

5

[Home](#)

Like

[Nanotechnology](#)

0

[Nanomaterials](#)[January 22, 2015](#)

+1

Graphene brings quantum effects to electronic circuits

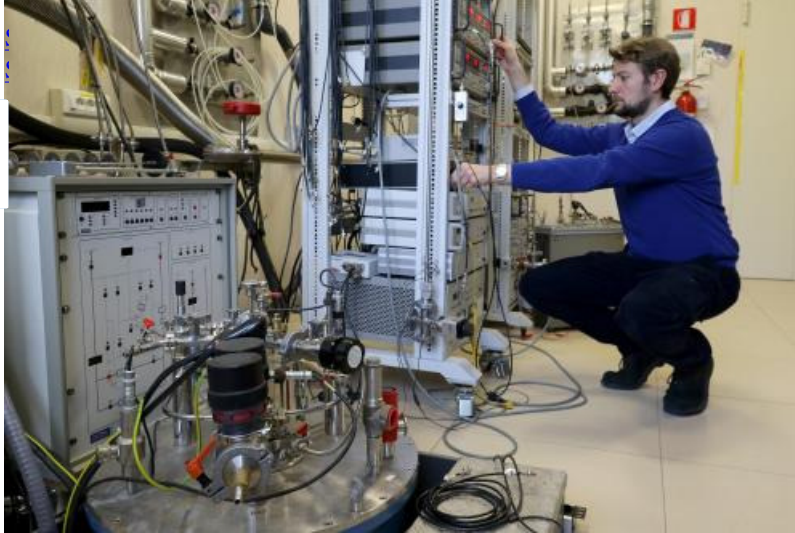
12

3 hours ago

Tweet

submit

reddit

[Enlarge](#)

Andrea Gamucci at work on the Heliox system for electrical measurements. Credit: Andrea Freccioni/Scuola Normale Superiore

Research by scientists attached to the EC's Graphene Flagship has revealed a superfluid phase in ultra-low temperature 2D materials, creating the potential for electronic devices which dissipate very little energy.

miniMOT

magneto-optical trap Cold
Atom Production
Simplified.



At the atomic and molecular scales, the world can be a very strange place, with everyday notions of temperature, energy and physical coherence thrown into disarray. With reality at the quantum level we must talk of statistical likelihood and probability rather than simple billiard ball cause and effect.

Take the concept of superfluidity, an ultra-cold state in which matter acts as a fluid with zero viscosity. You can think of superfluidity as a generalised thermodynamic analogue of the more commonly understood electrical superconductivity, whereby electrons move through materials without resistance and energy loss.

Superfluidity was first discovered in liquid helium, at temperatures of just a few degrees above absolute zero, but the phenomenon is evident at scales ranging from the atomic to the cosmic. It is related to the state of matter known as a Bose-Einstein condensate, in which a large fraction of the particles in bulk matter occupy the lowest quantum energy state. The particles, which at higher temperatures move around in a random, haphazard fashion, can in this way behave as a coherent or at least quasi-coherent whole, thus bringing quantum-mechanical effects into macroscopic visibility.

Fascinating if somewhat esoteric physics it may be, but there is a practical side to superfluidity and Bose-Einstein condensation. For one thing it has implications for the behaviour of electronic devices, albeit specialist ones operating at ultra-low temperatures. To this end a group of researchers associated with Europe's Graphene Flagship have investigated the properties of electrons moving in two-dimensional structures formed from graphene and [gallium arsenide](#).

Graphene is crystalline carbon arranged in transparent, single atom-thick layers, with the carbon atoms set in a honeycomb-like lattice. The best known of the hundreds of two-dimensional materials discovered to date, graphene has a number of unique electrical, mechanical and other properties that give it huge potential for applications ranging from electronics to super-strong structures.

