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Electrical conductivity and magnetoresistance in twisted graphene electrochemically decorated with Co particles

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A B S T R A C T

Application of magnetic metal/graphene hybrid structures in magnetosensorics requires the formation of high-quality low-ohmic (barrier-free) contacts and understanding of mechanisms of electric charge transfer near and through the metal/graphene contact area. In present paper we fabricate samples of twisted graphene electrochemically decorated with Co particles (Co-*G*/SiO_2) which demonstrate perfect ohmic electric contact between Co and graphene sheets. Temperature and magnetic field dependencies of surface resistance for pure twisted graphene (*G*/SiO_2) and Co-*G*/SiO_2 samples are considered within the models of 3D Mott variable range hopping and 2D weak-localization quantum corrections to the Drude conductivity. Phenomenological model is proposed explaining the experimentally observed transition from predominantly negative magnetoresistive effect in weak magnetic fields *B* (below 1–2 T) to positive magnetoresistance (PMR) at *B* beyond 5 T assuming the growth of PMR due to the distortion of current-conducting routes under the influence of Lorentz force which originates from the enhancement of large-scale potential relief in Co-*G*/SiO_2 sample. This work considers the new approach to the application of *G*/SiO_2 decoration with Co particles for creation both metallic (distributed, defragmented) shunts and high-quality ohmic electrodes in magnetic sensing.

1. Introduction

In the last decade, graphene being one of the most important allotrope modification of carbon nanomaterial is widely studied due to its extraordinary physical properties such as high electrical and thermal conductivities, large specific surface area, high mechanical strength and flexibility, etc. as well as future applications. These fascinating properties initiate designing of various graphene-based structures for fabrication of new types of sensors, transducers, spintronic devices, memristors as well as for application in energy storage, magnetic bio-imaging, etc. [1–3].

In particular, a significant part of research is devoted to metal/graphene hybrid structures [4–7], which could be potentially applied in magnetosensorics [7–11]. This application, first of all, needs the formation of high-quality low-ohmic (barrier-free) contacts that do not introduce distortions into the crystal lattice of graphene. However, this point still remains a strong challenge both from fundamental and technological aspects. Therefore, understanding of mechanisms of the charge carriers' movement near and through the metal/graphene contact area becomes crucial. Carrier transport in such metal/graphene nanostructures depends on many factors, such as the method of graphene synthesis (micro-cleavage, CVD, epitaxy, etc.), the type of graphene (single-layered, multilayered, twisted) and substrate, on which graphene is deposited, as well as the type, concentration and distribution of possible defects in graphene, including those incorporated by polycrystallinity and deposition of metallic clusters [1–3,11].

Several mechanisms of electric carrier's transport both with and without external magnetic field observed in graphene and metal/graphene structures are generally discussed in literature. Most commonly, carrier transport in pristine graphene is described by the interferential mechanisms considered in the theory of quantum corrections to the Drude conductivity in weak localization conditions [12,13,15–19]. As reported in Ref. [19], for graphene produced by mechanical exfoliation this mechanism includes several contributions – low localization taking into account electron-electron interaction [12,13,16–18], intervalley scattering and chirality breaking [16], weak antilocalization [16,17], etc. The second mechanism of electrical conductivity in graphene is variable range hopping (VRH) of electrons by the localized states

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