Graphene (GN) has been in the focus of intensive research in material science and nanotechnology in recent years due to its unique electrical, optical, thermal and mechanical properties. Creation of the graphene-nanoparticles (GN-NPs) system could lead to the improvement of the physical properties of GN due to the change of its topography via creation of wrinkles.

We have focused on the basic characterization of the GN-NPs systems, especially on the study of the NP spatial distribution on the substrate, which has a significant influence on the GN wrinkling. The samples possessing different concentration of the CoFe₂O₄ NPs (6 nm) on the Si/SiO₂ substrate covered by the GN layer were characterized by High Resolution Scanning Electron Microscopy (HRSEM) and Atomic Force Microscopy (AFM). Different concentration of the NPs for individual samples was confirmed both by the HRSEM and AFM measurements and creation of the GN wrinkles around the NPs below the GN monolayer and their dependence on the NP concentration has been observed (Fig. 1).

The real NP spatial distribution determined by the HRSEM and AFM was compared with that one obtained from simulation in Matlab as follows: the NPs were randomly distributed inside the square box of 1 µm edge length, divided to the regular lattice with inter-node distances equal to the NP diameter for prevention of the NP overlap. The mean interparticle distances were calculated in both cases (real and simulated NP spatial distribution) for the nearest neighbors using the triangulation procedure. The results of both NP spatial distributions clearly demonstrate decrease of the interparticle distances (Fig. 2). Moreover, the resulting interparticle distances obtained from the simulation correspond very well to those obtained from the real positions of NPs determined by the AFM, showing that the NPs are randomly distributed on the surface and the influence of the substrate corrugations on the NP distribution is negligible.

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Fig. 1: The SEM image of the GN-NPs sample with high (a) and low (b) concentration of NPs. The GN wrinkles are clearly visible on both images, the border between the GN and substrate could be found on right image.

Fig. 2: The concentration, c dependence of interparticle distance, d for GN-NPs samples (a). The simulated NPs spatial distribution for the least (1:10000) concentrated (b) and the most (1:1000) concentrated (c) samples.