Graphene Oxide

Single Layer Graphene Oxide ACS
Material--Your best choice



Focusing on measurements of Coulomb drag – the frictional coupling between electric currents in spatially separated conductors – researchers from the Graphene Flagship, led by Marco Polini of the Nanoscience Institute of the National Research Council and Scuola Normale Superiore in Pisa, Italy, Vittorio Pellegrini, at the Graphene Labs of the Italian Institute of Technology in Genova, and Andrea Ferrari of the Cambridge Graphene Centre, have found that the drag resistivity increases markedly at temperatures of less than around 5 Kelvin (-268.15 Celsius). This is an unexpected result, departing as it does from the usual temperature dependence displayed in weakly-correlated Fermi liquids: a theoretical model which describes the behaviour of most electrically conductive materials at ultra-low temperatures.

In a paper published recently in the journal *Nature Communications*, the first author of which is Andrea Gamucci, the researchers report on a new class of compound electronic structures in which single or bi-layer graphene is set in close proximity to a quantum well made from gallium arsenide.

A quantum well, formed from a semiconductor with discrete energy values, confines charged particle motion to a two-dimensional plane. Combining graphene with a quantum well results in a heterostructure formed from two different two-dimensional materials, and such a compound assembly may be used to investigate the interaction of electrons and electron holes. A hole is formed when an electron is excited into a higher energy state, leaving in its wake a quasi-particle which behaves as if it were a 'missing' electron, or an electron with positive rather than negative charge. Note that electron holes are not the same thing as the physically real anti-particles known as positrons.

In the case of the graphene-GaAs heterostructures reported in the *Nature Communications* paper, the Coulomb drag measurements are consistent with strong interactions between the material layers, with the attractive electrostatic force between electrons and holes in solid-state devices predicted to result in superfluidity and Bose-Einstein condensation. In other words, the strong interaction between material layers leads to quantum effects manifest in large ensembles of electrons and holes confined within micrometre-sized devices.

"We show that such effects may happen when electrons are confined in a thin well made of gallium arsenide, with holes confined in monolayer or bilayer graphene," says Polini. "Electrons and holes separated by a few tens of nanometres attract each other through one of the strongest forces exhibited in nature – the electrical force. At sufficiently low temperatures, our experiments reveal the possible emergence of a superfluid phase, in which opposite currents flow in the two separate two-dimensional systems." Pellegrini continues: "Such currents flow with minimal dissipation, and may make possible a number of coherent electronic devices which dissipate little energy." Ferrari adds: "This is another example of cutting edge results enabled by the deterministic assembly of graphene and other two-dimensional structures, which is precisely the overall target of the Graphene Flagship."

Superfluidity and Bose-Einstein condensation are ultra-low temperature phenomena, so the effects described here in graphene-gallium arsenide heterostructures will not apply to everyday [electronic devices](#). Still, there are many applications which require the use of cryogenically-cooled electronics, and these could exploit anomalous low-temperature Coulomb drag in bulk [two-dimensional materials](#).

Examples of such applications include high-performance and quantum computing, spectroscopy, magnetic and infrared sensing, and analogue-to-digital conversion. The discovery of the Graphene Flagship researchers outlined here could benefit these technology areas and more.

Explore further: [Fractional quantum Hall effect: Experimental progress and quantum computing applications](#)

More information: A. Gamucci, D. Spirito, M. Carrega, B. Karmakar, A. Lombardo, M. Bruna, L. N. Pfeiffer, K. W. West, A. C. Ferrari, M. Polini & V. Pellegrini, "Anomalous low-temperature Coulomb drag in graphene-GaAs heterostructures", *Nature Commun* 5:5824 (2014). DOI: [10.1038/ncomms6824](https://doi.org/10.1038/ncomms6824)

Journal reference: [Nature Communications](#)

Provided by Graphene Flagship

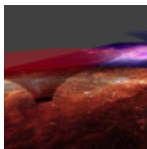
-
-
-
-

•

[view popular](#)

