Transformation of graphene flakes into carbon nanostructures during γ-irradiation

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Carbon nanostructures are widely studied in last twenty years in connection with their unique electronic, magnetic and mechanical properties [1]. Special attention is directed on the graphite single layers (graphene) because of their extremely high electron mobility and transparency in wide range of wavelengths [2, 3]. Stability and transformation of the graphene layers under different radiation exposures are important directions of research. The presented work considers transformation of the graphene flakes synthesized on Ni film into different carbon nanostructures during γ-irradiation.

The graphene layers were synthesized by the vacuum thermal treatment at 700-900°C for 2-20 min of sandwich a-$Si_{1-X}C_X$/Ni structure deposited on SiO_2 film with thickness about 200 nm. The a-$Si_{1-X}C_X$ was deposited on oxidized Si wafer by RF magnetron sputtering of the polycrystalline SiC target in Ar ambience, and the Ni film by DC magnetron sputtering of Ni target without withdrawing of the wafer from a chamber [4]. Fabricated structures were subjected by γ-irradiation with doses up to $5x10^6$ Rad (Si) in vacuum and air. The graphene surface morphology and distribution of electrical potential were studied by optical microscopy (Axioscop 2 MAT, Carl Zeiss) in standard and differential interference contrast (DIC) mode, AFM and scanning Kelvin probe force microscopy (SKPFM, NanoScope IIIa Dimension 3000). Structure of graphene layers was studied by micro-Raman spectroscopy (mRS, triple Raman spectrometer T-64000 Horiba Jobin-Yvon, equipped with electrically cooled CCD detector, and excitation by the 514 nm line of an Ar-Kr ion laser). To identify the origin of the structures generated under irradiation the graphene surface was examined additionally by scanning electron microscopy (SEM) combined with local high resolution Auger electron spectroscopy (JAMP-9500 F).

The technique of graphene synthesis from solid source results in formation of the graphene flakes with size about 20x20 μm (Fig.1a, b) which cover about 80% of the Ni surface [5]. Raman spectroscopy shows that the flakes possess different thickness (Fig. 1 c) and different deffectiveness (not shown here) in central and edge parts. In the central aria of the flake has usually single graphene layer but in the edge part the flake has multilayer graphite. It can be seen that surface potential is also different in middle and edge areas (Fig. 1 b).

The γ-irradiation in vacuum does not lead to any changes in structure of the graphene flakes up to dose of $5x10^6$ Rad. However the radiation in air with dose of $5x10^5$ Rad results in formation of new structures such as “domes” with height about 100 nm and “stars” with “rays” size about 10-15 μm (Fig. 2 a, b). Results of the SKPFM and Auger electron spectroscopy (AES) attest on location of these structures on surface of multilayer graphene (see Fig. 3 a). The mRS and AES show that the structures compose of carbon. The “rays” are probably carbon tubes with diameters about 100-120 nm (see Fig. 2 c). The “domes” have a surface potential considerable higher than carbon layer (Fig. 3) that assumes either another carbon phase formation or incorporation in the graphene layer any inclusions in these places.

A nature of such carbon structures synthesis during the irradiation is discussed.

