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# B—1—1 Properties of Heteroepitaxial $In_xGa_{1-x}As$ by Molecular Beam Epitaxy

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$In_xGa_{1-x}As$ has a direct band gap for all values of x. By varying x from 0 to 1 its room-temperature band gap can be adjusted over the range from 1.425 eV (0.87 μm) to 0.36 eV (3.4 μm) which includes a low-loss region of optical fibers (1.0 ~ 1.3 μm). The crystal has been considerably investigated for optoelectronic applications.

In this paper we report electrical and optical characteristics of $In_xGa_{1-x}As$ films ($x < 0.3$) prepared on GaAs substrates by molecular beam epitaxy (MBE) and make clear a role of buffer layers to improve the quality of the films. We also report the first observation of electroluminescence from $In_xGa_{1-x}As$ diodes by MBE at a wavelength of 1.08 μm.

Monocrystalline $In_xGa_{1-x}As$ ~~were~~ was obtained under the condition that the ratio of beam intensities, $As_4/(Ga + In)$ was 10 ~ 15 and substrates were kept at 500 ~ 560 °C.

In Fig. 1 electron mobility (μ) at room temperature is plotted in terms of the composition for 2 ~ 3-μm-thick films with carrier concentrations of 1 ~ 2 x $10^{17}$ $cm^{-3}$. Compared with thin films (CVD[1], MBE[2]), a considerable improvement in mobility can be seen. The mobility amounts to almost the same with that of thick VPE films[3,4]. Fig. 2 shows profiles of the mobility, carrier concentration and photoluminescence intensity across a 4.5-μm-thick $In_xGa_{1-x}As$ layer which were measured by step etching. This film has a buffer layer with a step-compositional grading (x = 0.04, 0.07, 0.11; 0.5-μm-thick each) followed by a uniform composition layer (x = 0.14). The mobility remains constant over the range of 2 ~ 4.5 μm of the distance from the substrate and begins to decrease slightly from the point of 2 μm, while the photoluminescence intensity shows a steep decrease in the region less than 3 μm. Besides, photoluminescence was not observed from thin films (less than 1.5 μm, x = 0.1) without the buffer layer.

Electroluminescence diodes of $In_xGa_{1-x}As$ were prepared by MBE which have ~~the~~ similar buffer layer between substrate and p-n junction as shown in Fig. 3. A typical spectrum with an emission peak at a wavelength of 1.08 μm is shown in Fig. 4. The full width at half-maximum intensity is 0.06 μm. The I-V characteristics for this diode is given in Fig. 5.

In the case of $In_xGa_{1-x}As$ films ($x < 0.3$) grown on GaAs substrates by MBE, it was revealed that buffer layers with, at least, 2 ~ 3-μm-thickness should be required in order to eliminate the effect of lattice mismatch which is more serious in optical quality rather than in electrical quality. Furthermore, preparing buffer layers with various profiles of composition which can be achieved easily by MBE, we can expect high quality $In_xGa_{1-x}As$ films with even larger x.


References

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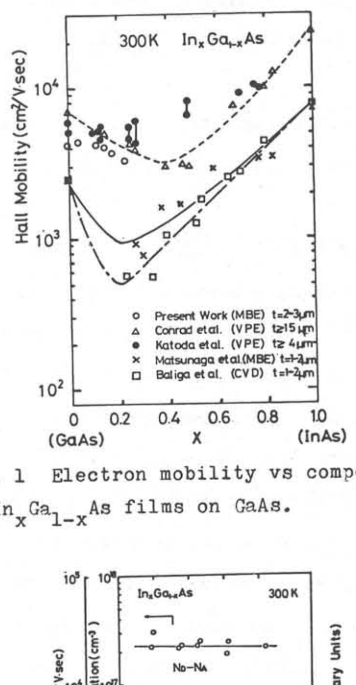


Fig. 1 Electron mobility vs composition in $In_xGa_{1-x}As$ films on GaAs.

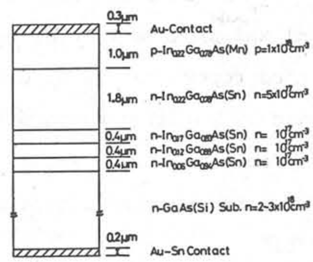


Fig. 3 Structure of multilayer diode.

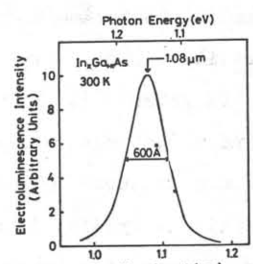


Fig. 4 Electroluminescence for junction edge emission.

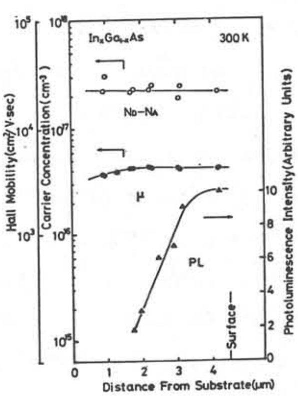


Fig. 2 Profiles of electron mobility, carrier concentration and photoluminescence intensity across a 4.5-μm-thick $In_xGa_{1-x}As$ layer.

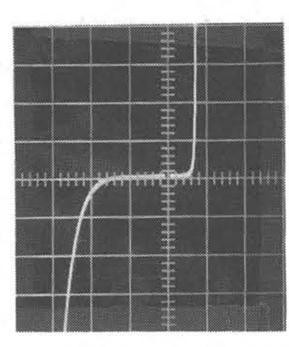

Fig. 5 I - V characteristics for the diode (1 mA/div., 1 V/div.).