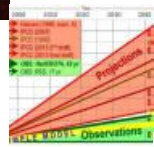
5/5 (1 vote)

- [Featured](#)
- [Popular](#)
- [Most shared](#)



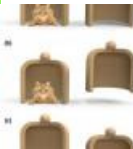
[In theory, the Milky Way could be a 'galactic transport system'](#)

Jan 21, 2015 32



[Peer-reviewed pocket-calculator climate model exposes serious errors in complex computer models](#)

21 hours ago 62



[Atoms can be in two places at the same time](#)

Jan 20, 2015 38



[Laser-generated surface structures create extremely water-repellent metals](#)

Jan 20, 2015 4



[Scientists tame Schrodinger's cat for a new type of quantum computer](#)

Jan 19, 2015 21

Phys.org



Segui

+1

+ 91.365

[Phys.org on facebook](#)

Like Sandro Mignuzzi, Pasquale Pq Cilibrio and 894,006 others like this.

Relevant PhysicsForums posts

[Process in which catalytic Agent provides -OH or -O \(Epoxy\)?](#)

1 hour ago

[why so much o2 left after So2 to so3 conversion](#)

Jan 21, 2015

[Stability of SU-8 Pillars](#)

Jan 20, 2015

[Composite ply layup notation](#)

Jan 19, 2015

[What happened to the photoresist \(S1818\) after RIE?](#)

Jan 18, 2015

[Equilibrium modelling in kraft mills](#)

Jan 16, 2015

More from [Materials and Chemical Engineering](#)**UK Store Sells iPads & iPhones For Pennies**

Swoggi

**Retailers hate this! They don't want you to find out about this online s...**

MadBid.com

**For The Men: Signs A Woman Is Flirting With You**

MadameNoire

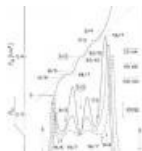
**10 Things You Didn't Know About Area 51!**

RIPBird

Sponsored Links by Taboola

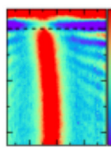
- [Top](#)
- [Send Feedback](#)

Related Stories

[Fractional quantum Hall effect: Experimental progress and quantum computing applications](#)

Jan 06, 2015

The Hall effect, discovered in 1879, is observable when a Hall voltage perpendicular to the current is produced across a conductor under a magnetic field. Although the Hall effect was discovered in a sheet ...

[Graphene plasmons go ballistic](#)

Jan 12, 2015

Squeezing light into tiny circuits and controlling its flow electrically is a holy grail that has become a realistic scenario thanks to the discovery of graphene. This tantalizing achievement is realized ...

[Graphene multiplies the power of light](#)

Jan 19, 2015

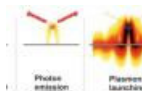
Recommended for you ... the efficiency? Scientists have shown that graphene can convert a single photon into multiple electrons, showing much promise for future photovoltaic devices.

[The importance of building small things](#)[User comments](#) [atomically thin materials](#)



40 minutes ago

Please [login](#) to add a comment. Registration is free, and takes less than a minute. [Read more](#)

Strong materials, such as concrete, are usually heavy, and lightweight materials, such as rubber (for latex gloves) and paper, are usually weak and susceptible to tearing and damage. Junia R. Green, professor...
When it comes to engineering single-layer atomic structures, "minding the gap" will help researchers create artificial electronic materials one atomic layer at a time, according to a team of materials scientists. ...



[Transparent artificial nacre: A brick wall at the nanoscale](#)[Graphene enables all-electrical control of energy flow from light emitters](#)

2 hours ago

  Natural materials have extraordinary mechanical properties, which are based on sophisticated arrangements and combinations of multiple building blocks. One key aspect of today's materials research therefore ...

At the heart of lasers, displays and other light-emitting devices lies the emission of photons. Electrically controlled modulation of this emission is of importance in applications such as optical communication, ...

