DEEP LEVELS IN GaAs PREPARED BY VPE*,**

BY A. BABIŃSKI, J. M. BARANOWSKI

Institute of Experimental Physics, Warsaw University***

AND M. CZUB

Institute for Technology of Electronic Materials, Warsaw

(Received June 20, 1989)

Deep levels in undoped n-GaAs layers, grown by a hydride VPE method with several As/Ga mol fraction values were investigated by means of DLTS method. It has been found that the dominant centers are 0.48 eV and 0.82 eV traps. The 0.48 eV trap is present only in etched samples and does not exist in the surface layer. The possible identification of 0.48 eV trap is discussed. The concentration of the 0.82 eV trap increases with As/Ga ratio. It is proposed that 0.82 eV trap is related to the EL2 defect.

PACS numbers: 68.55.–a, 71.55.–i

1. Introduction

The DLTS technique [1] is now widely used for characterization of semiconductors. Information, obtained by means of this method is helpful to understanding of crystal and deep traps origin and chemistry. In this work, we report experimental results on electron deep traps in GaAs epilayers grown with several As/Ga mol fraction ratio. Parameters of observed traps are presented and probably assignments are proposed. A dependence of deep traps concentration on As/Ga ratio and on depth in epilayer has been analyzed.

2. Sample preparation

Undoped n-GaAs layers, grown in ITEM by $Ga/AsH_3/H_2$ reactor system were used for all measurements. Epilayers were grown on (100) oriented n^+GaAs (Te doped). A gas phase stoichiometry was controlled by the HCl pressure in the reactor (higher HCl pressure

* Proc. XVIII International School on Physics of Semiconducting Compounds, Jaszowiec 1989.

** This work is supported in part by the CPBP 01.05 Grant.

*** Address: Instytut Fizyki Doświadczalnej, Uniwersytet Warszawski, Hoża 69, 00-681 Warszawa, Poland.

corresponds to higher Ga concentration). Investigated samples (11, 10, 08, 12) were grown with following As/Ga ratio (0.3, 5, 10, 12 — respectively).

Two kinds of samples were prepared. The first one was etched in $H_2SO_4 : H_2O_2 : H_2O$ (5 : 1 : 1) for 2 minutes before Schottky barrier evaporation (11E, 10E, 08E, 12E), the second one (10 N, 08 N, 12 N) was not. Schottky barriers of 0.25 mm^2 were fabricated by resistively evaporating Au through a metal mask. Ohmic contacts on n^+-side were formed from indium, and annealed for 10 minutes in temperature 300°C in vacuum of approx. 10^{-4} Torr.

3. Experimental results

Electron concentration was obtained from C-V characteristic. The parameters of deep levels were measured in the temperature scanning mode of DLTS in the temperature range between 77 K and 400 K. The activation energies and capture cross-sections were obtained from Arrhenius plot. The concentrations of deep levels were obtained from peak height [1]. A dependence of capture cross-section on temperature was not measured.

In summary, five electron traps were detected. Electron and deep traps concentrations in investigated samples are presented in Table I.

The main level, present in both kinds of samples (etched and nonetched) is 0.82 eV trap ($\sigma_\infty = 1.0\text{–}2.0 \times 10^{-13}$ cm^2). Signature of 0.82 eV trap and characteristic metastability of capacitance, observed after 1.0 μm illumination in 77 K [2] suggest that 0.82 eV trap

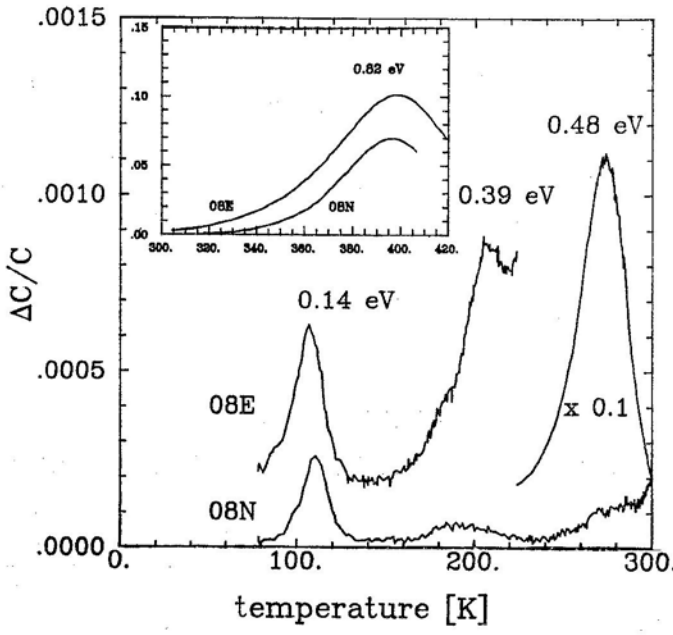

Fig. 1. DLTS spectra for etched (08E) and nonetched (08N) samples. Window rate is 106 s^{-1}. Spectra for temperature above 300 K in insert

