Digest of Tech. Papers The 8th Conf. (1976 International) on Solid State Devices, Tokyo

A-4-2
(INVITED)

Deep Levels in GaAs and GaP

T. Ikoma, M. Takikawa, and T. Okumura
Institute of Industrial Science, University of Tokyo
Roppongi, Minato-ku, Tokyo 106, Japan

The study of deep levels have gained increasing interest in III-V compound semiconductors because they play an important role in determining performance and reliability of both microwave and opto-electronic devices. Deep traps at the interface between an epi-layer and a substrate have a significant infuluence on a stable operation of GaAs planar devices[1]. An efficiency and a degradation of of LEDs are sensitive to existence of non-radiative deep centers since lifetime of injected minority carriers is determined by recombination centers, radiative and non-radiative.

This paper will summarize recent works on deep centers in GaAs and GaP.

The theoretical background is very weak for understanding of deep states. The electronic wave function is not sufficiently understood in a deep level. For optical cross section, only a delta-function and a quantum-defect (QD) models were studied [2,3]. The capture process was an old problem to be studied [4]. However, a multi-phonon-emission (MPE) process has been recently revived [5].

The junction-capacitance techniques have been extended to improve the resolution and to shorten measurement time [6]. A capture process has been directly measured by using a fast-pulse technique. This method has been modified to determine an in-depth profile of deep levels. The distributions of more than two levels can be measured separately by using light beams [7]. Described will be these new methods as well as results on temperature dependence of capture cross sections and in-depth profiles of hole traps in liquid-phase-epitaxial (LPE) materials.

Electronic and optical properties of deep centers will be summarized and compared with each other in GaAs and GaP. The most common electron trap in GaAs is a mid-gap one, which is observed in both bulk and vapour-phase-epitaxial (VPE) crystals but not in LPE wafers. The reliable value of this level is 0.74 eV below the bottom of the conduction band. This level has the activation energy of 0.08 eV for electron capture. The effect of annealing on the amount of deep states will be presented in detail. Another common trap is 0.45 eV hole-trap above the top of the valence band. We observed this level in bulk, VPE, and LPE crystals. Hole traps close to this level were reported by other authors [6,8]. However, the emission rates are scattered. The comparison will be made among the data about the characteristics of other traps so far reported. The characteristics of deep levels in a semi-insulating GaAs is another important subject from the view point of GaAs FETs. Some results on TSC measurements will be described.

Deep levels in GaP have been extensively studied by TSC, photocapacitance, and DLTS in relation with efficiency and degradation of LEDs (red and green). Crystalline defects, which are thought to decrease efficiency, seem to appear in an anomalous spectrum of photocapacitance [9].

References

1] M. Tanimoto et al.; 34th Device Research Conference at Salt Lake City, presented (June, 1976)

2] G. Lucovsky; Solid State Commun. 3, 299 (1965)

3] H. B. Bebb; Phys. Rev. 185, 1116 (1969)

4] K. Huang and A. Rhys; Proc. Roy. Soc. A204, 406 (1951)

5] D. V. Lang and C. H. Henry; Phys. Rev. Lett. 35, 1525 (1975)

6] D. V. Lang; J. Appl. Phys. 45, 3023 (1974)

7] M. Takikawa et al.; Spring Meeting of IECE Japan, #295 (Mar., 1976)

8] F. Hasegawa and A. Majerfeld; Electron. Lett. 11, 286 (1975)

9] T. Ikoma and T. Okumura; Abstract B1.4, 4th European Solid State Device Research Conference, Nottingham, England (Sept., 1974)