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Liquid phase epitaxy of high purity n-GaSb and $In_xGa_{1-x}Sb$ and their electron transfer effects

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From the electron transfer effects point of view, GaSb and $In_xGa_{1-x}Sb$ are very interesting materials to deal with, because of their energy band structures.

This paper describes (1) the processes to grow GaSb and $In_xGa_{1-x}Sb$ ($x \leqq 0.1$) utilizing a vertical (dipping) type liquid epitaxial techniques, (2) physical and electrical properties of the crystals grown and (3) preliminary experimental results on the high electric field effects in the n-type GaSb.

The crystal growth is carried out on substrates of either n^+ or p^+-type GaSb. Basic structures of the furnace and growth techniques used in the experiments are similar to those to grow GaAs and $GaAs_{1-x}Sb_x$$^{(1)}$. A Ga rich branch of a Ga-Sb phase diagram is employed. The starting temperature of the growth is determined precisely by observing an onset of a solidification over the solution surface. A temperature profile around the carbon boat which contains the solution is adjusted carefully to produce practically no temperature gradient in the solution and 0.5° C hotter zone just above the solution surface where the substrates are placed for about 30 minutes prior to the dipping. These procedures protect the substrate surfaces from being etched before the growth.

Surface appearances of the crystals are typical of those of crystals grown by the liquid phase epitaxy and is shown in Fig. 1 along with a clevaged face of an epitaxial wafer indicating the thickness of the grown layer to be 50 microns.

When $In_xGa_{1-x}Sb$ is grown on the GaSb substrates, the lattice mismatch (0.6% for $x = 0.1$) between the crystals causes generally the surface appearance of the grown layer to be rougher. One order of magnitude increase in numbers of the etch pit density observed in the hetero-epitaxial layer is due to a tension induced by the lattice mismatch at the boundary. It is experimentally found that even the small mismatch of about 0.2% (for $x = 0.03$) causes the tension and at least ten microns thick epitaxial layer is necessary to eliminate its influences.

Undoped GaSb crystals show p-type conduction due to a native acceptor level which is believed to be associated with Sb vacancies. Hall measurements are carried out on the epitaxial layers after lapping the highly conductive substrates off.

Fig. 2 shows a relation between the hole concentration of the undoped GaSb and the starting temperature of the growth, from which a formation energy of the acceptor level can be obtained as 1.10 eV. The crystals of hole concentration of less than 10^{16}/cc are grown below 420° C.

For n-type material, controlled amounts of Te are added to the solution to compensate the acceptors. Table 1 is a list of the crystals grown. The purest n-type GaSb obtained is of $n \simeq 8.3 \times 10^{15}/cc$ and the maximum electron mobility is 8,500 $cm^2/V.sec$ at 300°K.

Preliminary experiments on high field effects are performed with the n-GaSb. Specimens are made in a planer structure using the crystal of $n \simeq 10^{16}/cc$. The distance between ohmic contacts is about 430 μ and the thickness and the width of the specimens are 30∼40 μ and 500 μ, respectively. Fig. 3 is a V-I curve of the specimen at 77°K and 300°K measured, using voltage pulses of 10 nsec duration and 100 Hz repetition rate. Threshold field for the noisy oscillation observed at 77°K is about 840 V/cm. Though, a peculiar difficulty in forming good ohmic contacts for the n-type GaSb makes the estimation of the threshold field to be slightly unreliable, the threshold field obtained here, which is 1/4 of that for GaAs, is very informative.

One point which should be made here is that the current instabilities observed here is not associated with the acoustoelectric interaction which is known to occur in the GaSb, since it require relatively long incubation time and should not be observed with the very short pulse adopted here.

(1) A. Hojo and I. Kuru, Abstracts for NCCG-4 Sendai (1972)

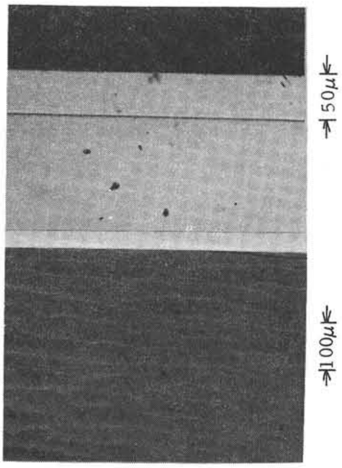

Fig. 1

Table 1

Sample	In atomic %	300°K 1/eR$_H$ (cm^{-3})	300°K R$_H\sigma$ (cm^2/V·sec)	77°K 1/eR$_H$ (cm^{-3})	77°K R$_H\sigma$ (cm^2/V·sec)
A-1	0	8.3×10^{15}	7400	—	
2	0	1.5×10^{16}	7930	2.4×10^{16}	12700
3	0	1.1×10^{16}	8450	1.8×10^{16}	12600
B-1	1.0	2.1×10^{16}	5020	3.3×10^{16}	5630
2	1.2	5.0×10^{15}	4400	—	
3	4.0	3.8×10^{16}	4940	—	

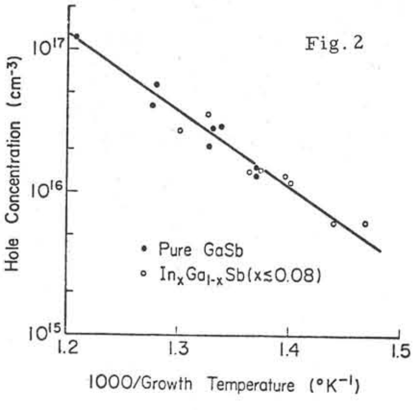

Fig. 2

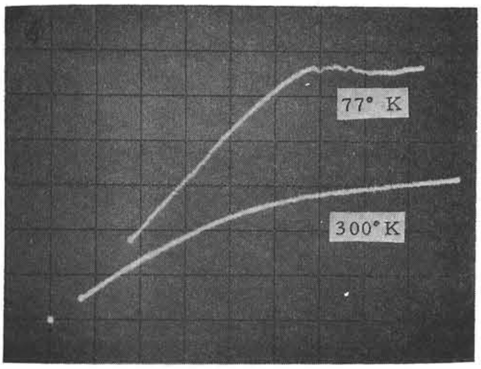

Fig. 3 Horizontal 10 V/div.
Vertical 1.4 A/div.
(Current is detected by 2.3 Ω load)