Author Modak, P.; Hudait, M. K.; Krupanidhi, S. B.

Author Affiliation Mater. Res. Centre, Indian Inst. of Sci., Bangalore, India

Editor Lal, K.

Title Epitaxial GaAs layers by MOCVD process: Growth and characterization

Appears In *Semiconductor Devices (Proc. SPIE Vol.2733)*. p. 361-3.

Conference Semiconductor Devices. New Delhi, India. 11-16 Dec. 1995.

Publisher Narosa Publishing House New Delhi, India. xx+659.

Abstract Device quality epitaxial layers of GaAs were grown by the MOCVD technique on both semi-insulating and semiconducting GaAs substrates with (100) orientation offset by 2 degrees . Systematic variation of the As/Ga ratio was performed to gain an understanding of the growth process, the type of formation and related physical properties. The films were characterized by SEM, EDAX, HRTEM and XRD, and exhibited repeatable epitaxial growth. The optical response was examined in terms of photoluminescence spectra which revealed emissions from free excitons. Abstract no. A9622-8115H-050B9611-0510D-173.

Identifers epitaxial GaAs layers. epitaxial GaAs MOCVD growth. device quality epitaxial layers. MOCVD technique. semi-insulating GaAs substrates. semiconducting GaAs substrates. orientation offset. As/Ga ratio. growth process. physical properties. SEM. EDAX. HRTEM. XRD. repeatable epitaxial growth. optical response. photoluminescence spectra. free exciton emissions. GaAs-GaAs:Cr. GaAs:Cr. GaAs-GaAs:Si. GaAs:Si

Subjects excitons
gallium arsenide
III-V semiconductors
photoluminescence
scanning electron microscopy
semiconductor growth
surface structure
transmission electron microscopy
vapour phase epitaxial growth
X-ray chemical analysis
X-ray diffraction

Classification A8115H ; A6855 ; A6820 ; A7135 ; A7865J ; B0510D ; B2520D

Codes

Chemical Indexing	GaAs-GaAs:Cr/int GaAs:Cr/int GaAs/int As/int Cr/int Ga/int GaAs:Cr/ss As/ss Cr/ss Ga/ss GaAs/bin As/bin Ga/bin Cr/el Cr/dop. GaAs:Cr/sur GaAs/sur As/sur Cr/sur Ga/sur GaAs:Cr/ss As/ss Cr/ss Ga/ss GaAs/bin As/bin Ga/bin Cr/el Cr/dop. GaAs-GaAs:Si/int GaAs:Si/int GaAs/int As/int Ga/int Si/int GaAs:Si/ss As/ss Ga/ss Si/ss GaAs/bin As/bin Ga/bin Si/el Si/dop. GaAs:Si/sur GaAs/sur As/sur Ga/sur Si/sur GaAs:Si/ss As/ss Ga/ss Si/ss GaAs/bin As/bin Ga/bin Si/el Si/dop
Material Identity No.	XX96-01839
Record Type	Conference Paper
Number of References	5
Treatment	Practical Experimental
Language	English
Country of Publication	India
INSPEC Accession Number	5392067

EPITAXIAL GaAs LAYERS BY MOCVD PROCESS : GROWTH AND CHARACTERIZATION

Prasanta Modak^, Mantu Kumar Hudait* and S.B. Krupanidhi
Materials Research Centre, Indian Institute of Science
BANGALORE - 560012, INDIA.
*** Central Research Labs., Bharat Electronics Ltd., Bangalore-560001, INDIA.**

Device quality epitaxial layers of GaAs were grown by MOCVD technique, on both semi-insulating and semiconducting substrates of GaAs substrates with (100) orientation offset by 2°. Systematic variation of As/Ga was performed to gain an understanding of growth process, type of formation and related physical properties. Films were characterized by SEM, EDAX, HRTEM and XRD. Films exhibted repeatedly epitaxial growth and the optical response was examined in terms of photoluminiscence spectra which revealed emissions from free exciton.

INTRODUCTION:

The AlGaAs/GaAs heterostructure system is potentially of great importance for many high speed electronics and optoelectronic devices, due to their excellent lattice match and insignificant concentration of undesirable interface state.. In addition, this family of compounds also promise number of interesting properties such as high mobility, resonant tunneling and fractional Hall mobility etc. Numerous attempts are evindent in the literature for developing epitaxial layers of GaAs and AlGaAs, involving a pletora of growth techniques, including MBE and MOCVD. Present papers reports the development of epitaxial layers of GaAs and discusses a close process-property correlation.

