Polarization-resolved photoluminescence study of isolated GaN nanowires grown by catalyst-free MBE

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Polarization- and temperature-dependent photoluminescence (PL) measurements were performed on individual GaN nanowires grown by catalyst-free molecular beam epitaxy on Si(111) substrates. The c-axis lattice constant (0.518 46 +/- 0.000 05 nm) for these wires, measured with x-ray diffraction, matched that of strain-free bulk GaN. The wires were typically 5-10 μm in length, c-axis oriented, and 30 - 100 nm in diameter. In most instances, wire diameters were uniform over the entire length with cross sections displaying a well-formed hexagonal growth habit with sides conforming to the prismatic planes. These wires were ultrasonically removed from the growth substrate and dispersed onto sapphire substrates to enable PL measurements on individual wires with a $\mathbf{k}\perp\mathbf{c}$ (pump light incident perpendicular to wire axis) geometry. Polarized and unpolarized PL spectra were collected from several dispersed nanowire samples. Strong near-band-edge emission occurred within 1 meV of energy peaks associated with both free and bound excitons of strain-free GaN at low temperatures (< 5 K). For a typical sample, the donor-bound exciton D^0X_A peak dominated the spectrum at the stress-free position of 3.472 eV. Free exciton peaks X_A and X_B were evident and respectively located at 3.478 eV and 3.483 eV. The first phonon replicas of these dominant peaks occured over the spectral range of 3.38 eV to 3.39 eV. Evidence of the second phonon replicas appeared above the noise floor at around 3.29 eV. Other weaker peaks observed at 3.41 eV, 3.34 eV, and 3.21 eV may indicate excitons bound to surface and or other structural defects. A peak at 3.43 eV was not yet assigned but was also observed in nanowire samples taken from separate growth runs. Broad blue luminescence centered around 2.9 eV was observed in PL spectra taken from the as-grown material (nanowires remaining on their growth substrate), while no such emission was observed in individual dispersed nanowires, or "clumps" of individual nanowires. This broad blue emission therefore is associated with the highly defective GaN "matrix" layer portion of the growth. No yellow luminescence (YL), which is widely reported to be associated with vacancy and structural defects in GaN films, was observed in the PL of individual nanowires. Polarized PL spectra differed for the $\boldsymbol{\sigma}$ **(E⊥c, k⊥c)** and $\boldsymbol{\pi}$ (**E**||**c**, **k**⊥**c**) polarization cases, illustrating the polarization anisotropy of the exciton emission associated with high-quality wurtzite GaN. This anisotropy in PL emission persisted even up to room temperature (4 K to 296 K). To the best of our knowledge, this is the first time such exitonic-polaritron anisotropy has been observed at room temperature for any type of wurtzite GaN. Additionally, the nanowire PL varied with excitation intensity and with (325 nm) pump exposure time. Further work is planned to isolate the effects of excitation intensity, light exposure, and nanowire sample preparation.