Heterostructures of ZnO on GaN Substrates Modified by Focused Ion Beam

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Zinc oxide (ZnO) is a wide bandgap semiconductor with a broad range of applications in optoelectronic devices. ZnO nanostructures can be grown by chemical bath deposition (CBD), which benefits from low temperature, large areas, and low cost. The necessary condition for CBD epitaxial growth of ZnO nanostructures is a crystallographically suitable substrate. While the preparation of high-quality ZnO seed layers remains an active topic, it is also possible to use other materials with similar lattice parameters as a substrate. Gallium nitride (GaN) is a great candidate for its mismatch of only 1,9 % to ZnO. GaN epitaxial layers are available on common substrates (Si, sapphire) with both n-type and p-type doping. This is an advantage since the production of reliable ZnO p-type is still restricted by its residual n-type conductivity. Therefore, the heterostructures of ZnO on GaN are promising for the realization of p-n junctions in optoelectronic devices.

We report on the preparation of well-defined heterostructures of ZnO/GaN on the nano-to-micro-scale using focused ion beam (FIB) lithography and solution growth. The FIB lithography enables direct patterning of the substrates by ion milling, where the shapes and the diameters of the structures are limited by the FIB resolution (several tens of nanometres). We show that the single-dot patterns can be used for the growth of highly ordered arrays of ZnO nanorods. Recent studies have demonstrated that the electronic properties of such nanorods are significantly enhanced in comparison with the nanorods grown on plain substrates without FIB patterning [1]. Our aim is to investigate the influence of the FIB treatment of the GaN substrate on the nucleation, growth, and the properties of the ZnO nanostructures.

A FIB-SEM system was used for the preparation and observation of the nanostructures, as well as for the preparation of cross-sections and lamellas for transmission electron microscopy (TEM). The ZnO/GaN interface was investigated by TEM.

The FIB patterning significantly changed the morphology and the crystal quality of the substrate. We investigated the influence of the FIB dose on these changes and thus on the nucleation and growth of the ZnO nanostructures. The results were used for further modelling of the growth processes [2], bringing us closer to the understanding of the growth mechanisms.

[1] Tiagulskyi, S., Yatskiv, R., Faitová, H., Kučerová, Š., Vaniš, J., & Grym, J. (2020). Electrical properties of nanoscale p-n heterojunctions formed between a single ZnO nanorod and GaN substrate. Materials Science in Semiconductor Processing, 2019, 11, 107.

[2] Černohorský, O., J. Grym, H. Faitová, N. Bašinová, Š. Kučerová, R. Yatskiv and J. Veselý, Modeling of Solution Growth of ZnO Hexagonal Nanorod Arrays in Batch Reactors. Crystal Growth & Design, 2020, 20, 3347