Ink-jet printed graphene electronics


University of Cambridge, 9 J.J. Thomson Avenue CB3 0FA, Cambridge, United Kingdom
ft242@cam.ac.uk

Ink-jet printing is one of the most promising techniques for inexpensive large area fabrication of flexible plastic electronics[1], due to its versatility, the limited number of process steps[2], the ease of mass fabrication[2]. Despite much progress, ink-jet printed organic Thin Film Transistor (TFT) still show poor air stability, limited lifetime, mobility (µ<0.5 cm²V⁻¹s⁻¹) [3], and ON/OFF ratios(<10⁵). The use of carbon nanotubes (CNT) ink [4,5] allowed to increase µ by at least one order of magnitude[3,4].

Graphene is at the centre of an ever expanding research area [6]. Near-ballistic transport and high mobility make it an ideal material for nanoelectronics, especially for high frequency applications. Furthermore, its optical and mechanical properties are ideal for thin-film transistors and transparent and conductive electrodes[7]. Here we exploit the extraordinary properties of graphene to fabricate graphene-based ink-jet printed transparent and conductive electrodes and TFTs. Liquid phase exfoliation (LPE) is ideal to produce printable graphene-based inks. High quality graphite flakes are dispersed in organic solvents by ultrasonication (~9 hours) followed by ultracentrifugation to remove large graphite fragments that are likely to clog the nozzle of the ink-jet printer. We investigate N,N-dimethylacetamide, Ethyl Acetate, 1-Methyl-2-pyrrolidone (NMP), Dimethylformamide as organic solvents. By Optical Absorption Spectroscopy (OAS), Transmission electron microscopy (TEM) and Raman spectroscopy we find that NMP gives the highest yield of monolayer graphene [8].

Graphene-ink stripes are then ink-jet printed on Si/SiO₂ modified by Self-Assembled Monolayers (SAM), which reduce the wettability of the substrate and allow uniform printing of graphene electrodes. AFM shows that a ~20 nm thick conductive stripe is obtained with a uniform distribution of graphene flakes. Its optical and electrical properties are studied respectively by OAS and electrical four-point probe measurements at room temperature. The ink-jet printed graphene-ink stripes are then utilized to fabricate graphene-based TFTs achieving mobility up to 95cm²V⁻¹s⁻¹ and ON/OFF ratio of ~10⁴-10⁵. The electrical and optical performances observed in our devices, demonstrate the viability of graphene-ink to fabricate electronic devices, paving the way to graphene ink-jet printed electronics [9].

References
Figures

**Figure**: a) Graphene-ink. b) Example of graphene ink-jet printed pattern. c) Graphene TFT fabrication steps: graphene-ink is printed on Si/SiO$_2$ substrate, gold pads define source and drain.