Graphene makes movement easy for electrons

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Researchers at The University of Manchester have found that electrons move more easily in graphene than all other materials, including gold, silicon, gallium arsenide and carbon nanotubes.

The work has implications for the future development of ultra-high frequency transistors and wiring in electronic circuits - and academics say their findings have singled graphene out as the "best possible" material for electronic applications.

With a high electronic quality - measured at around 200,000 cm^2/Vs and more than 100 times higher than for silicon - researchers believe graphene has the potential to improve upon the capabilities of current semiconductors and open up exciting new possibilities. These include ultra-high frequency detectors required for full-body security scanners, which would make people transparent by operating at terahertz (THz) frequencies.

The research is reported in the latest issue of the American Physical Society's journal *Physical Review Letters*, and has been carried out in conjunction with The Institute for Microelectronics Technology in Russia, The University of Nijmegen in the Netherlands and The Department of Physics at Michigan Technological University in the United States.

"The search is on for materials with higher electronic quality or intrinsic mobility, which should improve the existing applications and open up

new ones," said Professor Andre Geim, one of the paper's authors and director of The University of Manchester's Centre for Mesoscience and Nanotechnology.

"Graphene exhibits the highest electronic quality among all known materials - higher than copper, gold, silicon, gallium arsenide, carbon nanotubes, and anything we know. It is the only material where electrons at room temperature can move thousands of interatomic distances without scattering.

"We knew that it could be a long distances and longer than for silicon, but before our latest work we did not know, nor expected, that graphene could beat carbon nanotubes or the record holder Indium antimonide (InSb). Our work singles it out as the best possible material for electronic applications.

"Our findings mean it is worth investing even more effort to develop the material into viable products.

"Neither graphene nor carbon nanotubes can hope to compete with silicon for about another 20 years. The advantage of graphene is that it still holds a lot of promise, which must be investigated.

"The major problems for nanotubes do not exist for graphene. It does have its own problems but they seem doable at least, unlike those for nanotubes, which seemed impossible a few years ago and remain impossible now.

"Whatever comes out as applications, the physics is extremely rich and one can be sure that graphene is here to stay as long as silicon or gallium arsenide, with many more interesting effects to be found. Higher mobility will be a powerful facilitator."

Geim believes graphene-based devices like chemical gas sensors and THz sources and detectors could begin to materialise within three to five years.

Prof Geim added: "Our work puts fundamental limits on what can be potentially done by using graphene. Previously, researchers speculated that the sky was the limit for graphene's electronic quality. Now we know this limit accurately enough. It is not endless but sky-high."

Source: University of Manchester