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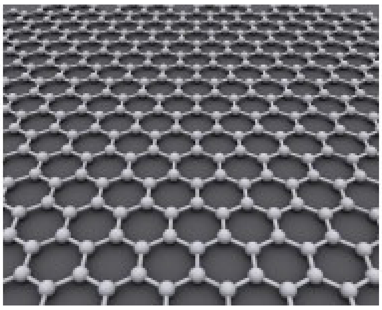
Graphene Inks at University of Cambridge



Researchers at the University of Cambridge lead by Prof. Andrea Ferrari have recently demonstrated a technique for producing inkjet-printable inks based predominantly on small (<1um) single-layer graphene flakes. This is an improvement over existing approaches, since this does not use the readily-soluble graphene oxide flakes, which act as electrically-defective insulators. This is important because graphene oxide fails to recover its full pristine electrical characteristics even when it is reduced (i.e., oxygen removed).

In the short to medium term, graphene inks may be employed as low-cost transparent printed conductors and resistors. This is because their technology offers high transparency (>85%), low curing temperature (120˚C) and moderate sheet electrical resistance (<30 kΩ/sq). The conductivity levels are currently on a par with carbon pastes, however they are expected to rapidly decrease as the ink formation techniques improve to maximise the single layer graphene content.

The ink is also optimised such that it can be deposited using standard inkjet printers, without requiring custom modifications. Currently, further research is under way to make this material compatible with other printing techniques, such as gravure and flexo. Critically, this ink has the potential to be available cheaply on a multi-tonne scale. This is because the precursor material is the commonplace graphite, which is widely available at very low prices.

The inks will initially occupy the space between low-cost low-conductivity carbon pastes and high-cost, high-conductivity silver flake polymer thick films. In the long term however, graphene inks can improve to become a viable low-cost substitute for sputtered indium tin oxide (ITO). This would be particularly attractive in applications requiring mechanical flexibility.

Consequently, we could witness the introduction of another entrant into the rapidly-expanding list of emerging materials that attempt to capture fractions of the multi-billion dollar printed conductor and ITO replacement markets. For this to take place however, the sheet resistance of ink-jet printed graphene-ink patterns must be brought closer to levels observed in chemically doped graphene sheets.

In the long term, the material can be applied to more complex functional devices. Indeed, Prof Ferrari and his colleagues have already shown that graphene ink can be inkjet-printed to produce field-effect transistors with a field-effect mobility value (a measure of the switching speed of the transistors) of 90 cm2/Vs. This is an impressive result considering that even non-printed amorphous silicon and organic semiconductors rarely achieve mobility levels above the 1 cm2/Vs mark.

The graphene-printed transistors however are not production ready yet since they face a number of critical challenges. One issue is that the current levels remain high even when the transistor is switched OFF, resulting in an increased power consumption.

This property stems from the inherently zero bandgap of graphene. This, however, may be improved by tuning the size and shape of the printed graphene flakes, or by mixing graphene in conventional semiconducting polymers. In fact, the Cambridge team reported improved mobility in graphene/polymer mixtures, while retaining the high ON/OFF ratio of the semiconducting polymers. Other device and material issues may arise when moving towards fully-printed transistors, in which the dielectric and the contact layers may also be printed. These are currently being investigated by the team.

More information on carbon nanotubes and graphene can be found in Carbon Nanotubes and Graphene for Electronics Applications 2012-2021.

For more attend:Printed Electronics Europe 2012 where the University of Cambridge will be speaking and exhibiting.