PAMBE growth of GaN nanowires on ZrN metallic buffer layers

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There is an increasing interest in growth of GaN nanowires (NWs) on metallic buffer layers being due to expected enhanced efficiency of NW-based devices. However, several issues such as difficult GaN nucleation or reaction of the metallic buffers with Ga flux have been reported.

In this work we use metallic layers of polycrystalline zirconium nitride (ZrN) for growth of GaN NWs by plasma-assisted MBE (PAMBE). Importantly, we found that ZrN buffers are chemically stable, do not react with Ga and N fluxes and are easily deposited on various substrates by sputtering. Fig. 1 shows result of self-assembled growth on Si(111) substrate coated with a 100 nm thick ZrN buffer layer. The arrays of device-relevant well-oriented NWs were obtained despite random orientation of ZrN grains on which epitaxially linked NWs nucleated. As discussed in our previous work [1] this observation can be attributed to the process of geometrical selection when due to unidirectional supply of the material fluxes in MBE, growth of NWs perpendicular to the substrates surface is favored over tilted ones.

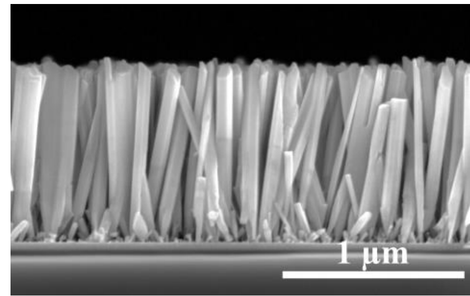

Fig.1: SEM image of GaN NWs on ZrN/Si(111) substrate (SEM A. Reszka).

We have observed that growth of GaN NWs on ZrN/Si(111) substrate is limited to temperatures below 800°C. Our XRD and AFM studies indicate that at higher temperatures ZrN films react with Si leading to formation of $ZrSi_2$ phases, degradation of the substrate surface and decreased electrical conductivity of the buffer. Therefore, for higher growth temperatures we replaced Si(111) wafers with sapphire (Al_2O_3). Then, stability of ZrN/Al_2O_3 substrates was preserved, allowing in addition extraction of light emitted by a NW based LED through the host wafer.

Interestingly, we found that under specific growth conditions (Ga/N flux ratio, substrate temperature) self-assembled nucleation of GaN on ZrN requires extremely long incubation times making ZrN useful as a mask for selective area growth (SAG) of GaN. This allowed us to obtain ordered arrays of high quality hexagonal GaN NWs (Fig. 2) grown selectively from openings in 7 nm thick ZrN mask on GaN/ Al_2O_3 template.

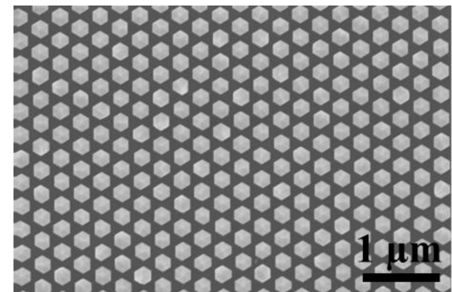

Fig. 2: SEM image of SAG GaN NWs on GaN/sapphire substrate with ZrN mask.

[1] K. Olszewski, et al. *Nanomaterials* **2023** 13 (18) 2587

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