Influence of Ion Irradiation on Properties of Graphite

E.A. Ligacheva[3], M.G. Ivanov[1], N.V. Gavrilov[2], D.R. Emlih[2], S.J. Becofen[3], A.E. Ligachev[4], V.V. Sohoreva[5], A.A. Safronov[3]

[1] Belgorod State University, Belgorod, Russia
[2] Institute of Electrophysicists UrD of the Russian Academy of Science, Ekaterinburg. Russia.
[3] Moscow Aviation-Technology Institute K.E.Tsiolkovskii by name, Moscow. Russia.
[4] Center of natural-scientific researches of Institute of the General Physics of the Russian Academy of Science, Moscow, Russia ,aeligachev@tochka.ru.
[5] Institute of Nuclear Physics, Tomsk, Russia

Abstract – Influence of N^+ irradiation (30 keV, 10^{16}–10^{18} cm^{-2}) on topography of a surface and structure nearsurface layer of graphite is studied.

1.Introduction

For increase of adhesive durability of various type coatings to a surface of graphite, preliminary treatment of a surface graphite by the charged particles (electrons, ions, beams of plasma) is perspective. In many cases such process treatment of a surface can be combined with operation of deposition of a coating in vacuum.

In the present work influence of preliminary treatment of a surface of graphite by ion beams (N^+) on structure nearsurface layer and topography of a surface of graphite is studied.

2. Materials and Research Methods

Irradiation of graphite by nitrogen ions carried out by means of a plasma ions source with the hollow cathode, developed in Institute of Electrophysics UrD of the RAS [1]. The ion source worked both in pulse-periodic, and in continuous modes of generation of a beam. The mode with duration of an impulse 1 mc and pulse density of a current 3 mA/cm^2 was used at a set of small dozes of an irradiation. Greater dozes have been received in a continuous mode at density of a ion current of a beam ~ 0,3 mA/cm^2. The accelerating voltage is 30 kV. The doze of ions varied from 10^{15} up to $5\cdot10^{18}$ cm^{-2}.

Topography of a surface of graphite investigated by means of a scaning electronic microscope.

The element structure nearsurface a layer was defined by means of a RBS-method (energy of α-particle, E_0=1,7 MeB), dispersion corner θ=170°. Concentration of elements were taken from power spectra of return dispersion by means of the program of mathematical modelling SIMRA with a degree of adjustment $\chi^2 \geq 1$.

The sizes of crystalline particle L_a and graphite defined interplane distance d_{002} are determined by means of x-ray diffraction (diffractometer DRON-2) on the filtered copper radiation.

3. Research Results and Discussion.

With increase in a dose of irradiated ions depth of penetration of ions increases for 10–15 % in comparison with the minimal dose of an ion irradiation (Fig. 1, N^+ 10^{15} cm^{-2}) and reaches 80 nm at a dose 10^{18} cm^{-2}.

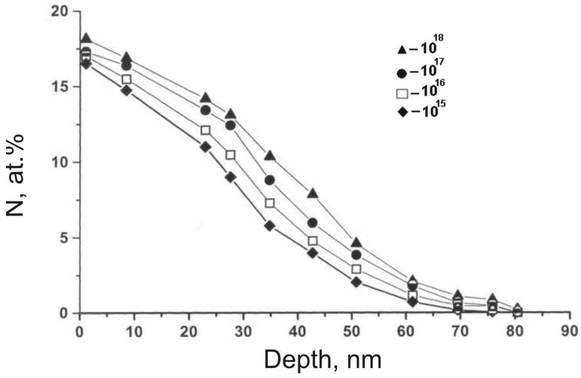


Fig. 1. Change of concentration of nitrogen in graphite after ion irradiation

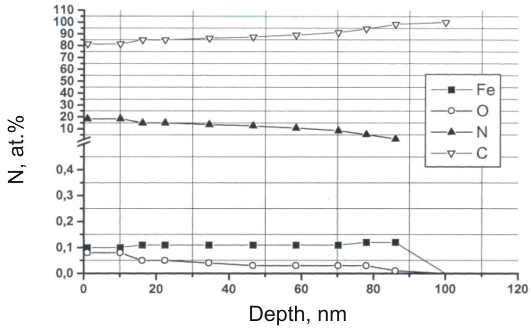


Fig. 2. Change of concentration impurities in a nearsurface layer of graphite after an ion irradiation

At a dose 10^{18} cm^{-2} oxygen and iron impurities are observed in the nearsurface layer graphite from the residual atmosphere vacuum system and because of dispersion of electrode surface on which there is an irradiated sample of graphite. Impurities were absorbed on the graphite surface during ion irradiation and then were mixed with ion beam (Fig. 2).

As a result of an ion irradiation (fig. 3) the interplane distance d_{002} is characterized by two values which occurrence is connected with a break of basic planes of graphite and their partial displacement concerning an initial condition with formation of two planes of an interference (fig. 4).

