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Volkov, Valentyn S.; Yakubovsky, Dmitry I. ; Stebunov, Yu V.; Kirtaev, Roman V. ; Voronin, K. V.; Arsenin, Aleksey V.

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Hybrid graphene-nanometallic structures

V S Volkov[1, 2, 3], D I Yakubovsky[1], Y V Stebunov[1, 3], R V Kirtaev[1], K V Voronin[1] and A V Arsenin[1, 3]

[1]Moscow Institute of Physics and Technology, Institutskyi 9, 141700 Dolgoprudnyi, Russia
[2]SDU Nano Optics, Mads Clausen Institute, University of Southern Denmark, Campusvej 55, DK-5230, Odense, Denmark
[3]GrapheneTek, 7 Nobel Street, Skolkovo Innovation Center, 143026, Russia

vsv@mci.sdu.dk

Abstract. The development of functional hybrid nanomaterials based on graphene and metal nanostructures is currently the subject of intense research interest. In this study we discuss different aspects relevant to growth morphology, properties (optical, electrical, and structural), as well as the nanoscale architecture of hybrid graphene-nanometallic structures based on graphene as a multifunctional platform. The peculiarities of growth kinetics of thin gold and copper films on graphene are analysed (by use of the variety of experimental methods) and compared. It is shown that the presence of graphene affects strongly the optical, electrical, and structural properties of thin metal films.

1. Introduction

The discovery of graphene (and its extraordinary structural, chemical, and electronic properties) has excited high expectations for the development of a new paradigm for the design of nanostructures. However, these properties only emerge in the 2D planar direction of the graphene structure, limiting its scope and application. A promising approach to overcome this problem has arisen lately, by developing structures wherein graphene acts as a platform (or a 2D planar substrate) for supporting other nanomaterials [1-3]. Nowadays the research in hybrid nanostructures of 2D materials/metal covers different fields with the focus to understand (and apply) the interesting properties of these nanomaterials, and other parts have been directed to basic science with the target to modify structure and surface of thin metal films. This later has allowed the diversification of their properties and possible uses, opening new possibilities in chemistry, engineering, material science, and bio-sensing [4, 5].

2. Methods

The deposition of metals was made on SiO_2/Si substrates without and with graphene in order to systematically study and compare metal films properties. All depositions of films were performed using gold and copper pellets with the purity of 99.999% and the e-beam evaporation procedure. The nominal thicknesses of the deposited films (25 and 50 nm, correspondingly) and the deposition rate (0.5-15 A/s) were monitored by the quartz-crystal mass thickness sensor mounted in the vacuum chamber. The thickness of thin films deposition was independently estimated by step height atomic force microscopy measurements (and the root-mean-square surface roughness value was determined for each film). The properties of the polycrystalline structure of the fabricated thin metal films as a function of the film thickness were systematically investigated from X-ray diffraction measurements using conventional scanning methods. The average grain size was estimated by the Debye-Scherrer equation, which relates the size of metallic crystallites in a thin film to the broadening of the peak in the experimental X-ray diffraction pattern [6]. Finally, the dielectric function spectra of the studied thin metal films were evaluated from data measured using variable angle spectroscopic ellipsometer in the photon energy range from 4.13 to 0.62 eV.

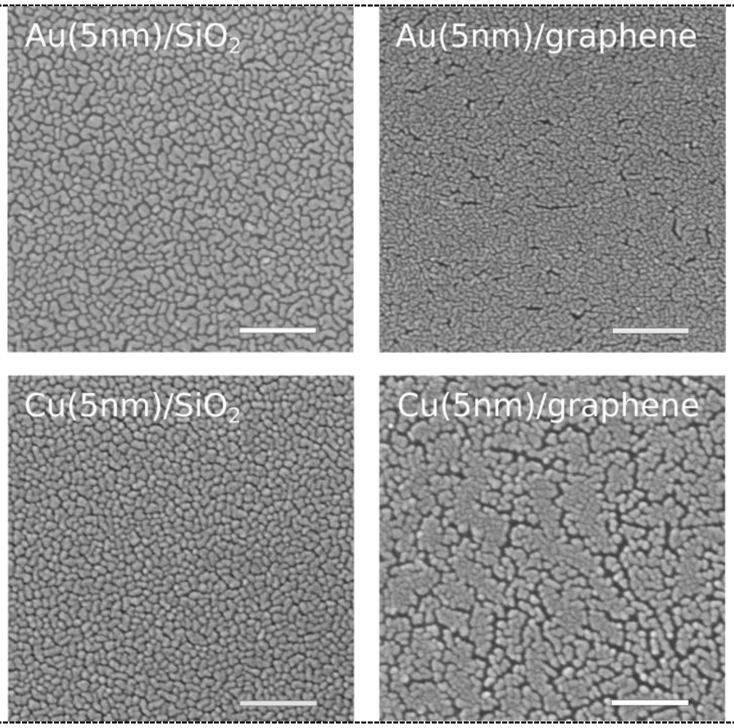

Figure 1. SEM micrographs (scale bar ≈ 200 nm) of thin gold and copper films (5-nm thick) deposited on SiO_2/Si substrates with/without graphene with a rate of 0.2-0.4 A/s at 20°C.

3. Results and discussion

Metal-graphene contact is a key interface in graphene-based device applications, and it has been recently studied in some detail [3], though, it is known that the growth of metals on the surface of graphene differs markedly from the growth of metals on ''typical'' substrates. For example, our results (see Figure 1) clearly demonstrate a significant difference in initial growth kinetics of ultrathin gold and copper films on SiO_2/Si substrates without and with graphene. It has also been shown, that this distinction in growth kinetics leads to a change of optical, electrical, and structural properties of thin metal films (20-200 nm) [7] that needs to be taken into account when developing and modelling systems/devices based on hybrid graphene-metal structures.

4. Conclusions

With the aim of preparing advanced functional materials, ultrathin gold and copper films have been integrated with graphene to study and fully exploit/optimize their properties. Thus, we studied optical, electrical and structural properties of continuous thin metal films on graphene transferred onto on SiO_2/Si substrates (grown by electron beam evaporation). The growth kinetics of thin gold and copper films on graphene has been investigated with the well-established microscopy techniques, including atomic force microscopy, scanning electron microscopy, and spectroscopic ellipsometry.

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