Active and Passive Elec. Comp., 1987, Vol. 12, pp. 223–229
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THE GROWTH AND ASSESSMENT OF GaAs EPITAXIAL LAYERS OBTAINED FROM Ga-As-Bi SOLUTIONS

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X-Ray investigations of GaAs epitaxial layers obtained from Ga-As-Bi solutions with different amounts of bismuth are presented. An equilibrium cooling and two phase technique for the deposition of the GaAs epitaxial layers on semi-insulating GaAs:Cr(100) substrates has been used.

It has been observed that independently of the growing solution composition, the epitaxial layers were single crystal of (100) crystallographic orientation. Bismuth and chromium were not identified as impurities in the investigated layers although this may be due to the low sensitivity (0.1 at .%) of the x-ray microprobe used.

1. INTRODUCTION

The usage of bismuth as a solvent instead of gallium in the liquid phase epitaxy (LPE) of GaAs has been recently reported and associated with a decrease of the carrier concentration and a considerable increase of carrier mobility in the deposited GaAs layers [1,2]. It is well known that silicon is a residual impurity which is always present in GaAs deposited by PLE techniques and therefore this may be explained by a high coefficient of bismuth and silicon interaction α_{Si-Bi} in the solutions [1]. In depositing GaAs from the Bi-solution we have in fact a three component system GaAs-Bi. The phase diagram of GaAs-Bi system in the area of Ga-Bi-GaAs has been experimentally defined by Evgenev and Ganina [3]. It is also known that the GaAs compound is the only interphase of a constant composition and that bismuth is an isoelectronic dopant in the analysed system [4]. Its segregation coefficient and solubility in GaAs are very low [1,2,3]. By depositing the GaAs epitaxial layers from stoichiometrical solution of Ga and As in bismuth, the greatest solubility Bi in GaAs should be obtained.

The physical properties of epitaxial layers obtained from Ga-As-Bi solution over a wide range of compositions of liquid phase have not been described in the literature so far. In this paper preliminary assessment of such layers obtained from Ga-As-Bi solutions with different amounts of bismuth are presented.

2. EXPERIMENTAL

2.1 Growth of Specimens

The epitaxial layers were grown on Cr-doped semi-insulating (100) — oriented GaAs substrates with $\varrho > 10^7 \Omega$cm and dislocation density $\cong 5.10^4/cm^3$ supplied by the CEMI (a local vendor). The substrates were cut to dimensions 10×11.5 mm and cleaned in organic solvents followed by an etch in a H_2SO_4:H_2O_2:H_2O solution (12:1:1 volume ratio) and finally rinsed in propan-2-ol. Bismuth, qallium and polycrystalline GaAs of 6N purity were used for preparing of solutions. The mass of the initial composition of liquid phase, i.e. $m_{Ga} + m_{Bi}$ was constant and equal to 2 gm. This corresponded to 3.2 mm (for 0 at .% Ga) height of the melt in the graphite boat.

The epitaxial deposition of GaAs layers were performed in horizontal open system quartz reactor, which contained a conventional graphite sliding boat [5] in a Pd purified H_2 ambient atmosphere.

The growth processes were performed in two different ways:

1. A two phase technique where the melt was saturated by arsenic from polycrystalline GaAs.
2. An equilibrium cooling technique where the melt was saturated with help of a dummy GaAs:Cr substrate which was identical to a proper substrate. (In this case of course the melt would also contain some chromium, which was present in the dummy substrate.)

The saturation of the melt or solution was made for 2 hours at 1073 K. 1073 K is also the normal deposition temperature regardless of melt composition. The compositions of the solutions used in this work are presented in Table 1.

Following saturation the melt was brought into contact (by moving the slider of the boat) with the substrate. Simultaneously, the program of the linear cooling with the rate, $v_n = 0.25$ K/min was initiated. The layer was deposited for 30 min. Growth times of subsequent layers also 30 mins. Taking into account composition of the solutions used, the epitaxial layers obtained were classified into six technological groups. The compositions of the used solutions and the thicknesses of the obtained layers are shown in Table 1.

2.2 *Electrical evaluations of the GaAs Epilayers*

Hall and C-V measurements were used to characterise the GaAs epitaxial layers and results are summarised in Table 2.

The measurements were carried out at 300K. The layers of IV to VI groups were not measured.

