Form 2

Dissertation Abstract No. _1/2_

Report no.	(Course-based) No. 1095	Name	Md. Dulal Haque
Dissertation title	Characterization of Intermediate Band Solar Cell Semiconductors by Two-wavelength Excited Photoluminescence (２波長励起フォトルミネッセンス法による中間バンド太陽電池用半導体材料の評価)		

A promising technology for the realization of high efficiency solar cells is the use of intermediate band solar cell (IBSC) materials. The mismatch of lattice parameters between host and intermediate band materials and the incorporation of impurity atoms produces interface and point defects as well as dislocations which act as nonradiative recombination (NRR) or trap centers in the crystal. The defect mediated NRR centers reduces the carrier lifetime and are responsible for the low photoconversion efficiency of the IBSC. To resolve these problems, it is indispensable not only to understand the fundamentals of as-grown defects and imperfections in these IBSC materials, but also to find out the correlations of these defects with the performance and reliability limiting problems, and attribute their physical origins

In this research work, different GaAs:N δ-doped and InAs/GaAs QDs superlattice (SL) structures have been characterized by two-wavelength excited photoluminescence (TWEPL) method. The sample is excited by the above-gap excitation (AGE) light of energy $h\nu_{A1} > E_{GaAs}$ for conduction-band excitation or $h\nu_{A2} > E_{IB}$ for IB band excitation of InAs QDs and GaAs:N δ-doped SL, respectively. Another intermittent below-gap excitation (BGE) light of energy $h\nu_B < E_{IB}$ is superposed over AGE at the same point on the sample surface.

The NRR centers in GaAs:N δ-doped SL structures grown by molecular beam epitaxy technique has been investigated by TWEPL for conduction band and E_- band excitation schemes. The change in photoluminescence (PL) intensity due to the superposition of BGE at energies of 0.75, 0.80, 0.92, and 0.95 eV and AGE at energies of 1.69 or 1.45 eV into the GaAs conduction band and E_- band implies the presence of NRR centers inside the GaAs:N δ-doped SL and/or GaAs layers. The change in PL intensity as a function of BGE power density is examined for both bands, which enables us to determine the distribution of NRR centers inside the GaAs:N δ-doped SL and GaAs layers. The increase and monotonical decrease of the PL intensity of E_- band indicate the change of the formation of NRR centers with increasing N concentration. We propose recombination models to explain experimental results. The rate equation analysis based on Shockley-Read-Hall (SRH) statistics has been performed to calculate the NRR density. The fitting of the experimental results with the simulation reveals reasonable agreement of the dependencies and validates our model consideration.

The characterization of NRR centers in GaAs:N δ-doped SL structure grown by metal organic vapor phase epitaxy with N concentration 0.15% has been performed. The PL intensity of both the E_- band and GaAs (e–A^0) quenches monotonically due to the superposition of BGE light at energies of 0.75, 0.80, 0.92, and 0.95 eV over an AGE

light either for the GaAs conduction band (1.69 eV) or E_- band excitation (1.45 eV), respectively, which indicates the existence of NRR centers inside the GaAs:N δ-doped SL and GaAs layers. The little change of PL intensity of E_- band for the BGE energy of 0.75 eV implies the existence of BGE energy dependence of NRR centers inside GaAs:N δ-doped SL region. The AGE density and BGE density dependence of the PL intensity have been studied for both excitation schemes. Recombination models based on two levels have been proposed to allocate the origins as well as to interpret the energy distribution of NRR centers inside GaAs:N δ-doped SL region whose energies correspond to $E_V + 0.20$ and $E_V + 0.98$ eV. The AGE and BGE density dependence of PL intensity of E_- band emission has been simulated by utilizing rate equation analysis based on SRH statistics to estimate the NRR density under conduction band and E_- band excitation.

The proton irradiated and as grown NRR centers of InAs/GaAs quantum dots (QDs) structures have been studied. The PL intensity quenching of GaAs and QD emissions due to the addition of a BGE light of energy of 0.80 eV indicates the presence of defect levels acting as NRR centers. The method enables us to discuss the distribution of NRR centers in GaAs and/or InAs QDs region by selecting either conduction band excitation (2.33 eV) or intermediate band excitation (1.27 eV). We have found that the densities of NRR centers in GaAs layers and the effect of quenching on GaAs emissions increase monotonously with increasing proton irradiation fluence. The QD emission intensity, however increases at moderate fluence of 7×10^{11} protons/cm^2 due to the defect assisted trapping of electrons into QDs. Further incorporation of NRR centers after 4×10^{12} protons/cm^2 fluence quenches the QD-PL intensity below that of unirradiated sample. The rate equations have been deduced from the recombination model and evaluated based on the SRH statistics. The defect related parameters that provide a qualitative insight of NRR centers has been analyzed by systematically solving the rate equations and fitting the result with the experiment.