GRAPHENE-ON-DIAMOND: SYNTHESIS AND STRUCTURE

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Received 12May 2017; accepted 25 May 2017

Abstract.

The electronic properties of diamond and graphene, though both built of carbon, differ in two extremities. While the energy bandgap of about 6 eV in the diamond electronic structure leads to the electrical resistivity as high as 10^{18} Ω·m, graphene shows a zero bandgap at Fermi level behaving as a semimetals with extraordinary electronic transport properties.

We have been investigating the properties at the interface when these two extremities meet in tight vicinity. We synthesize graphene-on-diamond (GoD) systems using various diamond substrates: monocrystals (111), (001) and nanocrystalline layers (200 nm thick). Three different methods have been employed for syntheses: direct graphitization of the diamond surface, catalytic transformation and transfer of graphene grown externally. These should result in different interactions at the interface, which is translated into different distances between graphene and diamond surfaces as well as in different levels of atomic disorder in graphene. Our means of investigating the interactions at the interface GoD are methods of electron microscopy: SEM, TEM and STEM in atomic resolution.

Here we present the catalytic reaction of thin Ni films (thickness 20 and 500 nm) with nanocrystalline diamond (NCD; grains ~200 nm in diameter). The films are deposited on Si substrates by sputter deposition to yield a Ni-NCD-Si sequence. After reaction by annealing at a temperature of 900°C, samples were studied prior and after the removal of any residual Ni surface layer using scanning electron microscopy (SEM) and transmission electron microscopy (TEM). TEM specimens were prepared in a cross-sectional geometry by focused ion beam (FIB) thinning using protective layers of Au and Pt. After annealing of the samples with 500 nm thick Ni films (denoted NCD-500), a surface layer of C covers columns of $NiSi_2$ (see Figs. 1(a) and (b)). While graphite is observed directly at the interface with $NiSi_2$, with increasing distance to the interface the layered structure of graphite seems to become more and more disordered finally yielding amorphous C (a-C) (see Fig. 1(c)). Graphite is arising by a catalytic reaction of the Ni with diamond [1]. $NiSi_2$ is arsing by a reaction of Ni diffusing along the grain boundaries of the NCD towards the Si substrate. Also Si and C have interacted to form nanocrystallites of NiC. After annealing of samples with 20 nm thick Ni films (denoted NCD-20), isolated Ni nanoparticles arise by dewetting of the Ni film; catalytic etching by the Ni nanoparticles causes the formation of grooves in the NCD (see Fig. 2(a)) On top of the NCD, a continuous layer of a-C is observed (see Figs. 2(b) and (c)). Since the catalytic reaction of Ni and C is expected to yield the formation of graphite [1], in the present case the a-C might have formed by radiation damage during the specimen preparation via FIB [2].

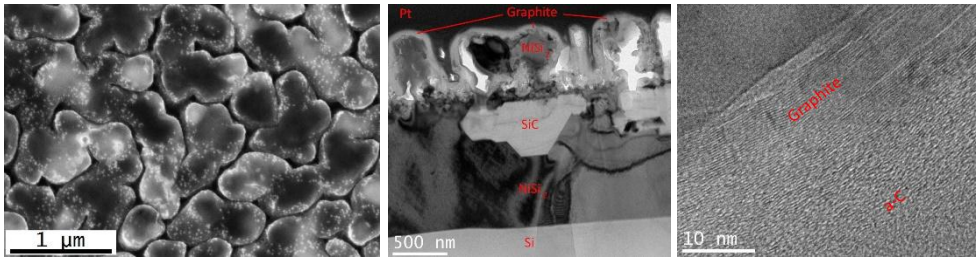

Fig.1: *NCD-500. (a) SEM image of $NiSi_2$ columns decorated with Ni nanoparticles. (b) TEM images of (a) C-$NiSi_2$-SiC-Si reaction nanostructures and (c) graphite gradually changing to amorphous C.*

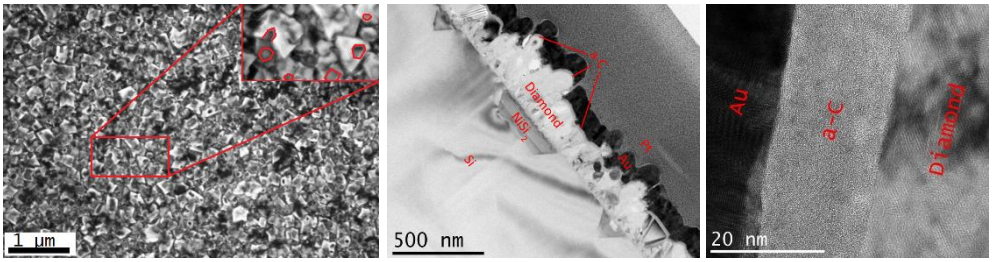

Fig. 2: *NCD-20. (a) SEM image of NCD showing grooves. TEM images (b) of the reaction layers and (c) the interface between the NCD and a-C.*

Acknowledgement
We kindly acknowledge financial support by the Austrian Science Fund (FWF I023442-N36), Czech Science Foundation GACR 16-34856L and Slovak Scientific Grant Agency VEGA 1/1004/15.

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