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Evaluation of Mechanical Strain and Electrical Fields in GaN-based LED Devices with V-Defects

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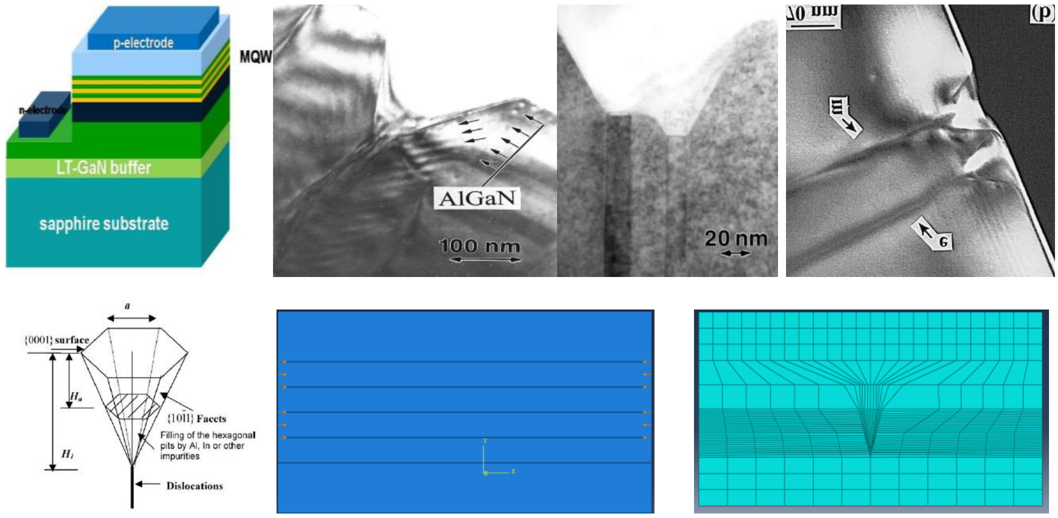
Multi quantum well (MQW) in the GaN-based LED devices are made up of successive layers of GaN and InGaN. The band gap, luminous efficiency and the color of light depends on the percentage of indium in LED devices. Percentage of indium also increases lattice mismatch between GaN and InGaN layers in the MQW region. Various types of defects such as V-defects are formed to relieve the high misfit strain in the MQW region. GaN/InGaN layers also exhibit piezoelectric property which induces electric field that can influence optoelectronic properties of these devices. Therefore, accurate evaluation of the stresses, strains and electric fields is important in predicting the overall performance of these devices. V-defects in the MQW in one hand restrict the formation of nonradiative recombination centers by blocking the threading dislocation while reduces the overall light illumination area. It is of great interest for industry to increase the overall efficiency of these devices by engineering the v-defects in the MQW region. Our aim is to quantify the change in the field variables with and without v-defects in MQW región. This work can help in understanding the mechanisms in the misfit strain relief in the presence of v-defects in the MQW región.

Multi quantum well region (MQW) along with n-GaN and p-GaN layers has been modeled in the commercial finite element tool, ABAQUS with and without v-defects. Four layers of GaN and InGaN are of 10 nm thick while n-GaN and p-GaN are 100 nm thick which have been modeled as *n-GaN/GaN/InGaN/GaN/InGaN/p-GaN* (Fig. 1 b). The lattice parameters of InGaN have been calculated by using Veegard's law in terms of the lattice constants of GaN and indium nitride. The mismatch between these layers depends on the percentage of induim content. Cases of 10, 20, 30 and 40% indium have been considered. Lattice parameters of InGaN are bigger than the GaN lattice, therefore, InGaN lattice has to be compressed to match with the GaN lattice. The misfit has been accomodated in the model by applying compressive displacement load to the InGaN layers (Fig. 2). The models have been meshed by piezoelectric elements available in ABAQUS. Four different cases have been considered for v-defects in the model, (i) v-defects in the p-GaN region, (ii) v-defects in the n-GaN, (iii) v-defects in the p-GaN and MQW and (iv) v-defects in the every region.



(a) (b) (c)

Fig. 1: (a) Schamatic model of v-defect in AlGaN epitaxial layer (Soh et al., 2004), (b) ABAQUS model of multi quantum well made up of successive layers of GaN/InGaN including n-GaN at the bottom and p-GaN at the top without v-defect (b) Meshed model of multi quantum well with v-defect

General static analysis has been carried out to evaluate the distribution of the field variables such as elastic strain, ε_{ij}, and the electric field, E_i, for the v-defect free model and the models with v-defects in the various regions as discussed above. These electroelastic fields can be used to calculate the optoelectronic performance of the devices in presence of the v-defects.

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