Position control of MOVPE grown GaN nanorods using nanoimprint lithography

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Nano Imprint Lithography (NIL) is a promising technology that combines low costs with high throughput for fabrication of sub 100 nm scale features. One of the first application areas in which NIL is used is manufacturing of various types of LED's. The wafers used for producing LED's are typically III/V semiconductor materials grown with epitaxial processes suffering from growth defects like hexagonal spikes, v-pits, waferbowing etc on the scale of a few µm or even larger islands of irregularities. The mentioned irregularities are particularly disturbing when NIL based processes are utilized to create patterns onto the wafer surface, see figure 1. The defects can cause large areas without nano-patterns, substrate breakage or as in the case where the stamp is applied directly onto the substrate, breakage of the stamp itself. Using Obducat's IPS®/STU® manufacturing process circumvents this since no hard materials touch each other during the entire process sequence, see figure 2. The IPS® material is flexible which allows the stamp to adjust to the curvature and roughness of the substrate, thereby giving a uniform residual layer on full wafer scale. Indeed, this is essential for high volume manufacturing where the imprinted nanostructures must have an even quality every time. The nanopatterns created by NIL can be applied to control metal organic vapour phase epitaxy (MOVPE) growth of GaN nanorods (NRs) containing optically highly efficient defect-free quantum discs with tunable emission wavelength or core shell heterostructures to improve high efficiency light emitting devices.

Here, we show a method of positioning the GaN nanorods by using NIL performed using a Sindre® 400 by Obducat. A master stamp was manufactured using e-beam lithography on a Si wafer with resist and replicated to a nickel mother stamp by electroplating. The nickel stamp was then coated with an anti-adhesion monolayer of a fluorinated alkyl phosphate. The stamp had several types of patterns ranging from 150 nm to 250 nm with varying pitches. The depth was kept constant at 100 nm. The substrates used were two inch sapphire substrates with a 30 nm SiO_2 masking layer deposited by CVD on top a GaN layer. The substrates were spin-coated with 98 nm TU2 resist. The imprint process was optimized to give a residual layer below 20 nm with a structure depth of 97 ± 5 nm. An appropriate reactive ion etching (RIE) step opened the desired hole-pattern in this SiO_2 layer. The quality of the subsequent MOVPE grown NRs such as e.g., position, shape, size and defect density, is determined by the highly precise NIL process. Based on the described stamp, the different patterns will be evaluated in order to find the optimal pattern for the best positioning of the nanorods resulting in a better light extraction from the produced LEDs.

This paper will show that NIL is the preferred technology to produce nanopatterned GaN substrates highly suitable to grow defect free arrays of position-controlled nanorods for ultrahigh brightness LED applications.

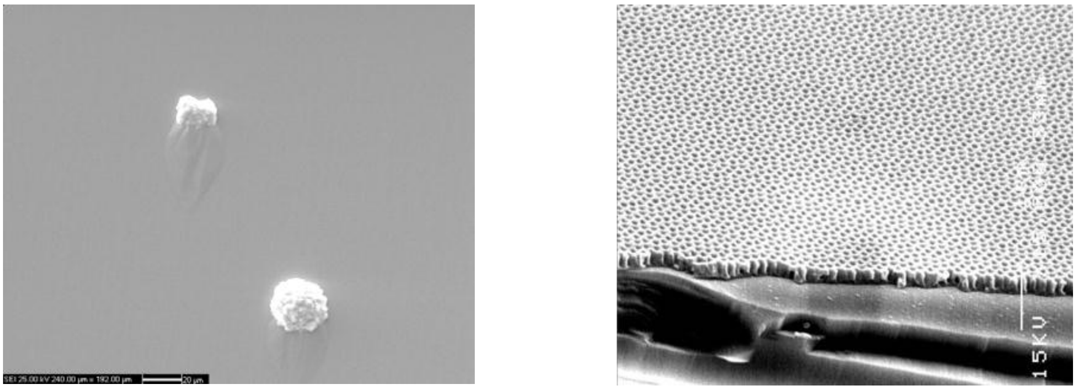

Fig. 1 SEM measurements showing µm-sized cauliflower-shaped epitaxial growth defects (left) and SEM measurements of a quasi crystal pattern printed on a GaN epi-layer. The pattern covers the entire surface despite the growth defect shown to the right. The hole diameter is 90 nm.

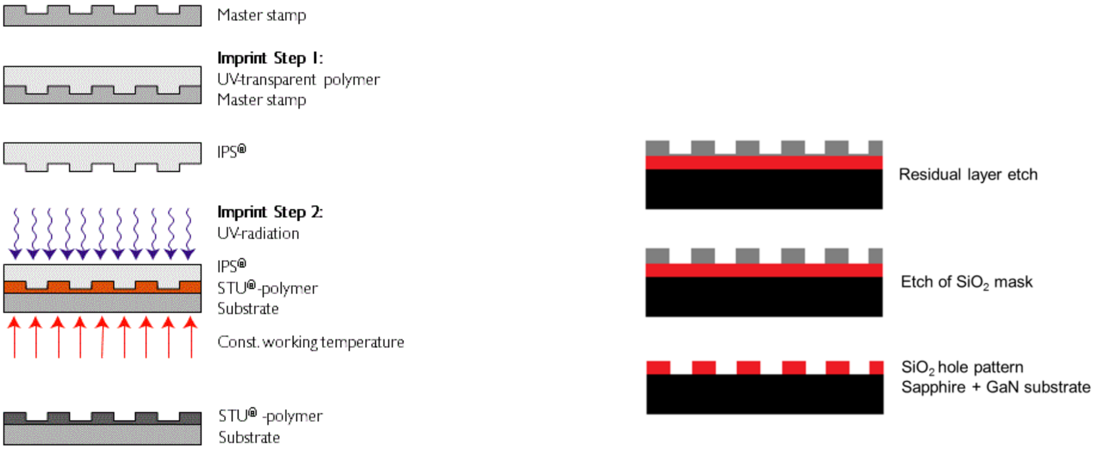

Fig. 2 Process flow for the IPS/STU process (left)) and etching of substrates to prepare for MOCVD growth of nanorods.

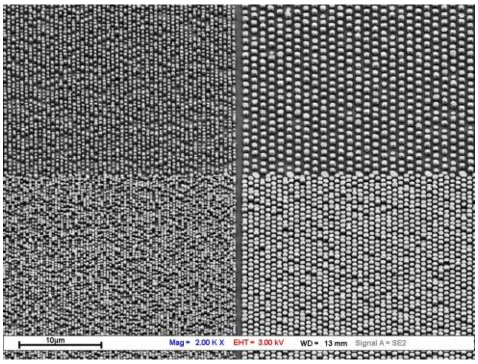

Fig. 3 SEM image of MOVPE-grown nanorods 90 s after nucleation. The diameter as well as the distance of the nanorods is controlled by the SIO2 mask fabricated by NIL process.