Conductivity mechanisms in the structures based on virgin and partially fluorinated graphene films

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New graphene-based materials with tunable electronic properties are required for the development of graphene nanoelectronics due to a set of excellent electronic and structural graphene properties and zero bandgap in its electronic structure [1]. Traditional pathways to open the bandgap in graphene layers is nanolithography causing a dramatic decrease in carrier mobility due to chemically active dangling bonds near the formed edges.

The stability of graphene-based nanostructures without edge atoms has been investigated theoretically recently [2]. We develop two methods to create such materials. The first one is based on embedding graphene islands into a stable matrix of fluorinated graphene by selective functionalization [3,4] of graphene layers and suspensions. Structural properties, conduction mechanisms, and electronic structure were investigated for films in the wide range of the functionalization degree (from metallic to dielectric depending on C/F atom ratio).

Another method, which we used to form a graphene-based structure with bandgap and minimal defects quantity, is to perforate graphene layers by high energy swift ions. Recently we found that it’s possible to cut holes in neighboring graphene layers and to bond the chemically active atoms from different layers forming a closed structure of sp2-hybridized carbon atoms. We demonstrate that the edge of the hole may be reconstructed in the range from the dangling bonds to connected edges. We experimentally observed the band gap and electric active traps appearance, dependently on ions energy. We found the conditions for tuning the electronic and structural properties of the films.

The formation of different types of graphene islands or continuous graphene surface between two perforated layers are very attractive as well as for nanoelectronic devices because of the band gap appearance in its electronic band structure, opportunity to save the carrier mobility and capability to transmit high electric currents in contrast to nanostructured graphene and semiconducting graphene nanoribbons. Moreover, such nanostructures are promising for sensors and molecule filters.

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