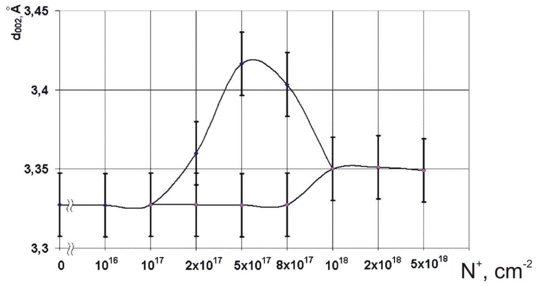


Fig. 3. Dependence of interplane distance d_{002} from a dose of ion irradiation

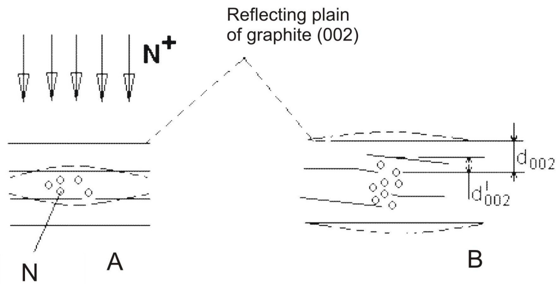


Fig. 4. Model of structure nearsurface layer of graphite after ion irradiation. A – the initial moment of an ion irradiation(dose $N^+<10^{16}$ cm^{-2}); B – structure of nearsurface a layer after dose $N^+ \approx 2\cdot10^{17}\div10^{18}$ cm^{-2}

Sharp distinction between two equivalent planes of an interference is observed up to dozes 10^{18}–$2\cdot10^{18}$ cm^{-2}. The further growth of a doze N^+ leads to disappearance of these distinction and value d_{002}, most likely, corresponds to interplane distance a nearsurface layer which is being an amorphous condition. With growth of a doze above $2\cdot10^{17}$ cm^{-2} sizes of crystalline particle L_a decreases owing to possible destruction of communications hexagons and displacement of basic planes of graphite rather each other (Fig. 5).

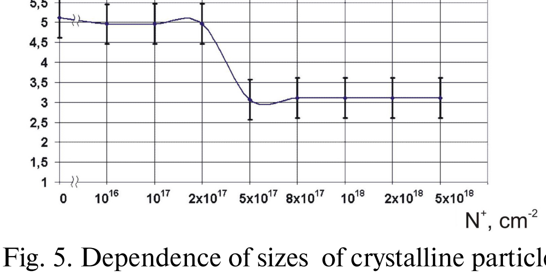
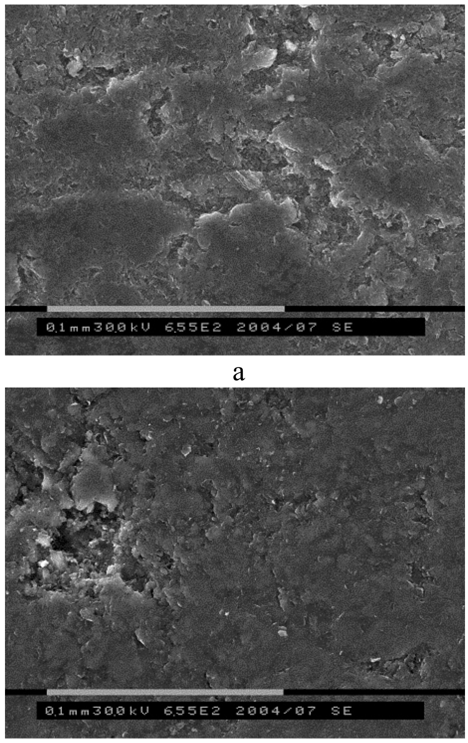


Fig. 5. Dependence of sizes of crystalline particle L_a as a function of N^+-ions dose

With growth of a dose of an ion irradiation the quantity of craters on graphite surface are increased (Fig. 6); at the same time the quantity of small craters (on diameter) are decreased, and the number of large craters are increased.



b

Fig. 6. Topography of graphite surface after an nitrogen ion irradiation. a – 10^{16} cm^{-2}, with small craters; b – $2\cdot10^{17}$ cm^{-2}, with large crater

By means of program Image Pro Plus 4.0 the estimation of changes of parameter L_a, on contrast of dark and more light areas which correlate with structure of a surface is executed. With growth of a dose of ion irradiation diameter of the ordered areas decreases, the quantity of an amorphous phase collapses and increases. The quantity of zones with crystal structure ($5\cdot10^{18}$ cm^{-2}) reaches the minimal value of equal 5–10 %.

4. Conclusion

The topography of a surface, and structure nearsurface layer of graphite after low-energy N^+-ions irradiation are studied. The maximum depth of penetration of N^+-ions in graphite does not exceed 80 nm. The mechanism of possible change of interplane distance is offered.

References

[1] N.V. Gavrilov, *in Proc. of 7th Int. Conf. on Modification of Materials with Particle Beams and Plasma Flows*, Tomsk, 2004, pp. 8–12.