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SONDERSEMINAR

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"III-nitride Nanowires for Optoelectronic Applications: Growth and Characterization"

In the last decade III-nitride nanowires (NWs) have gathered increasing interest in the scientific community as candidates suitable for future nano optoelectronics. We grew GaN NWs with extremely good crystal quality and strong luminescence efficiency by means of plasma-assisted molecular beam epitaxy on different substrates [1-5]. The self-assembled growth took place under N-rich conditions. For a detailed description of the experimental growth conditions and the influence of the different parameters please refer to [1-4]. Due to the large surface-to-volume ratio of the wires, the optoelectronic properties [6,7] as well as growth processes [2-4] are essentially dependent on the wire diameter. Therefore the precise control on the sizes and position of the nanowires is a crucial topic for future development of reliable and reproducible nanodevices. We present catalyst-free selective area growth of GaN NWs using a template approach [8,9]. A thin AlN layer with a thickness of approximately 10 nm is deposited on an n-doped Si(111) substrate. The sample was subsequently coated with silicon oxide, which patterned. The mask layout contains different areas with two-dimensional hole arrays arranged in hexagonal lattices. The influences of the growth parameters on the selectivity as well as the mask properties will be discussed. A substrate temperature as high as 825 °C and a gallium flux of 0.7 x 10^{-7} mbar were used to obtain optimal growth conditions. The nanowire morphology is at its best when choosing a hole diameter of approximately 60 nm. For a quantitative description of the growth phenomena, the volume of the nanowires is described using an elementary model which takes into account the direct impinging and the collection of adatoms on the substrate around the nanowire. Cathodoluminescence spectroscopy measurements on individual nanowires reveal their high optical quality [10].

For the use of NW structures in nanoelectronic or optoelectronic devices, both n- and p-type doping are important issues and have to be investigated in detail. Especially control over efficient p-type doping is a crucial task to master. To this end we investigated the effect of doping GaN NWs with Mg at different stages of the growth. The nucleation behaviour of Mg doped GaN NWs has been studied and compared to their undoped counterparts. A much more rapid nucleation (shorter incubation time) is observed if Mg is supplied going along with a higher number on NW nuclei. Under the employed growth conditions, the energy for nucleation of GaN was 4,0− 0,3 eV and 3,2− 0,3 eV for GaN grown under Mg supply [11]. The sharp difference in the PL and CL spectra of the samples with Mg at the top or bottom of the NWs suggests that Mg is much more likely to be incorporated when supplied after the NWs have already developed [12]. Polarity determination via EELS yields the same nitrogen polarity for both types of wires [12].

We performed also Raman characterization on nanowire ensemble in comparison with single nanowire measurements [13, 14]. The ensemble spectra of GaN NWs did not reveal a deviation from the selection rules for the wurtzite structure, in contrast in the single wire spectra, only A_1(TO) was observed, which intensity is almost suppressed if the laser polarization was perpendicular to the nanowire axis. These results indicate that the penetration of the laser light and the Raman scattering in isolated GaN nanowires thinner than 100 nm is governed by size effects.

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