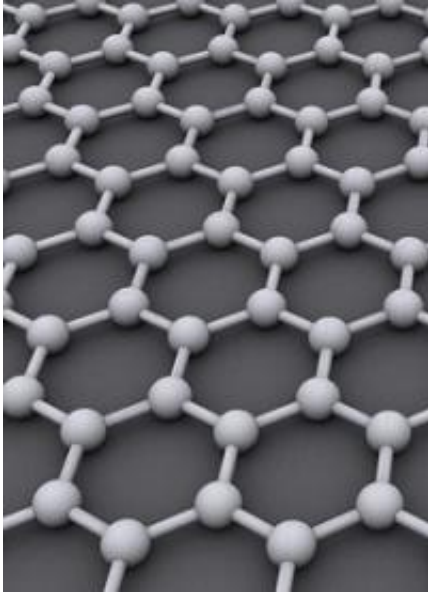


# A roadmap for graphene

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Graphene consists of a single layer of carbon atoms. Credit: Wikimedia Commons

Wonder material graphene could not only dominate the electronic market in the near future, it could also lead to a huge range of new markets and novel applications, a landmark University of Manchester paper claims.

Writing in *Nature*, Nobel Prize-winner Professor Kostya Novoselov and an international team of authors has produced a 'Graphene Roadmap' which for the first time sets out what the world's thinnest, strongest and most [conductive material](#) can truly achieve.

The paper details how graphene, isolated for the first time at The University of Manchester by Professor Novoselov and colleague Professor Andre Geim in 2004, has the potential to revolutionise diverse applications from smartphones and ultrafast broadband to [anticancer drugs](#) and [computer chips](#).

One key area is touchscreen devices, such as Apple's [iPad](#), which use [indium tin oxide](#). Graphene's outstanding mechanical flexibility and chemical durability are far superior. Graphene touchscreen devices would prove far more long-lasting and would open a way for [flexible devices](#).

The authors estimate that the first graphene touchscreen devices could be on the market within three to five years, but will only realise its full potential in flexible electronics applications.

Rollable e-paper is another application which should be available as a prototype by 2015 – graphene's flexibility proving ideal for fold-up electronic sheets which could revolutionise electronics.

Timescales for applications vary greatly upon the quality of graphene required, the report claims. For example, the researchers estimate devices including photo-detectors, high-speed wireless communications and THz generators (for use in [medical imaging](#) and security devices) would not be available until at least 2020, while anticancer drugs and graphene as a replacement for silicon is unlikely to become a reality until around 2030.

The paper also details the different ways of producing graphene – processes which have evolved hugely from the sticky tape method pioneered by the Nobel Laureates.

The paper asserts that there are three main methods for making

graphene:

- Liquid phase and thermal exfoliation – exposing graphite to a solvent which splits it into individual flakes of graphene. This method is ideal for energy applications (batteries and supercapacitors) as well as graphene paints and inks for products such as printed electronics, smart windows and electromagnetic shielding. Adding additional functionality to composite materials (extra strength, conductivity, moisture barrier) is another area such graphene can be applied.
- Chemical Vapour Deposition – growing graphene films on copper foils, for use in flexible and transparent [electronics applications](#) and photonics, among others.
- Synthesis on Silicon Carbide – growing graphene on either the silicon or carbon faces of this material commonly used for high power electronics. This can result in very high quality graphene with excellently-formed crystals, perfect for high-frequency transistors.

Professor Novoselov said: "Graphene has a potential to revolutionise many aspects of our lives simultaneously. Some applications might appear within a few years already and some still require years of hard work.

"Different applications require different grades of graphene and those which use the lowest grade will be the first to appear, probably as soon as in a few years. Those which require the highest quality may well take decades.

"Because the developments in the last few years were truly explosive, graphene's prospects continue to rapidly improve.

"Graphene is a unique crystal in a sense that it has singlehandedly

usurped quite a number of superior properties: from mechanical to electronic. This suggests that its full power will only be realised in novel applications, which are designed specifically with this material in mind, rather than when it is called to substitute other materials in existing applications.

"One thing is certain – scientists and engineers will continue looking into prospects offered by graphene and, along the way, many more ideas for new applications are likely to emerge."

His co-author Professor Volodya Falko, from Lancaster University, said: "By our paper, we aim to raise awareness of engineers, innovators, and entrepreneurs to the enormous potential of graphene to improve the existing technologies and to generate new products.

"To mention, in some countries, including Korea, Poland and the UK national funding agencies already run multi-million engineering-led research programmes aiming at commercialisation of [graphene](#) at a large scale."

**More information:** A roadmap for graphene, by K.S. Novoselov, V.I. Falko, L.Colombo, P.R. Gellert, M.G. Schwab and K.Kim, *Nature*, 2012.

Provided by University of Manchester

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