HYBRID STRUCTURES OF 2D/3D MATERIALS AND APPLICABILITY TO MAKE SYSTEMS FOR DETECTION OF EXTERNAL EFFECTS

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This report presents the results of the research on technology and properties of two-dimensional materials, namely graphene and molybdenum disulphide. The research was performed over the last few years and partly was supported by the long term FTMC scientific program on environment saving energy resources. The results were partly published and partly under submission procedures.

For the first time it was demonstrated that a n-MoS_2/p-Si heterostructure can be formed by our original CVD technique and applied for fabrication of self-powered near infrared (NIR) detector. The 2D layers of MoS2 were grown directly on a p-type silicon substrate and analysed by the AFM surface imaging and the Raman spectroscopy. The sample detectors based on the hybrid 2D/3D heterostructure were tested under illumination between 400 and 1200 nm. The sensitivity to the optical power of the illumination was up to about 210 V/W and was independent of the wavelength. Theoretical description based on the flat band model was proposed for the photovoltaic effect-driven response to the light.

Our studies of a relationship between the growth conditions and the properties of microcrystalline graphene (mcrGr) were based on an original plasma enhanced chemical vapour deposition (PECVD) technique acceptable to decrease the growth temperatures down to comparatively low temperatures about 400 °C. The layers with the effective thickness of 0.2 – 1.2 nm were grown on silicon substrate with insulating SiO_2 coating by the PECVD. We demonstrated that the effects produced on electrical properties of the microcrystalline graphene by both the water vapour and liquid water were originating from the same mechanisms if the initial stages of the interaction are compared. This report introduces an unexpected way to create dynamic conditions for the electrical processes in micro-crystalline graphene by changing a position of a water droplet. The effects were displayed by electrical resistance measurements under the dynamic conditions. Hybrid electrical conductance occurred due to combination of the conduction electrons and mobile ions. This combination was related to the proximity of the droplet to the surface and direct contact between liquid water and the solid produced. From our results we concluded that there were two mechanisms in the accumulating resistance change although only one were related directly to the landing of the droplet. Presence of sufficiently large source of liquid water on the surface leaded to an increase in mobile ions that were involved in the charge transport. In addition, some of the water molecules were bound to the sites at the edges of the mcrGr sheets. We think this bonding produced some quite stable structure of the water molecules formed during sufficiently long-lasting contact between the liquid and the surface.

If a monolayer graphene is used in a metal – graphene – metal system, an original way appears acceptable to create a screen with intentionally changeable tunnelling transparency for the electron transport between two metal surfaces. The experimental demonstration of the idea includes the results obtained by combined AFM force curve and local tunnelling current measurements. The model system included conductive Pt-probe that was pressed to the surface of monolayer graphene supported on a gold thin film. The idea was verified by calculations according with the combined model that included theoretical description of few processes resulting in formation of the localised tunnelling bridges across the graphene sheet. The method is acceptable to produce a group of the tunnelling bridges with individual characteristics, separated one from another on the graphene surface and functioning as independent channels for electron transfer between metal surfaces through graphene monolayer.