Induced dielectric polarization effects on valence band alignment in multi-quantum well structures in wurtzite semiconductors

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Nitride compounds, AlN, GaN, InN, and its solid solutions are much available for the optical infrastructures owing to the facts that these materials enable to emit light in the wide wavelength range from infrared to near vacuum ultraviolet, and to build a new type of photovoltaic cell [1]. A hetero-junction is sometimes employed to achieve the better efficiency in laser diodes and light emitting diode. In a sandwich structure or so-called a multi-quantum well (MQW) structure, however, the thicker well layers draw the rapid decrease of the intensity of the luminescence from the surfaces perpendicular to c-axis. In addition, it is observed that the peak position shifts to the lower energy (red-shift) than that of bulk in the thick well layers. Such materials belong to wurtzite group (P₆₃mc) and have a spontaneous polarization in the different degrees among those. The sandwich structures such as AlN/GaN/AlN or MQW structures composed of these materials generate a spontaneous electric field in each layer. The spontaneous electric field lowers the electric potential towards the interface of one side [2], leading to the red shift of the luminescence energy.

Now, we examine induced dielectric polarization effect to understand the weaker intensity of the surface luminescence with thicker well layers. The hetero-junction consisting of the materials with the different spontaneous polarization induces a dielectric polarization in the material with a smaller spontaneous polarization. This induced dielectric polarization may elongate the crystal length along the c-axis and perturbs the trigonal component of the ligand field, which causes the valence band splitting, converting the $\Gamma_7(p_z)$ band from the valence band bottom to the valence band top in GaN. The transition to the $\Gamma_7(p_z)$ band has the luminescence polarization parallel to the c-axis, and emits the luminescence from the edge of the sample. Therefore, the surface luminescence with the perpendicular polarization to the c-axis reduces. In this conference, we propose a model to elucidate the luminescence characteristics observed, taking the quantum confinement effect into account.