The emission of polarized light from GaN/AlN self-assembled quantum dots subject to variable excitation conditions and uniaxial interfacial stresses

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Group III-Nitride-based wurtzite self-assembled quantum dots (QDs) have attracted much attention in the fundamental semiconductor physics and for potential device applications. An important characteristic of group III-Nitride compounds is the existence of a large polarization field, originating from both piezoelectric and pyroelectric polarizations. The charge polarization will create electric fields along the [0001] QD growth axis that will be screened in a complex manner when electrons and holes begin to fill the excited energy levels of the QD during sufficient levels of excitation. In this work, GaN/AlN self-assembled QDs were grown by the Stranski-Krastanov method on a Si(111) substrate using molecular beam epitaxy. During the subsequent cooling from growth temperatures, the thermal expansion coefficient mismatch between the Si substrate and GaN/AlN film containing vertically stacked QDs leads to an additional tensile stress at the Si/III-Nitride interface, which is partially relaxed by the formation of microcracks that propagate parallel to the interface and mainly along the <11-20> directions. We demonstrate that these defects serve as excellent stressors which can modify the strain tensor of QDs in close proximity (i.e., within a few μm's) of the microcracks.[1,2] The excitonic luminescence of QDs with a uniaxial stress perturbation exhibits an in-plane linear polarization anisotropy. Localized cathodoluminescence (CL) spectroscopy of the QDs exhibits emissions from both the ground and excited states, whose relative contributions depend on the level of excitation and temperature. We have studied these emissions using time- and polarization-resolved CL for ensembles of QDs.[1,2] The effects of screening of the polarization field in the QD, state-filling, changes in the polarization anisotropy and lifetime with varying excitation were studied experimentally and modeled with a 6×6 **k·p** calculation method.[3,4] Using the method of ensemble CL, we excite locally groups of vertically stacked QDs in varying proximity to the microcracks. The local strain tensors for such QDs, which are subject to an interfacial stress perturbation, have been determined by modeling the dependence of the QD excitonic transition energy on the interfacial stress. Varying levels of excitation are employed by adjusting the *e*-beam current to analyze the effects of carrier filling in the QDs and the resulting emission from excited states. Experimental results indicate that the polarization anisotropy ($R_p = I_\perp/I_\parallel$). vanishes at high temperatures with an increasing excitation of the QDs, while the anisotropy decreases more slowly with excitation at low temperatures.[3] A theoretical modeling of the effect of carrier filling on the polarization anisotropy and lifetime was performed, as based on

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[1] G. Sarusi, O. Moshe, S. Khatsevich, D. H. Rich, and B. Damilano, Phys. Rev. B **75**, 075306 (2007).

[2] O. Moshe, D. H. Rich, B. Damilano and J. Massies, Phys. Rev. B **77**, 155322 (2008).

[3] O. Moshe, **D. H. Rich**, B. Damilano and J. Massies, "***Polarized emission from GaN/AlN quantum dots subject to uniaxial thermal interfacial stresses*"**, J. Vac. Sci. Technol. B **28** (4), C5E25 (2010).

[4] O. Moshe, **D. H. Rich**, S. Birner, M. Povolotskyi, B. Damilano, and J. Massies, ***Electronic and optical properties of*** **GaN/AlN** ***quantum dots on*** **Si(111)** ***subject to in-plane uniaxial stresses and variable excitation***, J. Appl. Phys. **108,** 83510 (2010).

3D self-consistent solutions of the Schrödinger and the Poission equations using the 6×6 **k·p** and effective mass methods for the calculation of the *e-h* wavefunctions, including the effects of the interfacial stress, microcrack-induced stress perturbation, carrier-induced screening of the QD polarization field, temperature, and occupation of the QD excited sates through changes in the quasi-electron and -hole Fermi levels.