Graphene Electrodes For Nano-LEDs

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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. Finally, the efficiency of a nanolight emitter will be increased if the NCs are aligned in a periodic pattern.

Normally the transparent conducting electrode used for the light emitting diodes (LEDs) is the indium tin oxide (ITO), but this material has a high cost and is instable in the presence of acids or bases and has poor transparency in the blue and near-infrared light ranges [4]. Furthermore the need for a substitute for ITO is ever increasing due to the limited availability of indium on earth [5]. Graphene is the ideal candidate in order to replace the ITO due to its excellent electrical, optical and mechanical properties. So in this work we used graphene as a transparent electrode to fabricate the nanoLEDs.

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 an area of 400 μm^2. After this one step process, the sample was inserted inside a plasma assisted MBE in order to grow the NCs. With different conditions one can create NCs with diverse doping (n or p) creating nanoLEDs. These devices are coated with a layer of SiO_2 as isolator. Finally, on top we deposit a layer of graphene as transparent electrode. The electrical characterization of the devices was made with AFM and with a probe station with a semiconductor analyzer. In figure 2, one can observe different steps in the fabrication of the nanoLED: AFM image of the nanoholes created by the ion beam system, SEM image of the nanoLEDs grow in the MBE system and I/V curve obtained in this device.

In conclusion, we propose the use of a graphene layer as a transparent electrode for GaN nanoLEDs. The electrical conductivity is higher than with ITO and its flexibility makes it the best material for contacting all the nanocolumns.

References

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Figures

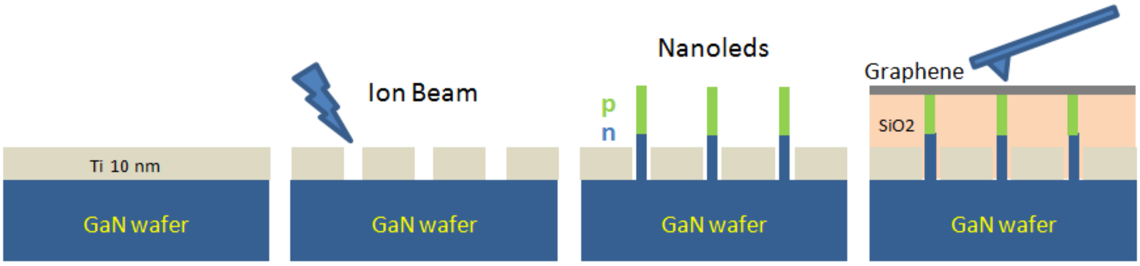
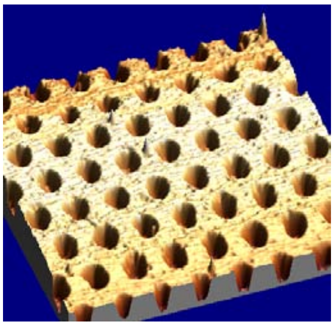
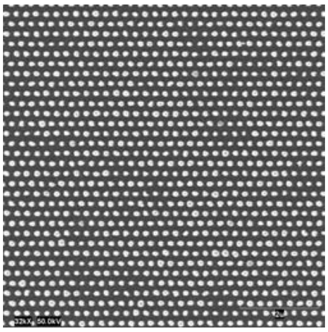


Figure1. Fabrication scheme of the GaN nanoLEDs. A Titanium thin metal layer is deposited along the wafer with an e-beam evaporator. In a second step, a metal layer is patterned with an ion beam equipment in order to create nano-holes arrays. In a third step, the sample in inserted in a MBE system and the nanoleds grow inside the patterned areas. Finally, is deposit a layer of SiO_2 and on top a graphene layer as electrode.





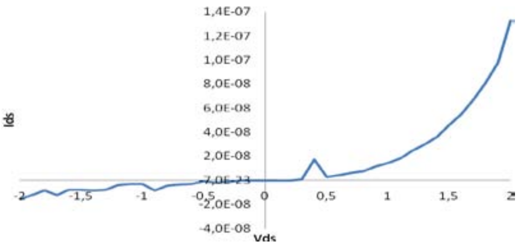


Figure 2. AFM image of the nano-patterned holes on the Ti metal layer.SEM image of the selective area growth of GaN NCs by PA-MBE. Electrical characterization of the nanoLEDs.