

# Inkjet printable water-based inks made by electrochemically exfoliated graphene

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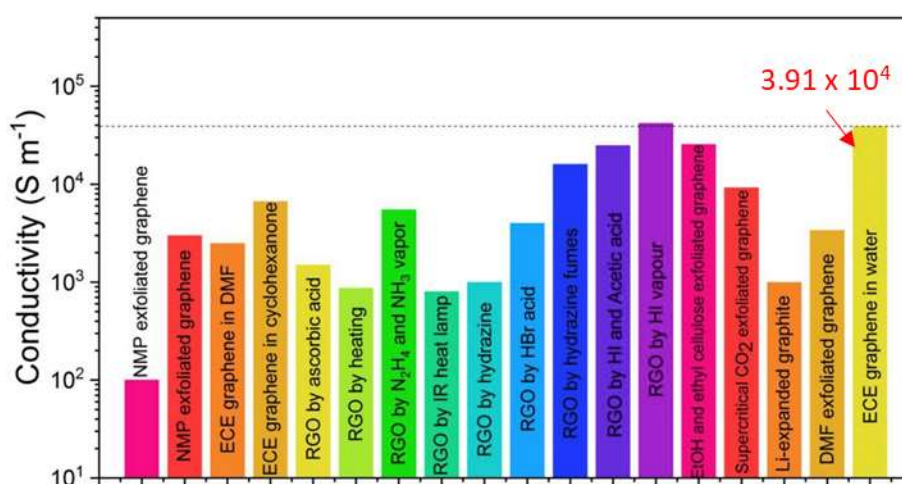
Abstract:

The field of printed electronics has developed rapidly, driven by printing techniques offering low-cost and simple methods for devices fabrication, whilst demonstrating compatibility with most substrates including those that are soft and flexible [1]. Inkjet printing of graphene inks are very attractive for applications in flexible and foldable electronics, such as wearable electronics and the Internet of Things. However, the ink preparation is still very time consuming as high concentrations can be achieved only with prolonged sonication (>24 h) or with expensive setups [2, 3]. In this work, we demonstrate a water-based inkjet printable ink made from electrochemically exfoliated graphene. The printable ink production is achieved in less than 5 h, leading to a stable (for over a month) formulation with concentrations up to 2.25 mg mL<sup>-1</sup> [4]. The formulated ink consists of over 75% single and few-layers graphene with an average lateral size of 740 nm. Such ink formulation allows stable jetting, rapid ink drying (<10 sec) as well as ensuring wetting of untreated substrates such as paper and glass. Thermal annealing of the printed films allows to achieve high C/O ratio which translates into one of the highest electrical conductivity (i.e.  $\sim 3.91 \times 10^4$  S m<sup>-1</sup>) reported so far for solution-processed inkjet printable graphene, without the use of any harsh chemical processing.

References

- [1] P. Calvert, *Chem. Mater.* 13 (2001) 3299-3305.
- [2] D. McManus, S. Vranic, F. Withers et al. *Nat. Nanotechnol.* 12 (2017) 343-350.
- [3] F. Torrisi, T. Hasan, W. Wu, Z. Sun, A. Lombardo et al, *ACS Nano* 6 (2012) 2992-3006.
- [4] K. Parvez, R. Worsley, A. Alieva, A. Felten, C. Casiraghi, *Carbon* 149 (2019) 213-221.

Figures



**Figure 1:** Comparison of the electrical conductivity measured on our inkjet printed electrochemically exfoliated graphene after annealing at 300 °C for 1 h with literature based on different types of inkjet printable graphene formulations.