High quality monolayer graphene synthesized by resistive heating cold wall chemical vapour deposition

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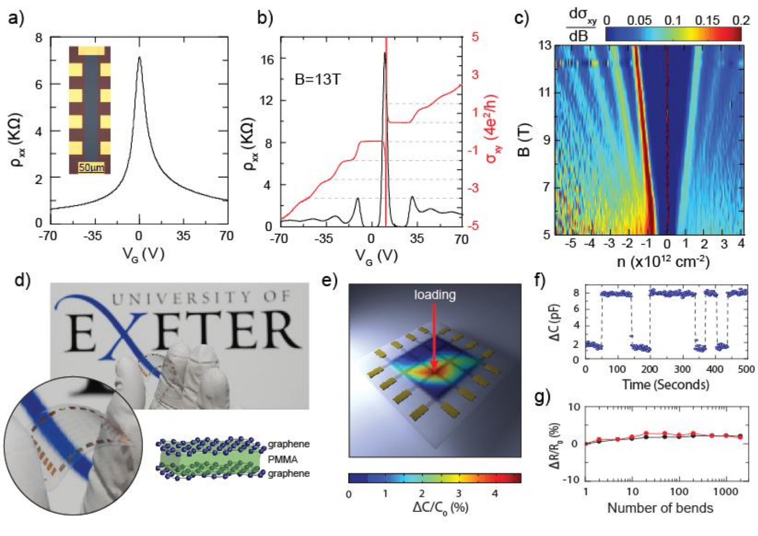
Abstract

Emerging flexible and wearable technologies such as healthcare electronics and energy-harvesting devices could be transformed by the unique properties of graphene. The vision for a graphene-driven industrial revolution is motivating intensive research on the synthesis of high-quality and high-throughput graphene. Resistive-heating cold-wall chemical vapour deposition (CVD) is a high-throughput method, but neither the growth of monolayer graphene nor its quality and suitability for flexible electronics have been demonstrated.
Here we demonstrate the growth of monolayer graphene using resistive-heating cold-wall CVD, a technique that is 100 times faster and 99% lower cost than standard CVD. We report a completely new mechanism for the growth of graphene by resistively heated stage cold-wall CVD which is markedly different form the growth mechanism of graphene in a hot-wall CVD. Through a combined study of Raman spectroscopy, atomic force microscopy (AFM) and scanning electron microscopy (SEM) we elucidate the early stage formation of graphene by monitoring the transition from disordered carbon adsorbed on Cu to graphene. A thorough complementary study of Raman spectroscopy, AFM, SEM and electrical magneto-transport measurements shows that our cold-wall CVD-grown graphene is of comparable quality to natural graphene. Finally, we demonstrate that graphene grown by cold-wall CVD is suitable for the next generation electronics by embedding it into the first transparent and flexible graphene capacitive touch-sensor that could enable the development of artificial skin for robots. Besides its importance for the quick industrial exploitation of graphene, our work could lead to new generations of flexible electronics and offers exciting new opportunities for the realization of graphene-based disruptive technologies.

References

[1] T. H. Bointon, M. D. Barnes, S. Russo, and M. F. Craciun, Advanced Materials (2015), DOI:10.1002/adma.201501600.

Figures



a) Longitudinal resistivity (ρ_{xx}) plotted against applied gate voltage at 4.2K. The inset shows a false colour photograph of the device. b) Longitudinal resistivity and the Hall conductance against applied gate voltage at 250mK with a 13T perpendicular applied field. c) Colour map of the differential conductance as a function of applied perpendicular magnetic field and carrier density. d) Shows a photograph of a flexible and transparent graphene touch sensor and a schematic of the touch sensor device. e) Colour map of the change in capacitance when a single element is loaded with a 36g mass. f) The change in capacitance of one element with respect to time when pressed with a human finger. g) The change in line resistance after flexing the device about a 2.5 cm radius. Black and red points show the resistance of line parallel and perpendicular to the bending radius respectively