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S E M I N A R
aus
Halbleiterphysik und Nanotechnologie

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"Nanoscale properties of graphene studied by atomic force microscopy"

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Prerequisite for graphene technological applications is a good understanding of its properties at nanoscale. Atomic force microscope (AFM) is an appropriate tool for this purpose since it allows not only imaging, but also characterization and various mechanical and electrical manipulations of graphene with a high resolution. This talk will cover our recent results in AFM based research of graphene.

Chemical vapour deposition (CVD) is a simple and cost-effective method for the production of large-area graphene necessary for applications. However, properties of CVD graphene are degraded due to grain boundaries and wrinkles. Here, the negative influence of wrinkles in CVD graphene on its electrical and wear properties will be explained [1]. Free graphene edges are studied by AFM based lateral manipulation. The following stages will be discussed with increasing normal load: small barriers at graphene-substrate interface, elastic deformation of graphene edges, stable wrinkle formation causing plastic deformation of graphene edges, and finally, wear initiated from graphene edges [2].

Nanoscale wear of graphene is addressed by AFM based scratching. It will be shown that the graphene wear consists of the following processes: the plastic deformation for lower normal loads, followed by a sudden tearing of graphene for sufficiently high normal load, with subsequent graphene peeling off from the substrate [3]. Efficiency of graphene as a protective coating will be demonstrated on several examples: mechanical protection of fragile DNA origami nanostructures by graphene encapsulation [4], enhancement of the mechanical load capacity and complete wear reduction of substrate beneath graphene [3], and reduction of friction [3] and energy dissipation [5] by graphene coatings.

Finally, our latest results on AFM based manipulation of organic nano-needles on graphene and hexagonal boron-nitride will be presented. It will be shown that there exist preferential sliding directions for needle movement, as well as anisotropic friction during needle rotations.

[1] B. Vasić, A. Zurutuza, R. Gajić, *Carbon* **102**, 204-310 (2016).
[2] B. Vasić, A. Matković, R. Gajić, I. Stanković, *Carbon* **107**, 723-732 (2016).
[3] B. Vasić, A. Matković, U. Ralević, M. Belić, R. Gajić, *Carbon* **120**, 137-144 (2017).
[4] A. Matković, B. Vasić, J. Pešić, J. Prinz, I. Bald, A. R. Milosavljević, R. Gajić, *New J. Phys.* **18**, 025016 (2016).
[5] B. Vasić, A. Matković, R. Gajić, *Nanotechnology*, **28** 465708 (2017).