[New conductivity in flexible touchscreens](#)

  [Graphene sandwich for next generation electronics](#)

Jan 21, 2015

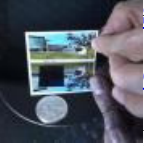
Sep 08, 2014


Mobile phones and smart phones still haven't been adapted to the carrying habits of their users. That much is clear to anyone who has tried sitting down with a mobile phone in their back pocket: the display of creating high-frequency electronic devices, University of Manchester scientists have found.

More news stories

[Self-assembled nanotextures create antireflective surface on silicon solar cells](#)

[Gold 'nano-drills'](#)

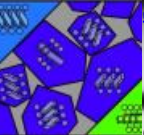
 Spherulite particles are aligned in the surface of solar cells helps maximize the conversion of the sun's rays to electricity equipment with nanopores for DNA analysis, for example. Now scientists ...

 [A contractile gel that stores light energy—and can tell who you are \(Update\)](#)

By [Jan 21, 2015](#) such parameters as the force applied by key presses and the time interval between them, a new self-powered non-mechanical intelligent keyboard could provide a stronger layer of security for computer ...

Living systems have the ability to produce collective molecular motions that have an effect at the macroscale, such as a muscle that contracts via the concerted action of protein motors. In order to reproduce ...

[The importance of building small things](#)

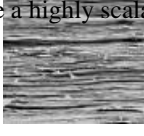
 [Solving an organic semiconductor mystery](#)


Jan 16, 2015

Strong materials, such as concrete, are usually heavy, and lightweight materials, such as rubber (for latex gloves) and paper, are usually weak and susceptible to tearing and damage. Julia R. Greer, professor ...


Organic semiconductors are prized for light emitting diodes (LEDs), field effect transistors (FETs) and photovoltaic cells. As they can be printed from solution, they provide a highly scalable, cost-effective ...

[Transparent artificial nacre: A brick wall at the nanoscale](#)

 Natural materials have extraordinary mechanical properties, which are based on sophisticated arrangements and combinations of multiple building blocks. One key aspect of today's materials research therefore ...

 [Graphene multiplies the power of light](#)


Could graphene turn light to electricity? Scientists have shown that graphene can convert a single photon into multiple electrons, showing much promise for future photovoltaic devices.

 [Researchers create stable gold\(III\) catalysts via oxidative addition of a carbon-carbon bond](#)


(Phys.org)—A team of researchers working at the University of California, has found a way to create stable gold(III) catalysts using oxidative addition of a carbon-carbon bond. In their paper published ...

[Study shows dying cells impact on surroundings causing changes to tissue shape and structure](#)


(Phys.org)—A study conducted by researchers affiliated with three major institutions in France has found that dying cells appear to cause more changes to surrounding tissue than has been previously thought. In their paper ...

 [Soils could keep contaminants in wastewater from reaching groundwater, streams](#)

With endocrine-disrupting compounds affecting fish populations in rivers as close as Pennsylvania's Susquehanna and as far away as Israel's Jordan, a new research study shows that soils can filter out and ...

 [Pumas in populated areas kill more and eat less](#)

Female pumas in areas with a high density of housing kill more deer but eat less of the carcasses than those in areas with little housing, finds a study in *Proceedings of the Royal Society B*.

 [How charter school foes are failing](#)



As charter schools continue to expand, new research indicates liberal opponents are failing to make effective arguments aimed at curbing the education reform movement.