Acknowledgements

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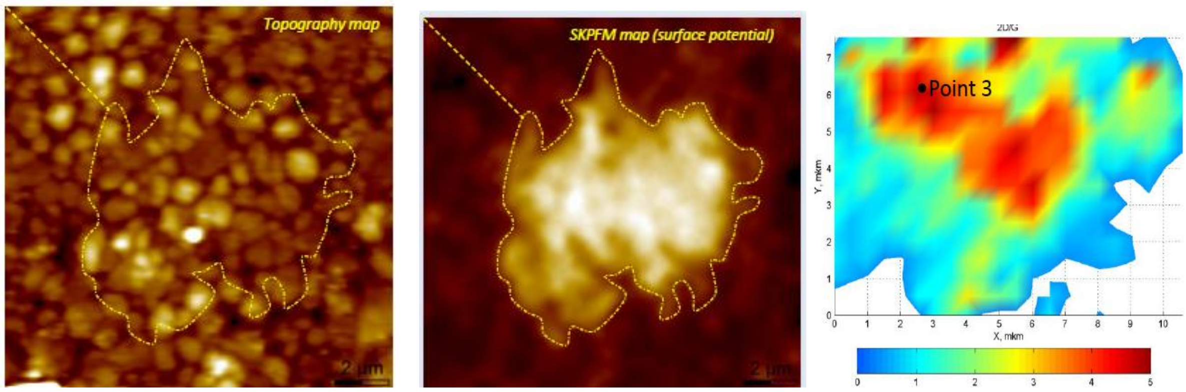
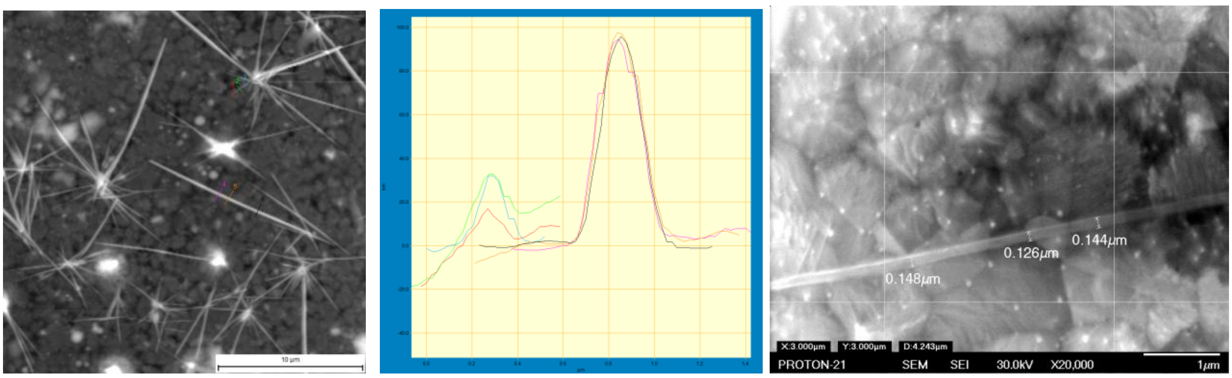


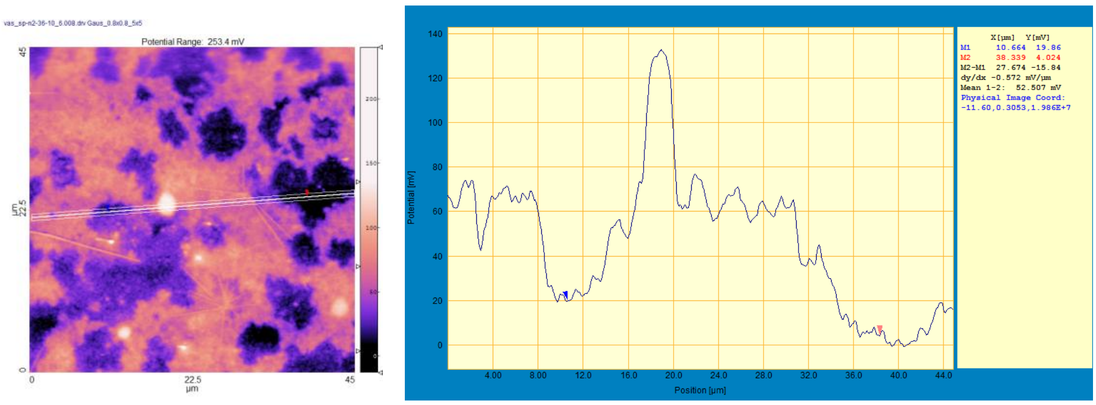
(a) **(b)** **(c)**

Figure 1. AFM surface map (a) and corresponding map of surface potential (b) and map of micro-Raman 2D/G bands intensity (c) of the surface fragment of the graphene/Ni structure



(a) **(b)** **(c)**

Figure 2. AFM surface map (a), AFM topography (b) along the lines shown in Fig. 2a and SEM (c) of the surface fragment of the graphene/Ni structure subjected by γ-irradiation in air with dose 5x10^5 Rad.



(a) **(b)**

Figure 3. The map of surface potential (a) of the surface fragment of the graphene/Ni structure after γ-irradiation in air with dose 5x10^5 Rad and surface potential (b) along the line in Fig. 3 (a).