TABLE 1
Technological groups of the deposited epitaxial layers

GROUP	Solvent composition [at %]		thickness [um]	
I	Bi — 95.98 Ga — 2.01 As — 2.01		5	
II	A Bi — 2.27 Ga — 95.79 As — 1.94	B Bi — 5.35 Ga — 92.74 As — 1.93	15.2	15
III	Ga — 97.9 As — 2.1		9	
IV	Bi — 95.97 Ga — 2.01 As — 2.01 Cr — 10^{-4}		5	
V	A Bi — 24.14 Ga — 74.1 As — 1.76 Cr — 10^{-4}	B Bi — 2.27 Ga — 95.79 As — 1.94 Cr — 10^{-4}	11	15
VI	Ga — 97.9 As — 2.1 Cr — 10^{-4}		8	

TABLE 2
Electrical parameters of the GaAs epilayers

group	I	II		III
		A	B	
n [cm^{-3}]	10^{14}	2.10^{16}	2.10^{16}	10^{16}
μH [cm^2/V·s]	$(5 + 6) \cdot 10^3$	3800 ÷ 4000	3800 ÷ 4000	4100

2.3 *X-Ray Investigations*

X-Ray diffraction patterns for the epitaxial layers taken from the technological groups presented in Table 1 were obtained. They were identical in spite of differences in the solution compositions used. (i.e. The same as for the monocrystalline GaAs with crystallographic orientation (100).) X-ray photographs obtained by the Laue method confirm the monocrystallinity of each layer. The X-ray photographs of the GaAs:Cr substrate and the epitaxial layers deposited on the substrate for the most representative groups I–VI are presented in Figure 1. Additionally, these layers were tested using X-ray microprobe.

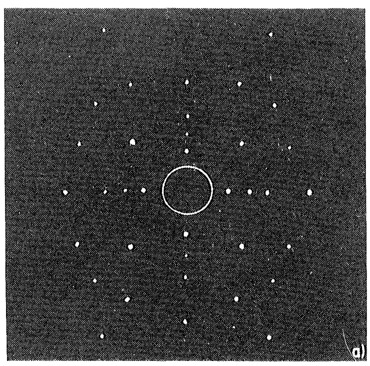


FIGURE 1(a) No layer

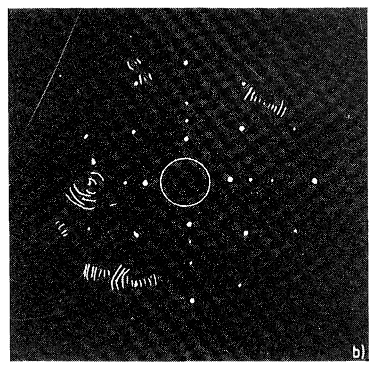


FIGURE 1(b) Layer from Group I

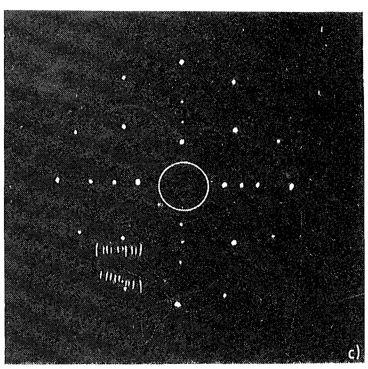


FIGURE 1(c) Layer from Group IIA

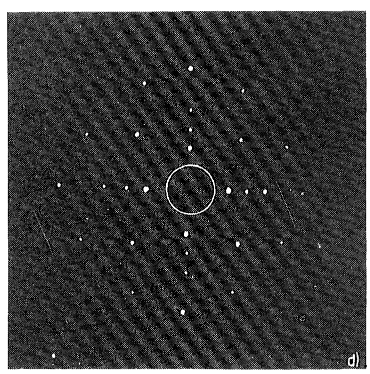


FIGURE 1(d) Layer from Group III

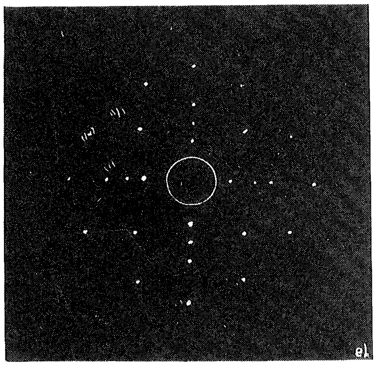


FIGURE 1(e) Layer from Group IV

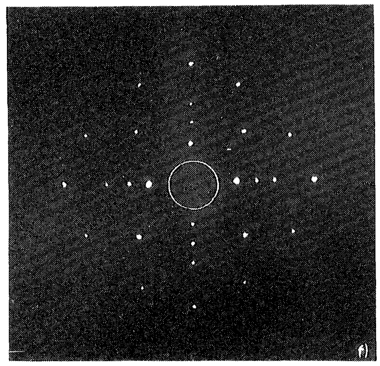


FIGURE 1(f) Layer from Group VA

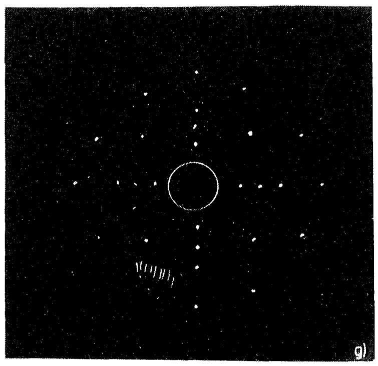


FIGURE 1(g) Layer from Group VI

FIGURE 1 Lane photographs of the GaAs:Cr substrate with and without epitaxial layers from the Groups shown in Table 1.

