3D GRAPHENE-BASED STRUCTURES: FORMATION, PROPERTIES, AND POTENTIAL APPLICATIONS

V. Ya. Prinz

A.V.Rzhanov Institute of Semiconductor Physics SB RAS, 630090, Novosibirsk
prinz@isp.nsc.ru

In the present report, we discuss the formation of two types of 3D graphene-based structures exhibiting unique properties and substantially enlarging the application area of graphene. The first type is precise graphene and hybrid graphene-semiconductor nanoshells. The second type is structures obtained by local functionalization of few layer graphene (multigraphene).

The 3D graphene-semiconductor nanoshells were fabricated using the technology of [1-2] that was used in many countries for forming unique precise semiconductor and metal solid nanoshells [3-5] substantially differing in their properties from planar films [6] and having many applications ranging from tubular lasers, мetamaterials, and sensors to nanorobotic.

Test samples of various graphene devices designed around such shells, including precise arrays of hybrid graphene-semiconductor field emitters [7]. It should be noted here that the technology of hybrid graphene-semiconductor shells enables fabrication of true out-of-plane elements, and it can be scaled to allow full-wafer processing in a parallel fashion.

Control of local buckling and bending in graphene-semiconductor films, and also controlled generation of elastic strains in graphene, provide a new engineering approach suitable for design of strain-based nanodevices. We numerically investigated 3D shapes obtained by local buckling of a graphene layer covering a strained InGaAs bilayer film on a GaAs substrate [8]. Such 3D shapes have potential in forming graphene-based quantum devices and biomedical instruments [9].

It is shown that, unlike planar graphene layers, graphene-based nanoshells exhibit unusual ballistic-transport properties and giant gradient phenomena.

In the second part of the report, we discuss some extraordinary properties of multigraphene layers comparable in thickness with Debye screening length in transverse direction. Surprising properties of functionalized multigraphene are outlined. For instance, we found that the current response of multigraphene to ammonia adsorption was strongly dependent on multigraphene thickness, and it exceeded the current response demonstrated by single-layer graphene by up to seven orders of magnitude [10]. We found that multigraphene intercalated with compounds experiences a sharp thermally stimulated semimetal-dielectric transition enabling fabrication of 3D functionalized structures with unique properties. Results on the formation, with the help of imprint nanolithography (Eitre 6 “Obducat”), of new graphene nanostructures, including metamaterials, moiré structures and structures intended for investigation of plasmon effects, are demonstrate.

[1] V. Ya. Prinz et al. Physica E, **6**, 828(2000).
[2] V. Ya. Prinz Microelectron. Eng. **69**, 466 (2003).
[3] V. Y. Prinz et al., Sci. Technol. Adv. Mater. **10**, 034502 (2009).
[4] V.Ya. Prinz, and V.A. Seleznev, Phys. Stat. Sol. (b), **244**, 4193 (2007).
[5] E. V. Naumova, V. Ya. Prinz, et al. J. Opt. A: Pure Appl. Opt. **11**, 074010 (2009).
[6] A. B. Vorob'ev et al., Phys. Rev. B 75 **20**, 205309 (2007).
[7] V. Ya. Prinz, S. V. Mutilin, S. V. Golod, Patent No. № 2400858 (2008).
[8] R. M.Tasiev, V. Ya. Prinz, Nanotechnology **22**, 305705 (2011).
[9] A. V. Kopilov, V. Ya. Prinz, Vestnik NSU: Fizica. **5**, 88 (2010).
[10] I. V. Antonova, S. V. Mutilin, R. A. Soots, V. Ya. Prinz, Nanotechnology, **22**, 85502 (2011).