-
-
-
-
-
-
-
-
-
-
- - [Profile](#)
 - [Newsletter](#)
 - [Favorites](#)
 - [Activity](#)
 - [PM](#)
 - [My news](#)
- [Sign In](#)
- [Register](#)
-
- [Physics](#)
 - [All Physics](#)
 - Previews will load in a moment
 - [General Physics](#)
 - Previews will load in a moment
 - [Condensed Matter](#)
 - Previews will load in a moment
 - [Optics & Photonics](#)
 - Previews will load in a moment
 - [Superconductivity](#)
 - Previews will load in a moment
 - [Plasma Physics](#)
 - Previews will load in a moment
 - [Soft Matter](#)
 - Previews will load in a moment
 - [Quantum Physics](#)
 - Previews will load in a moment
- [Nanotechnology](#)
 - [All Nanotechnology](#)
 - Previews will load in a moment
 - [Bio & Medicine](#)
 - Previews will load in a moment
 - [Nanophysics](#)
 - Previews will load in a moment
 - [Nanomaterials](#)
 - Previews will load in a moment
- [Earth](#)
 - [All Earth](#)
 - Previews will load in a moment
 - [Earth Sciences](#)
 - Previews will load in a moment
 - [Environment](#)
 - Previews will load in a moment
- [Astronomy & Space](#)
 - [All Astronomy & Space](#)
 - Previews will load in a moment
 - [Astronomy](#)
 - Previews will load in a moment
 - [Space Exploration](#)

- Previews will load in a moment
- [Chemistry](#)
 - [All Chemistry](#)
 - Previews will load in a moment
 - [Biochemistry](#)
 - Previews will load in a moment
 - [Polymers](#)
 - Previews will load in a moment
 - [Analytical Chemistry](#)
 - Previews will load in a moment
 - [Materials Science](#)
 - Previews will load in a moment
 - [Other](#)
 - Previews will load in a moment
- [Biology](#)
 - [All Biology](#)
 - Previews will load in a moment
 - [Plants & Animals](#)
 - Previews will load in a moment
 - [Evolution](#)
 - Previews will load in a moment
 - [Ecology](#)
 - Previews will load in a moment
 - [Cell & Microbiology](#)
 - Previews will load in a moment
 - [Biotechnology](#)
 - Previews will load in a moment
 - [Other](#)
 - Previews will load in a moment
- [Technology](#)
 - [All Technology](#)
 - Previews will load in a moment
 - [Internet](#)
 - Previews will load in a moment
 - [Software](#)
 - Previews will load in a moment
 - [Consumer & Gadgets](#)
 - Previews will load in a moment
 - [Hardware](#)
 - Previews will load in a moment
 - [Business](#)
 - Previews will load in a moment
 - [Robotics](#)
 - Previews will load in a moment
 - [Engineering](#)
 - Previews will load in a moment
 - [Semiconductors](#)
 - Previews will load in a moment
 - [Other](#)
 - Previews will load in a moment
 - [Telecom](#)
 - Previews will load in a moment
 - [Energy & Green Tech](#)
 - Previews will load in a moment
 - [Computer Sciences](#)
 - Previews will load in a moment
 - [Hi Tech & Innovation](#)
 - Previews will load in a moment
 - [Security](#)
 - Previews will load in a moment
- [Other Sciences](#)
 - [All Other Sciences](#)
 - Previews will load in a moment
 - [Mathematics](#)

- Previews will load in a moment
 - [Archaeology & Fossils](#)
 - Previews will load in a moment
 - [Other](#)
 - Previews will load in a moment
 - [Social Sciences](#)
 - Previews will load in a moment
 - [Economics & Business](#)
 - Previews will load in a moment
- [Medicine & Health](#)

-

- - [Top](#)
 - [Home](#)
 - [Medical Xpress](#)
 - [Search](#)
- - [Help](#)
 - [FAQ](#)
 - [About](#)
 - [Contact](#)
- - [Phys.org Account](#)
 - [Sponsored Account](#)
 - [Newsletter](#)
 - [RSS feeds](#)
- - [Feature Stories](#)
 - [Weblog & Reports](#)
 - [Podcasts](#)
 - [Archive](#)
- - [iPhone iPad Apps](#)
 - [Blackberry App](#)
 - [Android App & Widget](#)
 - [Amazon Kindle](#)
 - [PDA version](#)
-
-
-
-
-
-
- [Privacy Policy](#)
- [Terms of Use](#)