Besides Ga and As no other elements were identified in the range of sensitivity (0.1 at.%) of the X-ray microprobe used (Figure 2).

3. DISCUSSIONS AND CONCLUSIONS

The following conclusions can be drawn from the investigations:

- the epitaxial layers are GaAs monocrystalline with the crystallographic orientation (100) independent of the used solution composition.
- Bi and Cr were not identified in the investigated layers in the sensitivity range (0.1 at.%) of the X-ray microprobe used.

These preliminary results suggest that GaAs of good crystallinity and a carrier density as low as $10^{14}cm^{-3}$ can be grown by LPE from Ga-As-Bi solutions and that such a process may offer the potential for producing materials for device fabrication.

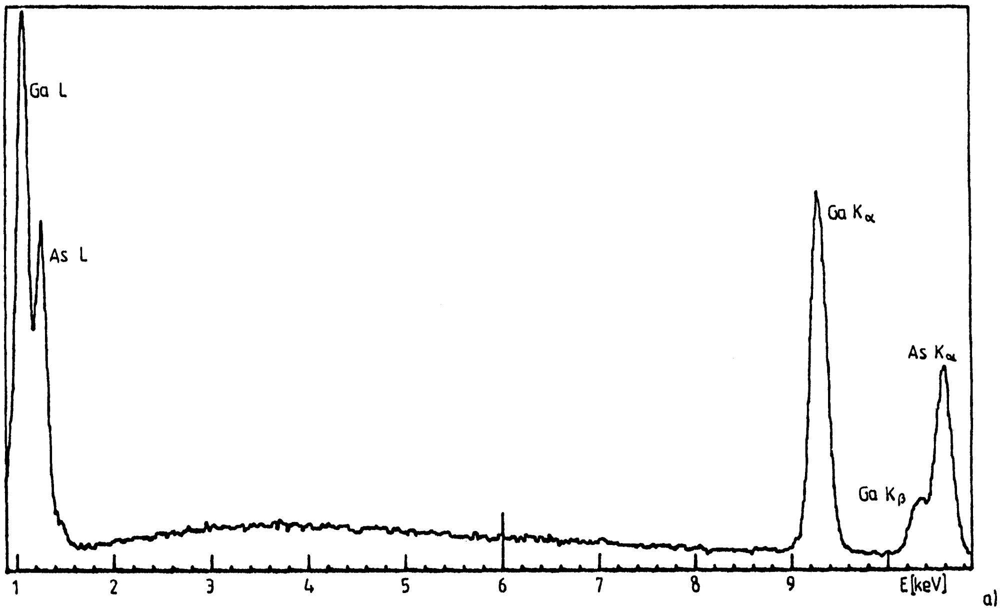


FIGURE 2(a) No layer

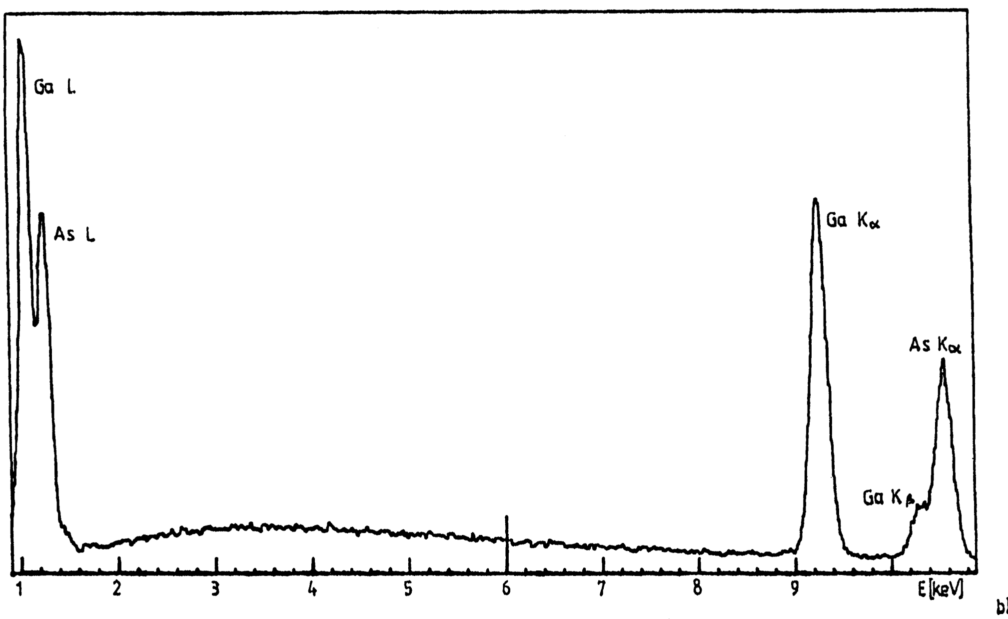
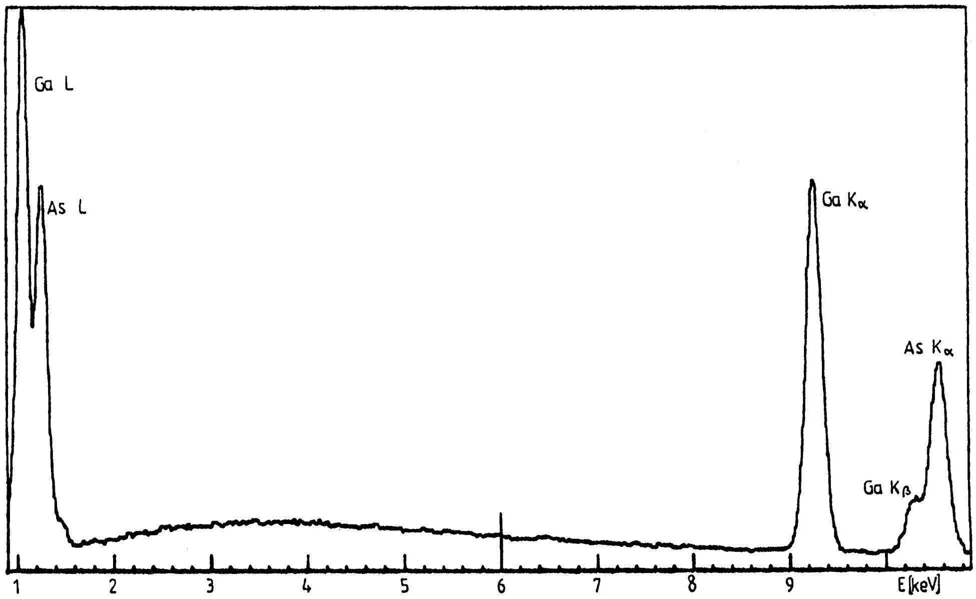


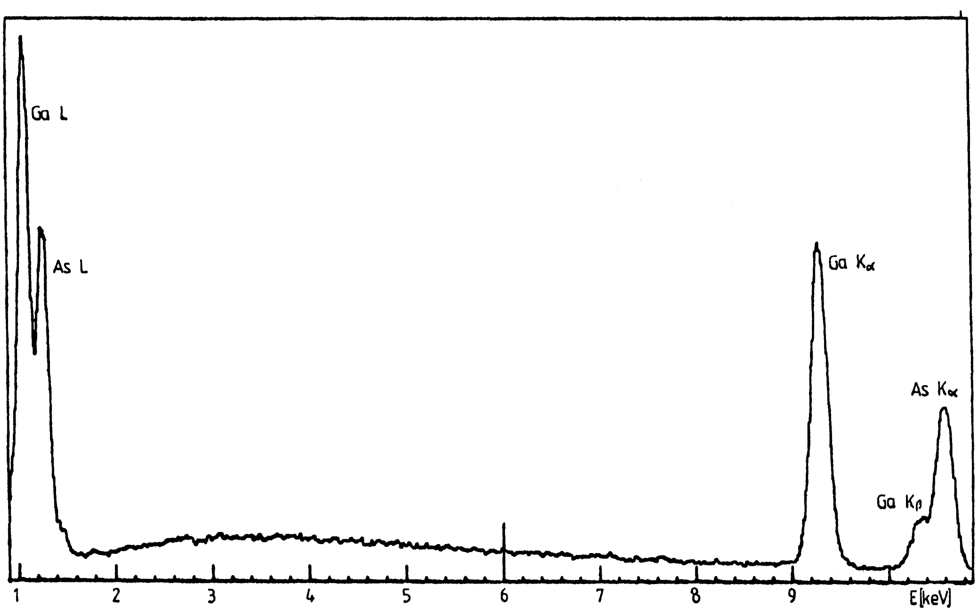
FIGURE 2(b) Layer from Group I

FIGURE 2 X-ray microprobe patterns of the GaAs:Cr substrate with and without epitaxial layers from some of the Groups shown in Table 1.



c)

FIGURE 2(c) Layer from Group IIA



d)

FIGURE 2(d) Layer from Group IV

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