EXPERIMENTAL:

Undoped GaAs epitaxial layers were grown in a low pressure horizontal MOCVD Reactor. The source material were palladium-purified H_2, Trimethylgallium (TM Ga), and Arsine (AsH_3, 100%). Cr-doped semi-insulating (100) GaAs or Si-doped n+ GaAs (100) substrates misoriented towards [110] by 2°, were used for epitaxial growth process. Each substrate was thoroughly degreased and cleaned and given a brief 1:1:10 H_2O_2:H_2SO_4:H_2O to remove surface oxide and residual contamination. Prior to initiation of growth and after the temperature of the susceptor reaches 350° C, AsH_3 flow is initiated to avoid arsenic escape from the substrate and is maintained when the temperature is above 700° C. During the growth the substrate was kept constant at 700° C. Once the desired temperature was reached, TMGa was introduced into the reaction chamber to initiate growth. The growth rates were linearly dependent on the flow rate of TMGa in the growth chamber. For reduced pressure growth, the exit of the reactor was connected to the high capacity vacuum pump. The pressure in the reactor tube was maintained at 100 Torr. After the completion of growth, the flow of TMGa was cut-off and AsH_3 flow was maintained until the temperature is cooled below 350° C. The unspent reactants were cracked by using cracking furnace at a temperature of 800° C and allow the process gases directly to go to the activated charcoal scrubber. Total flow rate was 2500 sccm. The (V/III) ratios of these samples were 31, 46, 55 and 83.

As the samples were grown under constant AsH_3 flow rate, the stoichiometry of the samples was found to be unchanged, as observed by Energy Dispersive Analysis of X-ray (EDAX). The thickness of each layer was varied by varying TMGa flow rate, and the typical growth rate was about 20 A°/sec. The thickness was measured by cross sectional Scanning Electron Microscopy (SEM). Hall-effect measurements by Van der Pauws method were performed at the room temperature. The conductivity was found to be p type at the (V/III) ratio of 31 and 46 and n-type at 55 and 83. The measured carrier concentration and mobility of p-type samples had $7*10^{15}$ cm^{-3} and 350 cm^2/V.sec at V/III ratio of 31 and n-type samples had $1*10^{15}$ cm^{-3} and 4500 cm^2/V.sec at V/III ratio of 55, respectively , at the room temperature.The intentional undoped carrier concentration, type of epilayer, and abrupt interface of the samples was measured by Electrochemical Capacitance Voltage measurements (ECV Polaron).

Photoluminescence (PL) measurements were carried out at 4.2 K using a MIDAC Fourier Transform Photoluminescence (FTPL) system. An Argon ion laser operating at a wavelength of 5145A° was used as a source of excitation. The exposed sample area was about $3mm^2$. PL signal was detected by a LN_2 cooled Ge-Photodetector whose operating range is about 0.75-1.9 ev,while resolution was kept at 0.5 mev.

RESULTS AND DISCUSSION:

The morphology of MOCVD growth GaAs film was seen by SEM (Fig.1). It may be seen from the figure that the film exhibits a uniform smooth surface and a dense cross-section. Within the current range of magnification, one may also observe a clear interface between the film and the substrate. The compositional homogeneity of the films was quantified in terms of estimating the Ga/As ratio, using EDAX analysis. Results indicated a near stoichiometric Ga/As ratio, irrespective of the flow ratios of incomming gas precursors. This is consistent with the expectation, as the present films were grown by keeping As flow pressure constant and varying the TMGa flow pressure.

Besides making conventional structural studies by grazing angle incidence X-ray Diffraction (XRD), the epitaxial growth of the films was established by High Resolution Tranismission Electron Microscopy (HRTEM) selective area diffration studies, and the typical data is presented in Fig.2. It was observed by lattice indexing that our MOCVD growth layers of GaAs, in the present growth conditions, clearly exhibits epitaxial growth in (100) direction normal to the substrate surface. Repeated observation in different areas of the film, and also in films from different batches indicated similar observation, confirming the reproducibility in epi-growth of GaAs.

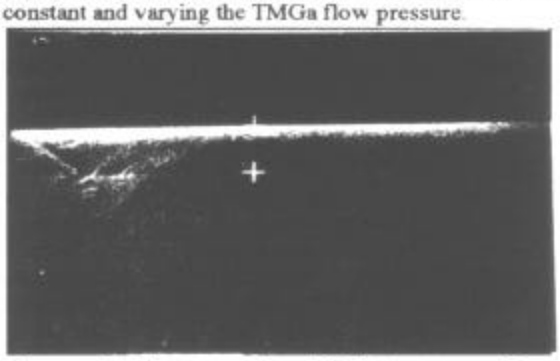

Figure 1: Cross-sectional SEM pattern of epi-GaAs film/Substrate.

The film quality was further envisaged in terms of observing the lattice imaging by HRTEM, to visualize the atomic arrangement. The results are shown in Fig.3, for a typical film, which clearly exhibited a lattice for GaAs, consistent to give zinc blende structure.

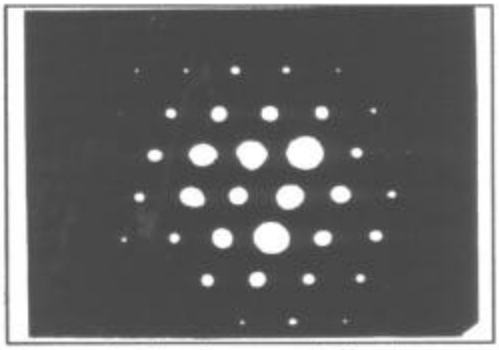

Figure 2: Selective area diffraction pattern of epi-GaAs film.

