Edge ferromagnetism of graphene oxide

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Graphene oxide (GO) is the starting material for producing a wide variety of other graphene-related materials that may inherit some of its properties. For this reason, in particular, the origin of the observed ferromagnetic hysteresis loops in GO [1] requires an explanation. The possible ferromagnetic impurities in GO [2] can be eliminated. The intrinsic ferromagnetism of GO is more interesting. Until now, it has been postulated that this magnetism can be cause by hydroxyl groups [3], a specific distribution of epoxy groups [4] resulting in the appearance of a large number of covering defects or magnetic moments arising due to the mixed sp^2-sp^3 hybridization [5]. However, the exchange interaction between randomly distributed magnetic moments attributed to the proposed surface defects in the monolayer GO should result in the antiferromagnetic order [6].

In this report, results of SQUID magnetometry and ferromagnetic resonance (FMR) studies of magnetic properties of the monolayer GO of a high purity [7] are presented. We used three types of GO. GO paper was obtained by drying the "as purchased" GO suspension. The second type of GO was obtained from suspension irradiated by ultrasound for several hours. The third diluted sample consisted of the monolayer GO flakes deposited on the spectrally pure MgO powder. We found that ultrasound irradiation slightly increases ferromagnetism of the produced GO paper and decreases the paramagnetic contribution. We also found that the mass magnetization of the diluted sample is twenty times higher than that of the GO paper. We studied impact of atmospheric gases on GO properties and showed that contact with air decreases magnetization of the GO paper and removes completely the FMR signal of GO flakes deposited on MgO. Additionally, the shape of the FMR line of GO and its temperature evolution are similar to those observed in graphene [8]. We concluded that the intrinsic ferromagnetism of GO is due to ordering of dangling bonds (broken σ bonds) at zigzag edges.

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