Extraordinary Magnetoresistance from Graphene with charged Nano-domes, Channels and Bubbles

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We found that extraordinary magnetoresistance may arise from graphene patterns[1,2] produced by a local decoupling of graphene monolayer from other layers of thin graphite or in epitaxial graphene. There new structures such as charged nanodomes and bubbles may be formed. Within these domes and bubbles the suspended "flat" graphene[4] may be created and there the Dirac gapless electronic spectrum arises[3]. Therefore these structures may be useful also in different graphene-electronic applications[5]. We study the formation of these structures with a detailed surface enhanced Raman spectroscopy mapping and show that the monolayer decoupling areas may have very different form, shape and size and they may be intrinsic or formed by an applied external stress. Depending on their form and size we call them nano-domes, channels or bubbles. Such graphene pattern may be also formed on other substrates where graphene is placed. We show both theoretically and experimentally that the found linear extra-ordinary magnetoresistance depends strongly on the graphene fraction, which covers thin graphite samples or on the graphene bubbles pattern. The strongest effect arises at the fraction, when nearly half of the graphite or the substrate surface is covered by graphene monolayer. The analysis is very general and applicable to any two phase systems in arbitrary magnetic field**.** For epitaxial graphene grown on 4H-SiC (000) substrate we found "bubbles" and "domes" with size ranging from few tens of nanometres to micrometers[6]. Their optical and electrical properties and their morphology properties have been studied with Atomic force microscopy (AFM), Ultrasonic Force Microscopy (UFM) and Raman spectroscopy. The UFM measurements showed domes with dimensions of 150 - 200 nm and larger bubbles of up to few µm, whereas height for both was on the order of 5-10 nm. Local Raman mappings of the graphene modes have confirmed the surface morphology change, i.e. the discovery of graphene new structures, step bunching existence, the defects variation and the doping distribution across the localised bubbles. For the first time we report the doping distribution inside the intrinsically- grown epitaxial bubble, where a redistribution of the charge-carrier density at the substrate-graphene interface occurs. The graphene bubble-substrate interface forms a charged capacitance. We have determined the respective quantum capacitor and investigated the electric field inside the bubbles created in epitaxial graphene on 4H-SiC face terminated carbon.

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