Monday

Tuesday

Wednesday

Thursday

Friday

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A semiconductor-like InN?

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There are considerable discrepancies between the reported theoretical data of the crystal-field splitting from 17 to 301 meV and the spin-orbit splitting from 1 to 13 meV of InN [1,2], which have played a very important role in elucidating the band structure of semiconductors and in investigating the control of spin relaxation rate for spintronics [3]. A few papers on photoreflectance (PR) or electroreflectance study in InN have been reported [4,5], and only the band gap has been characterized. A metal-semiconductor transition behavior in Ga- or Al-doped ZnO at low temperatures has been demonstrated, which is a candidate for transparent conducting oxides [6]. Recently, temperature-dependent electrical resistivity in InN films and InN nanowires with side lengths larger than 80 nm also shows similar behavior as observed in doped ZnO [7,8]. This makes it possible to measure PR spectra of InN at low temperatures due to the semiconductor-like properties.

Two native n-type InN samples are studied. The InN-1 sample is grown by metal organic chemical vapor deposition. The InN-2 sample is grown by plasma-assisted molecular beam epitaxy. Room-temperature Raman spectra and temperature-dependent PR and photoluminescence (PL) spectra are utilized to investigate the crystalline quality, electron concentrations, electronic band structures, and optical properties of the InN films. The electron concentrations are estimated to be 1.44×10^{19} and 0.58×10^{19} cm^{-3} at room temperature for InN-1 and InN-2, respectively, according to the PL peak positions considering the Burstein-Moss effect. For InN-2, PR feature is not detectable until the temperature is below about 100 K. This result can be attributed to a transition from a metal-like conductor (above 100 K) to a semiconductor caused by free electrons cooling down to trap states at such low temperatures. This observation is well consistent with Refs. [7,8]. The energy level of the trap has been reported around 52 meV below the conduction band minimum [7]. For InN-1, no PR signal is observed even at 15 K. The presence of high concentration of free carriers prevents efficient electromodulation. The temperature-dependent PL lineshapes are also different for InN-1 and InN-2. Based on the PR results and the appropriate Hamiltonian, the values of crystal-field splitting and spin-orbit splitting in InN are experimentally determined, for the first time, as 24.2 and 17.4 meV, respectively, at 30 K for example.

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