TABLE I

Electron and deep trap concentrations in investigated samples. Activation energies with respect to the bottom of the conduction band

Sample	As/Ga ratio	Electron concentration [cm^{-3}]	Deep trap concentration [cm^{-3}]				
			0.14 eV	0.39 eV	0.48 eV	0.68 eV	0.82 eV
10N	5	9.0×10^{14}	1.4×10^{11}	6.0×10^{11}	—	—	2.4×10^{14}
08N	10	4.5×10^{14}	4.5×10^{11}	—	—	—	2.3×10^{14}
12N	12	1.2×10^{15}	—	—	—	—	2.5×10^{14}
11E	0.3	2.8×10^{15}	—	—	3.6×10^{13}	5.2×10^{12}	1.4×10^{13}
10E	5	5.2×10^{14}	1.4×10^{11}	5.7×10^{11}	9.4×10^{12}	—	1.9×10^{14}
08E	10	1.5×10^{14}	2.6×10^{11}	—	7.3×10^{12}	—	5.0×10^{13}
12E	12	6.0×10^{14}	1.8×10^{11}	6.3×10^{11}	7.2×10^{12}	—	2.6×10^{14}

is the EL2 defect. Concentration of 0.82 eV trap in etched samples increases with As/Ga ratio. Concentration of 0.82 eV trap in nonetched samples doesn't depend on As/Ga ratio.

The second dominant deep trap — 0.48 eV ($\sigma_\infty = 3.6 \times 10^{-15}$ cm^2) is present only in etched samples (Fig. 1). Its concentration decreases with As/Ga ratio. This trap is very likely related to Ni atoms in Ga position [3]. Nickel contamination originates from gas cylinder or gas tube system and is introduced into reactor by HCl, used in growth processing [4].

Deep traps 0.39 eV ($\sigma_\infty = 3.0 \times 10^{-14}$ cm^2) and 0.14 eV ($\sigma_\infty = 0.2$–3.0×10^{-16} cm^2) are present in both kinds of samples. Concentration of these traps is about two orders of magnitude lower than 0.82 eV trap concentration and seems to be independent on As/Ga ratio. The most probably assignment of 0.39 eV level is EL 5 [5]. Deep trap 0.14 eV is usually observed in VPE-GaAs [5, 6] and is likely related to vanadium.

The deep trap 0.68 eV ($\sigma_\infty = 6.0 \times 10^{-14}$ cm^2), which is proba blythe same as EB 4 [7], is present only in 11E sample.

4. *Conclusions*

The concentration of EL2 defect (0.82 eV trap) in nonetched samples is greater than EL2 concentration in etched samples. The concentration of EL2 defect (0.82 eV trap) in nonetched samples doesn't depend on As/Ga ratio. This suggests that final surface layer (approx. 3 μm thick) grows in As-rich conditions.

The absence of deep trap 0.48 eV in the surface layer and the dependence of its concentration on As/Ga ratio in etched samples confirms, that nickel contamination is introduced by HCl used in VPE reactor.

REFERENCES

[1] D. V. Lang, *J. Appl. Phys.* **45**, 3023 (1974).
[2] G. Vincent, D. Bois, A. Chantre, *J. Appl. Phys.* **53**, 3643 (1982).
[3] D. L. Partin, J. W. Chen, A. G. Milnes, L. F. Vassamilet, *J. Appl. Phys.* **50**, 6845 (1979).
[4] R. E. Enström, J. R. Appert, *J. Electrochem. Soc.* **129**, 2566 (1982).
[5] G. M. Martin, A. Mittoneau, *J. Electron. Lett.* **13**, 191 (1977).
[6] A. Mircea, A. Mittoneau, *Appl. Phys.* **8**, 15–21 (1975).
[7] D. V. Lang, L. C. Kimerling, *A New Technique for Defect Spectroscopy...* in *Lattice Defects in Semiconductors*, Institute of Physics, London 1974, pp. 2558–2564.