Electron-beam-induced graphite oxide reduction

V.M. Mikoushkin, A.S. Kriukov, S.Yu. Nikonov

Ioffe Institute, Politekhnicheskaya st. 26, 194021, St. Petersburg, Russia
Mikoushkin@mail.ioffe.ru

In recent years, the interest in graphene oxide (GO) has sharply increased due to the possibility of using GO as an initial material for obtaining graphene by thermal or chemical reduction [1,2]. This way of graphene fabrication would be one of the most attractive if there was no the fundamental problem of defect formation. Thermal and chemical reductions are accompanied by formation of numerous defects and even holes because of the detachment of some carbon atoms together with departing oxygen groups [2,3]. Therefore, searching for new nonthermal and nondestructive reduction processes is a topical task. In this work, we demonstrate the possibility of the efficient nonthermal reduction of GO by a weak electron beam which does not heat the irradiated area.

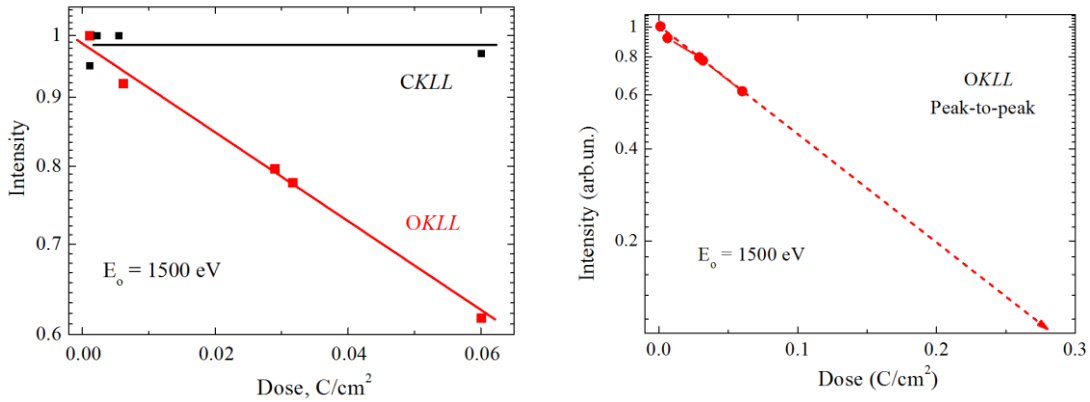

Figure 1: Dependences of the O*KLL* and C*KLL* Auger line intensities of the graphite oxide film on the electron irradiation dose density in different scales.

A multilayer GO film prepared in Ioffe Institute on the surface of a silicon wafer [4] has been studied. The film was tested previously by an original Auger diagnostics of the elemental and chemical compositions which revealed complete and reproducible oxidation of carbon providing the oxygen-carbon ration [O]/[C] = 0.7 and the wide bandgap as far as 3 eV [5]. The film was irradiated in the high vacuum chamber of the LHS-11 (Leybold-AG) electron spectrometer by a low-intense (15–250 nA) electron beam with the energy E_0 =1500 eV. Extremely low released power (2–40 mW/cm^2) excluded heating the irradiated area. The reduction process was controlled directly in the irradiated area by Auger electron spectroscopy using the same electron beam.

Fig.1 shows decrease of the Auger O*KVV* oxygen peak intensity almost by a factor of 2 in the range of very low irradiation doses. The intensity of the C*KVV* carbon line remains unchanged in the first approximation in the process of the film irradiation. This means that the atoms of the carbon layer do not form free complexes with oxygen groups and that the carbon layer remains mainly undamaged. The oxygen dose dependence proved to be possible to be described by one exponent. Its extrapolation shows the possibility of complete GO reduction at low doses. The effective cross section of the oxygen group detachment was estimated to be $\sigma_{in} \approx 1.2 \times 10^{-18}$ cm^2 [6]. The mechanism of the GO reduction obviously involves the local excitation of the valence electrons of an oxygen group and carbon atom bonded to it, subsequent transition of such a quasimolecular group to a repulsive state, and the removal of an oxygen group without the cage carbon atom.

References

[1] S. Stankovich, D.A. Dikin, R.D. Piner, K.A.Kohlhaas *et al.*, *Carbon* **45** (2007) 1558.
[2] C. Soldano, A. Mahmood, E. Dujardin, *Carbon* **48** (2010) 2127.
[3] A. Bagri, C. Mattevi, M. Acik, V.B. Sheno, *Nature Chemistry* **2** (2010) 581.
[4] A. Dideykin, A.E. Aleksenskiy, *et al.*, *Diamond and Related Materials* **20** (2011) 105.
[5] V.M. Mikoushkin, A.S. Kriukov *et al.*, *J. Electron Spectrosc. Relat. Phenom.* **199** (2015)51.
[6] V.M. Mikoushkin, A.S. Kriukov, *Technical Physics Letters* **42** (2016) 337.