Digest of Tech. Papers The 11th Conf. (1979 International) on Solid State Devices, Tokyo

B—2—7 $p\mathrm{In_xGa_{1-x}Sb}$-$n\mathrm{Ga_{1-y}Al_ySb}$ Heterojunction Photodiodes

T.Mizuki, Y.Sugimoto, A.Tanaka, and T.Sukegawa
Research Institute of Electronics, Shizuoka University
Johoku 3-5-1 Hamamatsu 432, Japan

As optical fibres with minimum loss in the range of 1.2∿1.6μm have been developed,[1,2] the demand for photodetectors in that wavelength range is increasing for future economical transmission systems. The $\mathrm{In_xGa_{1-x}Sb}$-$\mathrm{Ga_{1-y}Al_ySb}$ lattice matched heterostructure photodiodes are highly attractive for this purpose.[3] The energy gap of the solid solution in the Ga-Al-Sb system varies with the composition in the range 0.7∿1.5eV, and the lattice matched GaSb-$\mathrm{Ga_{1-y}Al_ySb}$ layer can be obtained by adding a small amount of InSb to GaSb layer. This paper reports the fabrication of the $p\mathrm{In_xGa_{1-x}Sb}$-$n\mathrm{Ga_{1-y}Al_ySb}$ heterostructure photodiode and some results on the electrical and optoelectronic properties of the diodes.

In-Ga melt and Ga-Al melt saturated with GaSb were provided for the growth of the ternary mixed crystals, $\mathrm{In_xGa_{1-x}Sb}$ and $\mathrm{Ga_{1-y}Al_ySb}$. The heterojunctions were prepared by liquid-phase-epitaxial (LPE) growth of an undoped p-type $\mathrm{In_xGa_{1-x}Sb}$ layer, followed by that of a tellurium doped n-type $\mathrm{Ga_{1-y}Al_ySb}$ layer, on (111)B surface of p-GaSb substrate using a slider apparatus described by Panish *et al.*.[4] Starting temperature of growth was 500 °C. Cooling rate of 4°C/h was employed. Figure 1 shows the cross sectional view of $\mathrm{In_{0.07}Ga_{0.93}Sb}$-$\mathrm{Ga_{0.3}Al_{0.7}Sb}$ heterostructure. The n-type $\mathrm{Ga_{0.3}Al_{0.7}Sb}$ layer was 10μm thick and at a carrier concentration of $3\sim5\times10^{17}\mathrm{cm^{-3}}$. The p-type $\mathrm{In_{0.07}Ga_{0.93}Sb}$ layer was 40μm thick and at a carrier concentration of $0.7\sim1\times10^{16}\mathrm{cm^{-3}}$. Figure 2 shows the results of the line scanning of electron-probe-microanalysis along the growth direction of the same sample. The composition change in each layer was very small. By considering the Végards law for the lattice parameters and the

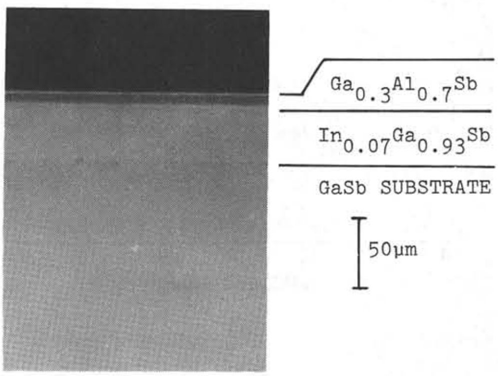

Fig.1 Cleaved cross section of a grown crystal.

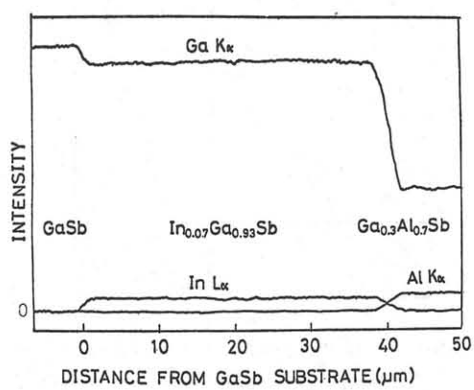

Fig.2 Electron-probe-microanalysis result.

compositions of these solid solutions, it is found that both epitaxial layers have the nearly equal lattice parameters, 6.12Å. The $In_{0.07}Ga_{0.93}Sb$ layer is enough thick to reduce the defects caused by the lattice mismatch between this layer and GaSb substrate.

To carry out the electrical and photoresponse measurements, 250μm diameter Au+Te, Ag+Sn, and Au dots were evaporated onto the $n Ga_{0.3}Al_{0.7}Sb$ side of the sample and an In+Zn layer onto the entire back side. These were alloyed at 350°C for 10 minutes in flowing hydrogen. The wafers were scribed into $4mm^2$ samples and mounted on a stem. A typical current-voltage characteristics at room temperature is shown in Fig.3. The C-V measurements revealed that the junction structure was an abrupt junction and the depletion layer spreaded into *p*-type $In_{0.07}Ga_{0.93}Sb$ side. The spectral photocurrent response of the diode at zero bias is shown in Fig.4. The nearly flat response was observed in the wavelength range from 1.0μm to 1.8μm. The external quantum efficiency was 32% at zero bias in the vicinity of 1.5μm. It should be mentioned that $In_xGa_{1-x}Sb$-$Ga_{1-y}Al_ySb$ heterostructure photodiodes are very promising detectors which are attractive for optical-fibre communication system.

References

1. M.Horiguchi, Electron. Lett. 12, 310 (1976).
2. Y.Terunuma, T.Miya, T.Hosaka, and T.Miyashita, Convention of IECE, Japan, March, 1979, No.916.
3. T.Sukegawa, T.Hiraguchi, A.Tanaka, and M.Hagino, Appl. Phys. Lett. 32, 376 (1978).
4. M.B.Panish, I.Hayashi, and S.Symski, IEEE J. Quantum Electron. 5, 211 (1964).

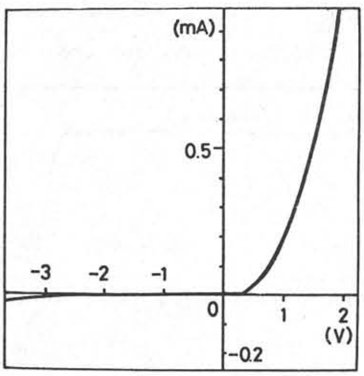

Fig.3 Current-voltage characteristics of $pIn_{0.07}Ga_{0.93}Sb$-$nGa_{0.3}Al_{0.7}Sb$ heterostructure photodiode.

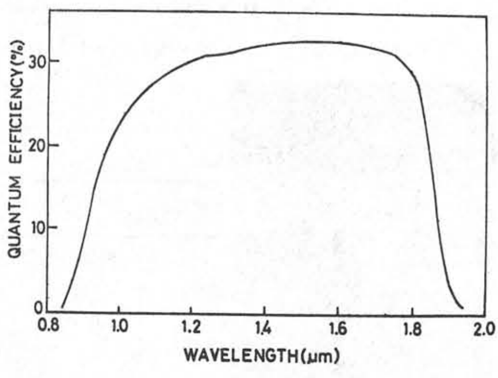

Fig.4 Spectral photocurrent response of $pIn_{0.07}Ga_{0.93}Sb$-$nGa_{0.3}Al_{0.7}Sb$ heterostructure photodiode at zero bias.