Photoluminescence spectroscopy is a sensitive and non destructive technique that can provide valuable information concerning the type and distribution of defects and impurity in a crystal. All our films were unintentionally doped with a net carrier concentration $/N_D-N_A/$ ranging between $1*10^{15}$-$7*10^{15}$ cm-3. Typical PL spectra observed in the near band-edge region can be seen in Fig.4. Two characteristic photoluminescence bands were observed from all samples. These peaks were identified [1,2] as the radiative recombination of free exciton (FE) (1.5151ev) and an exciton bound to neutral donor (D^o,X) (1.5142ev), an ionized donor (D^+,X) (1.5133ev). The presence of emission due to the free exciton in our samples confirm their high purity [3,4]. The other photoluminescence band was observed around 1.49 ev and the FWHM of this band was 3.0 mev. The peak 1.4914ev is assumed to be D-A pair transition [4] involving carbon acceptor. Referring to several papers [2-5], this luminescence band is attributed to the recombination of carbon acceptors which might incorporated into the undoped GaAs by partial dissociation of TMGa during the growth.

BIO-RAD Polaron Electrochemical profiler (PN4300PC) were used to determine the carrier concentration of undoped GaAs layers, type of epilayer and abruptness between the 2-m thin GaAs epilayer and substrate.The results are presented in Fig.5, which clearly establish an abrupt and unreacted interface, which is an essential requirement for multi-layer structure development, such as in heterostructure lasers, multi-quantum wells (MQWs) and optoelectronic devices.

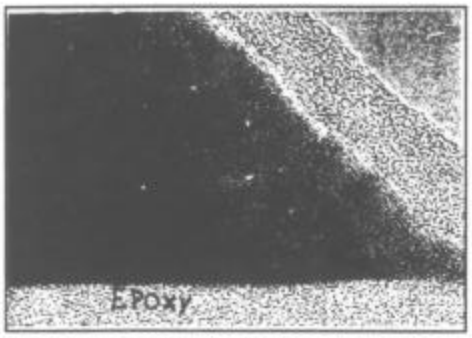

Figure 3: HRTEM lattice imaging of epi-GaAs film.

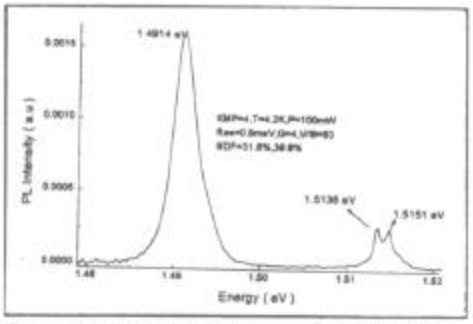

Figure 4: Photoluminiscence spectrum of MOCVD grown epi-GaAs film at 4.2K.

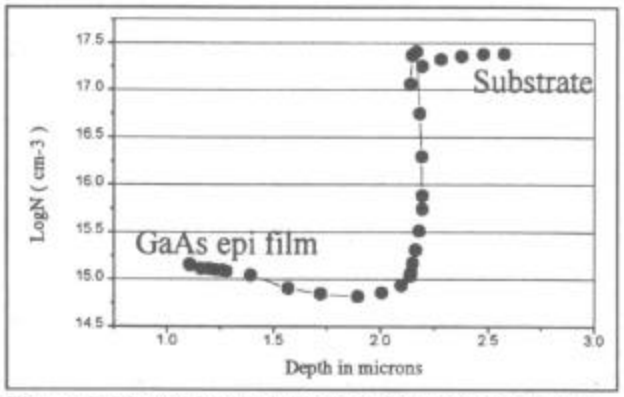

Figure 5: Electrochemical depth profiling of back ground impurity for MOCVD grown epi-GaAs film.

CONCLUSIONS:

Device quality epi-layers of GaAs were grown by MOCVD, with excellent smooth surface n and p type films were successfully grown, by varying mere Ga/As ratios. Studies of photoluminiscence indicates the emissions from free exciton and confirmed the high quality of the films. The epitaxy was confirmed by HRTEM selective area diffraction and lattice imaging. Electrochemical depth profiling exhibited homogeneous background carrier distribution and excellent film/substrate interfaces. The room temperature Hall mobility measurements indicated mobilities of about 4500 cm^2/V-s, for n-type and 350 cm^2/V-s for p-type respectively.

REFERENCES:

[1]. E.W.Williams and H.B.Bebb,in *Semiconductors and Semimetals*, edited by R.K.Willardson and C.A.Beer (Academic,New York, 1972) , **vol.8**, p321.

[2]. Lorenzo Pavesi and Mario Guzzi, J. Appl.Phys.,**75**, 4779 (1994).

[3]. Junichi Kasano,Y.Segawa, S.Iwai,Y.Aoyagi, and S.Namba, J.Appl.Phys.,**62**,1376 (1987).

[4] V.Swaminathan,D.L.VanHaren,J.L.Zilko,P.Y.Lu,andN.E.Schumaker,J.Appl.Phys.,**57**,5349 (1985).

[5]. T.K.Kuech, I.B.M.Watson Res.Centre,1986,Solid State Physics,**RC 12066** (#54361) and reference there in.