Novel highly conductive graphene-based materials

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The development of future flexible and transparent electronics relies on novel materials, which are mechanically flexible, lightweight and low-cost, in addition to being electrically conductive and optically transparent. Currently, tin doped indium oxide (ITO) is the most wide spread transparent conductor in consumer electronics. The mechanical rigidity of this material limits its use for future flexible electronic applications. The leading candidates to substitute ITO are graphene based materials. Graphene is an atomically thin conductive, transparent and flexible material. However, the use of graphene as a truly transparent conductor remains a great challenge because the lowest values of its resistivity demonstrated so far are above the values of commercially available ITO. Chemical functionalization of graphene offers a simple way to improve the electrical properties of these materials.

Here we report novel graphene-based transparent conductors obtained by intercalating few-layer graphene (FLG) with ferric chloride (FeCl3). Through a combined study of electrical transport and optical transmission measurements we demonstrate that FeCl3 enhances the electrical conductivity of FLG by two orders of magnitude while leaving these materials highly transparent. We find that the optical transmittance in the visible range of FeCl3-FLG is typically between 88% and 84%, whereas the resistivity is as low as 8.8 Ω. These parameters outperform the best values found in ITO (i.e. resistivity of 10 Ω at an optical transmittance of 85%), making therefore FeCl3-FLG the best candidate for flexible and transparent electronics. The temperature and magnetic field dependence of the electrical transport properties show that this material is metallic with typical carrier concentration of n=3x1014 cm-2 and macroscopic hole mean free path close to 1μm. Analysis of Shubnikov-de Haas oscillations together with Raman spectroscopy show decoupling of FLG into isolated graphene monolayers providing several parallel hole gas. The unique combination of record low resistivity, high optical, transparency and macroscopic room temperature mean free path has not been demonstrated so far in any other doped graphene system, and opens new avenues for graphene-based optoelectronics.

[1] I. Khrapach, F. Withers, T. H. Bointon, D. K. Pplyushkin, W. L. Barnes, S. Russo, M. F. Craciun, Adv. Mater. 24, 2844 (2012).