Fabrication of GaN nanorods by focused ion beam

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Keywords: Nanorods, FIB, GaN

Abstract Text

III- Nitride nanocolumns (III-N NCs) are the subject of intense research since the past decade because of their unique properties and potential electronic and optoelectronic applications. NCs are usually grown on Si(111), Si (100), SiC, and sapphire substrates by a self-assembly process using plasma-assisted molecular beam epitaxy [1-3]. Unlike continuous layers, NCs accommodate the lattice-mismatch with the substrate through a network of misfit dislocations localized at the hetero-interface. Therefore, they grow fully relaxed and free of extended defects such as basal plane stacking faults or threading dislocations. This fact makes III-N NCs excellent candidates to develop arrays of highly efficient nanolight-emitters in the infrared-visible-ultraviolet range.

The efficiency of a nanolight emitter will be increased if the NCs are aligned in a periodic pattern. Several research groups have tried different methods for the patterning. The most used one has been e-beam lithography. In this case, periodic structures can be fabricated, but most of the times remains resist residues along the sample and in that case a plasma treatment is needed. This problem affect in the posterior growth of the NCs in the MBE system Another approach has been the use of colloidal lithography with nanospheres. This technique requires less fabrication steps than the e-beam lithography and it is free from residues over the substrate. But the disadvantage of this technique is that is quite difficult to have a regular pattern along large areas.

In our approach, we decided to use a focus ion beam system (ionLine from Raith, Germany) in order to create the nanostructures (see Fig. 1). This technique will pattern our substrate in only one step and with high precision in the periodicity due to the laser interferometric stage. The sample used was a 2 inch wafer of GaN over a sapphire substrate (Lumilog, France). A thin layer of 7 nm of Ti was deposit on top. The metal layer was patterning by the ionLine with holes of 100 nm and a pitch of 250 nm in writing fields of 50 µm. A matrix of 64 elements was fabricated covering and area of 400 μm^2 (see Fig. 2). We duplicate the dose in every writing field. After this one step process, the sample was inserted inside an MBE in order to grow the NCs. At low doses, (see Fig 3 top) one can observe that there are single GaN NCs in every hole. This behavior will be expected also inside the holes patterning with bigger doses, but as one can observe (see Fig 3 bottom) the NCs is a vertical cylinder with a hole inside. This effect can be observed more clear when the samples are tilted 45 º (see Fig 4)

In conclusion, we propose a single step processing for the fabrication of GaN NCs. This technology is very efficient because there is no need of a resist layer and the system can pattern large areas. Finally with the ion dose one can control the geometry of the NCs, from single ones to circular ones.

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Figure 1. Ionline system from Raith.

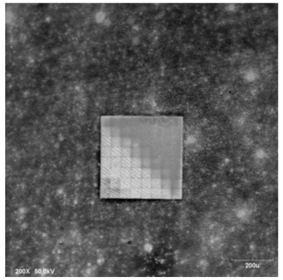

Figure 2. 400 x 400 µm patterned region

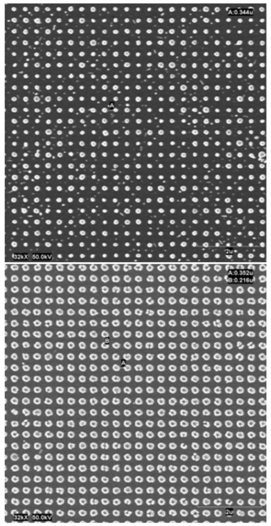

Figure 3. GaN nanorods with different shape. Top image: single nanorods. Bottom image: circular nanorods

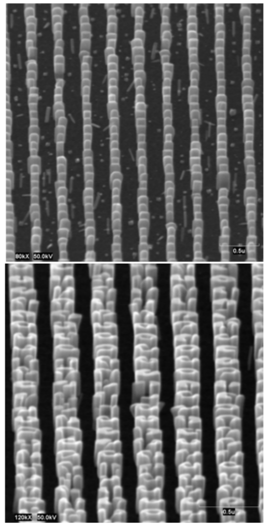

Figure 4. SEM pictures of the previous structures tilted 45º.