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Studies of scattering processes in graphene on nanowires substrate

The structure of graphene on gallium nitride (GaN) nanowires can be used for the construction of light-emitting diodes or light sensors. Studies of interactions between these two materials are crucial to obtain higher-performance devices. The subject of this dissertation are studies regarding four aspects of a possible influence of GaN nanowire substrates on scattering processes in graphene. These aspects are the influence of the substrate on the Raman scattering intensity in graphene, distribution of strain in graphene, carrier transport, and operation of gated graphene structures. As part of the research, several samples of mono and few-layer graphene were performed and transferred on nanowire substrates and reference epitaxial structures. Their morphology was investigated by scanning electron microscopy while graphene properties were mainly studied by Raman spectroscopy. Moreover, results obtained from the measurements of X-ray diffraction, electroreflectance, scanning electron microscopy, scanning tunneling microscopy, contactless transport, current-voltage, and capacitance-voltage characteristics were used.

As part of the first aspect of research, properties of graphene on GaN nanowires capped with $Al_xGa_{1-x}N$ of different aluminium content were analyzed. These studies showed that, contrary to other literature reports, polarization induced charges are screened in nanowires. Comparison of Raman results with numerical simulations suggested, that both light interference and the electromagnetic SERS effect are not responsible for the observed enhancement of the Raman spectra of graphene on nanowires. A comparative study for graphene deposited on gold structures showed that graphene on GaN nanowires is characterized by a low dispersion of spectral intensities. Spectra of graphene on GaN nanowires are characterized by a lower intensity and weaker luminescence background as compared to samples of graphene on gold nanostructures.

In the second part of the dissertation, it was investigated how the morphology of GaN nanowires affects the distribution of strain in graphene. In graphene on nanowires, wrinkles are formed which connect the nearest nanowires. Wrinkles between nanowires of large diameter are multiple. The strain gradient in these graphene wrinkles depends on the distance between the edges of the nearest nanowires. A local increase of this distance increases the strain gradient between suspended graphene areas located near and far from the nanowires. Moreover, the presence of wrinkles is accompanied by a modification of the local density of electronic states and an enhancement of the D’ band. The obtained results suggest that an induction of pseudomagnetic fields is possible close to the wrinkles of graphene on GaN nanowires.

As part of the third aspect of research, it was studied how a modification of the composition and morphology of nanowire ends affects the characteristics for the signal of weak localization scattering lengths. Measurements of samples of two and three layers did not show a significant influence of the number of graphene layers on scattering lengths. It was observed that a modification of the composition of nanowire ends from GaN to AlN leads to a shortening of coherence length and intervalley scattering. This suggests the presence of defects having a magnetic moment. Studies of graphene on nanowires with different morphology enable to correlate coherence lengths and long-range scattering lengths with distances between nanowire edges. Moreover, a correlation between the intervalley scattering length and the strain gradient between areas of suspended graphene located near and far from nanowires was observed. These observations suggest that an additional factor that affects the scattering lengths in graphene on nanowires is the interaction with pseudomagnetic fields.

As part of the last aspect of research, structures of graphene on gated epitaxial GaN layers and GaN nanowires were analyzed. The junction between graphene and GaN structures exhibits Schottky diode behavior. After application of a bias, the value of carrier concentration of graphene on a GaN epilayer changes significantly. For comparison, the modification of carrier concentration for graphene on GaN nanowires is one order of magnitude lower. Additionally, graphene on nanowires is affected by electrostatically induced strain. Its value scales with the percent of graphene surface in contact with nanowires. Moreover, the area of graphene in contact with nanowires affects the capacitance of the graphene/GaN junction.

The performed studies enable us to obtain several important results which characterize interactions that occur at the interface of graphene and nanowires. These results open the way for future research and show perspectives for possible applications for this kind of heterostructures.