Water-based 2D-crystal Inks: from Formulation Engineering to All-Printed Heterostructures

Cinzia Casiraghi

School of chemistry, University of Manchester (UK)

The isolation of various two-dimensional (2D) materials allows combining these materials into heterostructures. Such a concept can be used to study particular phenomena [1-3] or to make functional devices: tunnel diodes [4], tunnelling transistors [5,6], photodetectors [7] and light emitters [8] have been recently demonstrated, using mechanically exfoliated 2D crystals.

Exploiting the properties of 2D crystals for commercial applications requires a mass production method able to produce heterostructures of arbitrary complexity on any substrate. Solution processing of 2D crystals allows simple and low-cost techniques, such as inkjet printing, to be used for device fabrication [9-11]. However, available printable formulations are still far from ideal: for example they are not suitable for thin-film heterostructure fabrication due to the re-mixing of different 2D crystals, leading to uncontrolled interfaces and poor device performance.

Here we show a general approach to achieve inkjet printable water-based 2D crystal formulations, which also provide optimal film formation for multi-stack fabrication [12]. We show examples of all-inkjet printed heterostructures, such as large area arrays of photosensors on plastic and paper and programmable logic memory devices [12]. Finally, in vitro dose-escalation cytotoxicity assays confirm the inks biocompatibility, extending the possible use of such inks to biomedical applications [12].

1. Ponomarenko et al, Nature Physics 7, 958 (2011)
2. Gorbachev et al, Nature Physics 8, 896 (2012)
3. Ponomarenko et al, Nature 497, 594 (2013)
4. Britnell et al, Nano Lett., 12, 1707 (2012)
5. Britnell et al, Science, 335, 947 (2012)
6. Georgiou et al, Nature Nanotech., 8, 100 (2013)
7. Britnell et al, Science, 340, 1311 (2013)
8. Withers et al, Nature Materials, 14, 301 (2015)
9. Coleman et al., Science 331, 568 (2011)
10. F. Withers et al, Nano Letters, 14, 3987 (2014)
11. F. Torrisi et al, ACS Nano, 6, 2992 (2012)
12. D. McManus et al, Nature Nanotechnology, accepted