Effect of Threading Dislocations on Semi- and Nonpolar GaN/AlN Quantum Dots

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ABSTRACT

The effect of adjacent threading dislocation at the edge of polar GaN/AlN quantum dot was widely discussed in the literature, see e.g. [1]. Anyway, development of growth techniques for the III-nitrides is moving towards semipolar or even nonpolar orientations, where more efficient radiative recombination is expected due to less significant quantum confinement Stark effect and elimination of spontaneous polarisation. New growth orientations entails entirely new geometry of quantum structures, what calls into question already done analyzes carried out for polar setup. First off all, there are only a few experimental reports showing the real geometry of semipolar and nonpolar quantum dots which differs significantly from well known truncated hexagonal pyramid shape, see e.g. [2]. Secondly, there is no clear information about the geometric relation of the dislocation line and the quantum dot as it was clearly presented in the polar case. However, such relation definitely exists as it is well documented that its dislocation density is much higher compared to crystals grown in the polar regime. Finally, the possible effect of charged dislocation line may additionally alter the optoelectronic properties of the quantum dot [3].

In this work, finite element method is used to determine how the threading dislocation affects semipolar and nonpolar quantum dots and alternates its build-in elastic and electric fields, so in this way modify band-to-band transition energy for the recombining pair of carriers. Threading dislocation, modeled by use of classical continuum dislocation theory via polynomial approximation for distortion field, generates axisymmetric elastic and electric fields. Coupled fields around dislocation line affect neighbouring quantum dot with its build-in fields related to lattice mismatch between GaN dot and AlN matrix and in a limited extent to spontaneous polarisation. Additionally, electric charge localised along the dislocation line is taken into account, and generates extra negative potential field affecting close surroundings of the threading dislocation. Two common types of threading dislocations for III-nitride epitaxial layers are considered: perfect edge- and perfect screw-type dislocation.

It is demonstrated that local elastic and electric fields around threading dislocation together with the presence of an electric charge along dislocation line affect local piezoelectric field build-in the quantum dot, creates geometrical shift of the carrier localization regions, and reduce band-to-band transition energy.

REFERENCES

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