

High-quality seed layers for patterned growth of ordered ZnO nanorod arrays

Šárka Kučerová^{1,2}, Nikola Bašínová¹, Ondřej Černohorský¹, Jozef Veselý², Roman Yatskiv¹, Stanislav Tiagulskyi¹, Jan Vaniš¹, and Jan Grym¹

¹*Institute of Photonics and Electronics, CAS, Chaberská 57, Prague, 182 51, Czech Republic*

²*Faculty of Mathematics and Physics, Charles University, Ke Karlovu 3, Prague, 121 16, Czech Republic*

Properties of ZnO seed layers (SLs) are fundamental for the growth of ZnO nanorods (NRs). Crystalline structure of the ZnO SL affects the nucleation and growth of ZnO NRs in ways, which significantly differ from the nucleation and growth of ZnO NRs on ZnO bulk substrates or from heteroepitaxially prepared ZnO layers.

The size, the shape, and the preferential orientation along the c-axis as well as the in-plane orientation of the crystallites within the ZnO SL are crucial for the uniform nucleation, vertical alignment, and crystalline quality of the ZnO NRs. We have recently prepared high-quality ZnO SL by the sol-gel process [1].

However, the influence of the ZnO SLs is even more significant and visible during patterned growth, where the NRs do not nucleate randomly - their positions are lithographically defined. Any deviation from the orientation of the crystallites along c-axis causes visible misalignment of the grown nanorods. For good crystallinity, ideally monocrystallinity, of the ZnO NRs grown on patterned ZnO SL, the correlation between the size of an opening in the patterning mask and the size of the crystallites in the SL is crucial. If the size of the opening is equal or smaller than the average size of the crystallites in the SL, the probability of the nucleation and growth of a monocrystalline NR from a single crystallite is significantly increased. Consequently, the requirements for the SL are a high texture with the c-axis oriented perpendicular to the substrate surface, maximum size of the crystallites with a small dispersion of sizes, and a low surface roughness to ensure high quality and reproducibility of lithographic patterning. When all the requirements are fulfilled, highly ordered arrays of identical, monocrystalline, well aligned ZnO NRs can be grown.

We present patterned growth of ordered ZnO NRs on the SLs, where the parameters of the sol-gel process are varied. The SLs were examined with SEM, EBSD, photoluminescence, AFM, AC impedance measurements, TEM, ACOM-ASTAR, and EDX. A significant influence of the concentration of precursors on the average size of the crystallites was observed and the impact of the heat treatment on the shape of the crystallites was investigated. Finally, a patterned growth of ZnO nanorod arrays was performed by chemical bath deposition. The NRs were investigated by SEM, TEM, ACOM-ASTAR, and EDX to describe the relationship between the properties of the patterned ZnO seed layers and the properties of the ZnO nanorods and to shed light on their nucleation and growth.

- [1] Bašínová, N., Černohorský, O., Grym, J., Kučerová, S., Faitová, H., Yatskiv, R., . . . Maixner, J. (2019). Highly Textured Seed Layers for the Growth of Vertically Oriented ZnO Nanorods. *Crystals*, 9(11), 566.