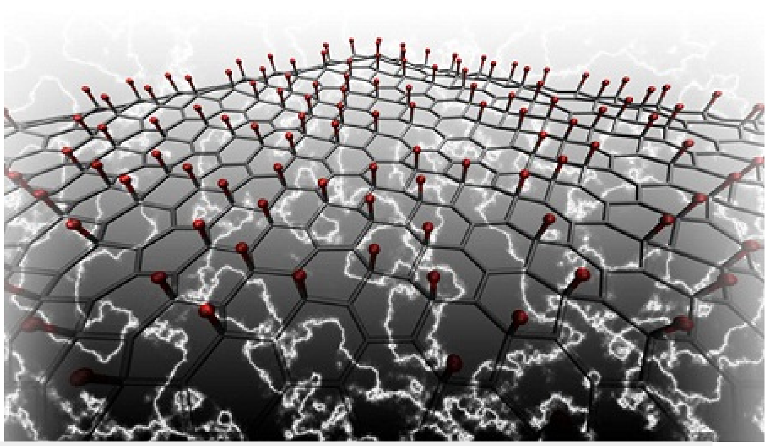
Docket #: S11-288

Designer Piezoelectricity in Graphene

Engineers at Stanford University have developed a technique for producing piezoelectric graphene that could be used to create two-dimensional “straintronic” materials for powering or controling nanoscale devices. This technology uses selective surface adsorption of atoms to confer piezoelectric properties to graphene. Then, by applying an electric field to the graphene, the user can strategically strain and deform the graphene in predictable ways at the nanoscale level. Conversely, the material could generate electricity when bent, squeezed or twisted. This piezoelectric graphene could provide an unparalleled degree of electrical, optical, or mechanical control for applications ranging from RF filters to touch-screens to nanoscale transistors and could lead to the development of revolutionary new devices including nanoelectromechanical transducers, nanoscale fluid pumps, sensors, energy harvesters, nanorobots, and other nano-locomotive devices.



Lithium atoms (red) adhered to a graphene lattice that will produce electricity when bent, squeezed, or twisted. Conversely, the graphene will deform when an electric field is applied

Stage of Development

Adsorption of atoms on graphene and application of external fields have been separately reduced to practice. Exhaustive simulations have characterized the piezoelectric effect for different dopant types and levels of coverage.

Validated Piezoelectric Effect: **Wu et al. 2014 Nature**

Applications

- **Ultrathin piezoelectric material** for nanoscale control of or harnessing electrical power for end-user devices such as:
  - RF filters and other Surface Acoustic Wave (SAW) devices
  - Nanoscale devices such as transistors, FETs, relays, nano-balloons, sensors and actuators, energy harvesters, nanoscale fluid transport, transducers, sensors, fluid pumps, nano-locomotive devices (nano-pistons, nanocars, nanorobots)

Advantages

- **Ultrathin, flexible material** - thickness of one atom creates two-dimensional piezoelectric layer effective for nanoscale devices
- **Dynamic, reversible control:**
  - selective doping allows materials to be deformed controllably
  - fine tuning of mechanical, chemical and electronic properties
- **Ultrahigh sensitivity** to displacements allows for nanomechanical sensors
- **High magnitude of piezoelectricity** - similar to traditional three dimensional materials
- **High conductivity** - graphene is 100 times better at conducting electricity than silicon

Publications

- Mitchell T. Ong, and Evan J. Reed, Engineered Piezoelectricity in Graphene, ACS Nano, 2012, 6 (2), pp 1387–1394, published online December 23, 2011, DOI: 10.1021/nn204198g
- Straintronics: Stanford engineers create piezoelectric graphene, Stanford News, April 3, 2012.

- A Roadmap for Engineering Piezoelectricity in Graphene, NERSC website, February 23, 2012.
- Dynamically controlling graphene's properties with engineered piezoelectricity, Nanowerk website, March 22, 2012.
- Engineering of Graphene Gives it Piezoelectric Properties, IEEE Spectrum Blog, March 16, 2012.
- Karel-Alexander N. Duerloo, Mitchell T. Ong, and Evan J. Reed, Intrinsic Piezoelectricity in 2D Materials, J. Phys. Chem. Lett., 2012, 3 (19), pp 2871–2876, published online: 17 Sep 2012, DOI: 10.1021/jz3012436.

Patents

- Published Application: 20140062255

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