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Epitaxial Graphene on 4H- and 6H-SiC: Growth Optimization and Characterization.

ABSTRACT - Masterthesis

The Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig which is the National Metrological Laboratory of Germany is exploring a new generation of electrical quantum standards. Currently the unit of electrical resistance (Ohm) is reproduced by measuring the quantum Hall resistance in GaAs heterostructures at very low temperatures (below 4 K) and high magnetic fields (~10T). This material could be substituted with single layer graphene which remarkably has influenced the quantum resistance standard due to its unconventional integer quantum Hall effect. Since the quantum Hall effect (QHE) can be observed in graphene up to room temperature, the goal is to fabricate graphene based resistance standard which enables the operation at higher temperature and lower magnetic fields.

The epitaxial graphene growth on silicon carbide (SiC/G) which is based on graphitization of SiC at high temperature (above 1600°C) in argon ambient (about 1 atm) is known as a promising technique for producing monolayer graphene, however, one main challenge is regarding the reproducibility of this technique. The goal of this thesis is to optimize and characterize the epitaxial graphene growth on SiC in order to tackle the problem of reproducibility of this method. For this purpose, the graphene growth on two common SiC polytypes, 4H-SiC and 6H-SiC substrates are investigated and compared.

In this thesis, argon gas flow as a neglected but key parameter of the epitaxial graphene growth is introduced and investigated. The optimized values for argon flux are found which substantially improve the SiC-graphene smoothness. In addition, applying several different creative growth techniques in this work yielded a reproducible method which enable us to have a highly precise sub-nanometric control in epitaxial SiC/G growth, resulting in an outstanding quality of graphene which meets the objective of this research. The produced monolayer graphene exhibits a high morpholoqical homogeneity, not merely about the center of the graphene samples, but also substantially very close to the edge areas. This emphasizes the capability and reliability of the implemented techniques for producing a uniform wafer size graphene. A distinct electronic feature of the presented SiC/G makes it by far the most superior quality among the already existing materials of its kind. Herein, instead of the so far

reported anisotropic resistance of SiC/G (amounts ranging from several tens to few kilo Ohm), this graphene exhibits an isotropic resistance behavior which ranges within a few Ohm. Finally, the quantum Hall measurements carried out on the produced graphene (on both polytypes, i.e. 4H-SiC and 6H-SiC) show a considerable improvement compared to the previous similar works at the PTB.