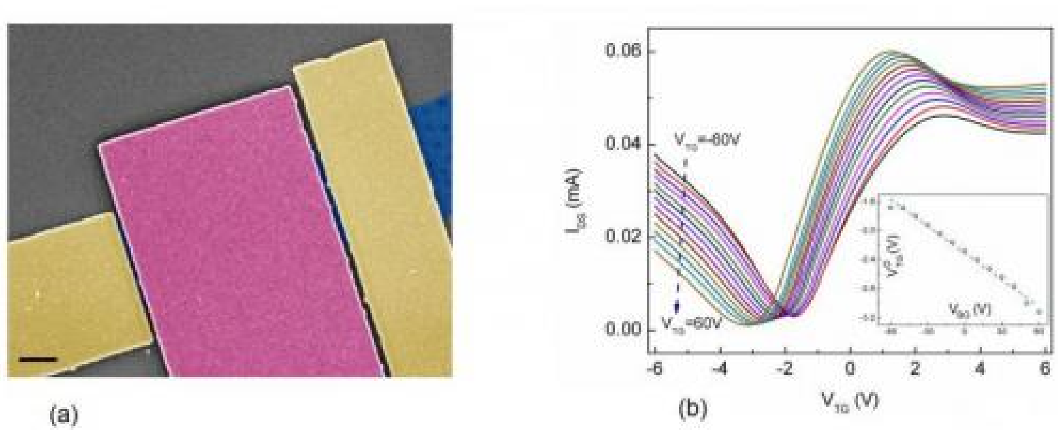
Researchers get around bad gap problem with graphene by using negative differential resistance

August 22 2013, by Bob Yirka



Experimentally observed negative differential resistance characteristics in graphene devices. (a) SEM of top-view SEM of a typical dual-gate graphene device. Gold color is the source/drain, pink color is the top gate and the blue color underneath is graphene flake. The gate and graphene channel is separated by a two-layer of AlOx and HfO2 oxide stack. The scale bar is 1μm. (b) The transfer characteristics of BLG device under different back-gate voltage. The increased resistance at large back-gate voltage indicated band gap opening by perpendicular electric field. The inset shows the Dirac point shift as the back-gate voltage changes. Credit: arXiv:1308.2931 [cond-mat.mes-hall]

(Phys.org) —A team of researchers at the University of California has come up with a way to use graphene in a transistor without sacrificing speed. In a paper they've uploaded to the preprint server *arXiv*, the team describes how they took advantage of a property of graphene known as negative differential resistance to coax transistor-like properties out of graphene without causing it to behave as a semiconductor.

As most everyone knows, using silicon as the basis for building transistors is reaching its logical conclusion—basic physics dictates that transistors based on it can only be made so small. Thus, efforts have been underway for several years to find a replacement material. One of the leading candidates, of course, is graphene—it has a variety of properties that would make it ideal, the best of which is the incredible speed in which electrons can move through it. Unfortunately, graphene is not a semiconducting material—it has no bad gap. That makes it useless as material for use in a transistor, which by its very nature must have a component that turns on and off. Graphene stays on all the time.

Researchers have spent a lot of time, money and effort trying to force graphene to behave like a semiconductor, but most efforts have either failed completely, or resulted in a slowdown of the movement of electrons—defeating the whole point of using grahene in the first now. Now, however, it appears the team at UC has found a way to use graphene in a transistor, without forcing it to have a band gap.

The researchers took advantage of a property of graphene known as negative differential resistance—this occurs when a charge is applied under certain conditions to a material and the overall voltage level of the circuit is reduced. Thus, instead of changing the way graphene behaves, the team found a way to use another of its properties. They used the drop in voltage as a logic gate, which of course is one of the basic components of a transistor.

The team hasn't built an actual transistor yet, but express optimism that it can be done. If they succeed, it could mean the creation of transistors that operate in the 400GHz range—orders of magnitude faster than today's silicon based technology, though they wouldn't appear in consumer products for at least ten years due to the need to completely change production processes.

More information: Graphene-Based Non-Boolean Logic Circuits, arXiv:1308.2931 [cond-mat.mes-hall] arxiv.org/abs/1308.2931

Abstract
Graphene revealed a number of unique properties beneficial for electronics. However, graphene does not have an energy band-gap, which presents a serious hurdle for its applications in digital logic gates. The efforts to induce a band-gap in graphene via quantum confinement or surface functionalization have not resulted in a breakthrough. Here we show that the negative differential resistance experimentally observed in graphene field-effect transistors of "conventional" design allows for construction of viable non-Boolean computational architectures with the gap-less graphene. The negative differential resistance - observed under certain biasing schemes - is an intrinsic property of graphene resulting from its symmetric band structure. Our atomistic modeling shows that the negative differential resistance appears not only in the drift-diffusion regime but also in the ballistic regime at the nanometer-scale - although the physics changes. The obtained results present a conceptual change in graphene research and indicate an alternative route for graphene's applications in information processing.

via Arxiv blog

Citation: Researchers get around bad gap problem with graphene by using negative differential resistance (2013, August 22) retrieved 23 April 2024 from https://phys.org/news/2013-08-bad-gap-problem-graphene-negative.html