1-5 Velocity-Field Characteristics and Current Oscillation in III-V Mixed Crystals, $GaSb_xAs_{1-x}$ and $In_xGa_{1-x}As$

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To develop cw long Gunn diodes with functional operation, a much reduction of the threshold field compared with that of GaAs Gunn diodes is required. Possible ways to improve the threshold field of Gunn effect are to lower the energy separation between the lower valley and the upper valleys, and to increase the density of state in the upper valleys by getting simultaneous contribution of both X and L valleys, by using III-V mixed crystals with controlled conduction band structure and appreciable high mobility.

In order to get fundamental informations about high-field electrical transport in III-V mixed crystals, we focus our attention onto systems of $GaSb_xAs_{1-x}$ and $In_xGa_{1-x}As$ in which X and L valleys are leveled in energy at about $x = 0.2$ -0.4. Velocity-Field Characteristics by using microwave heating method and properties of current oscillation are measured.

Both mixed crystals were prepared by liquid-phase epitaxial method with a sliding graphite boat in a pure hydrogen gas at temperatures around 750°C. The composition of obtained mixed crystals was determined by photoluminescence spectra at 77 K and electron microprobe X-ray analyzer. Electrical properties was measured by using Van der Pauw method.In spite of low alloy composition, electron mobility in the epitaxial layer was not so high as in GaAs. The low-field mobility of mixed crystals seems to be considerably controlled by additional scatterings, probably scattering due to lattice mismatch and alloy scattering which becomes dominant with increasing composition x. In order to reduce the mobility killer effect due to the lattice mismatch, buffer epitaxial layers with low alloy composition were grown on GaAs substrate. The low-field mobility of $In_{0.1}Ga_{0.9}As$ grown on the thin buffer layer was 12000 $cm^2/V\cdot s$ at 77 K.

In Fig.1 we show the velocity-field characteristic measured by using microwave heating technique for two kinds of mixed crystal having nearly equal low-field mobility. Contrary to a decrease of low-field mobility in comparison with GaAs the threshold field becomes lower with increasing x in $GaSb_xAs_{1-x}$. This can be attributed to an effective intervalley electron transfer. It should be noted that in $GaSb_{0.07}As_{0.93}$ the energy difference between Γ and X valleys is estimated to be about 0.3 eV, being smaller than that of GaAs. Moreover, an influence of

L valley located slightly above X valley could not be probably neglected. In GaAs - InAs system, Γ-X valley separation become larger than that of GaAs with increasing x contrary to the case of $GaSb_xAs_{1-x}$, accompanying L valley closely upon the X valley at compositions above x = 0.3. Supposing the empirical relation for the variation of energy separation with alloy composition as shown in Fig.2, the intervalley separation Γ-X and X-L in $In_{0.16}Ga_{0.84}As$ are estimated to be about 0.45 eV and 0.05 eV, respectively. The threshold field is seen to be 7.2 kV/cm and the peak velocity 4.7 x 10^6cm/s in $In_{0.16}Ga_{0.84}As$, being much larger in comparison with that of $GaSb_{0.07}As_{0.93}$. In both crystals, however, low negative differential mobility is observed owing presumably to smaller low-field mobility. We are now attempting to prevent the mobility killer scattering due to crystal lattice mismatch in epitaxial glowth system.

The calculated velocity - field characteristics as a function of alloy composition in both mixed crystals are shown in Fig.3. The model is the same two band model used in InP by James and the calculation include the effects of non-parabolicity and polar optical phonon scattering. The parameters were obtained by linear interpolation between the values for GaAs and those for InAs or GaSb. Increasing the lower valley mobility and the energy separation of the two valleys, and decreasing the density of states ratio increased the peak velocity while increasing the threshold field. Thus a optimum mixed crystal would improve the threshold field and the efficiency of microwave devices. Properties of current oscillation, and relaxation time effect on intervalley scattering will be presented in the Conference.

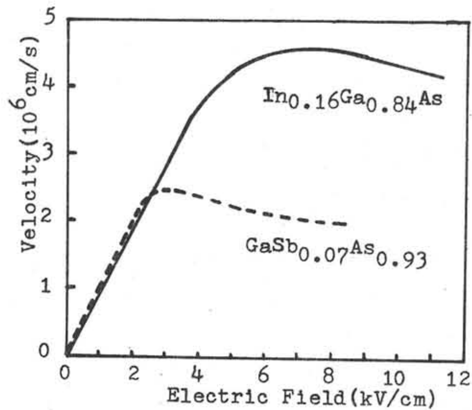

Fig.1

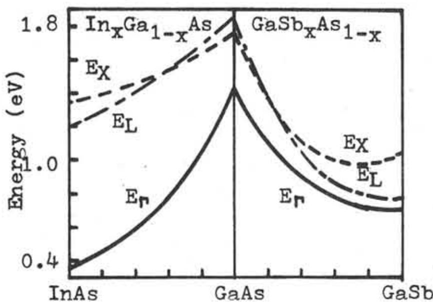

Fig.2

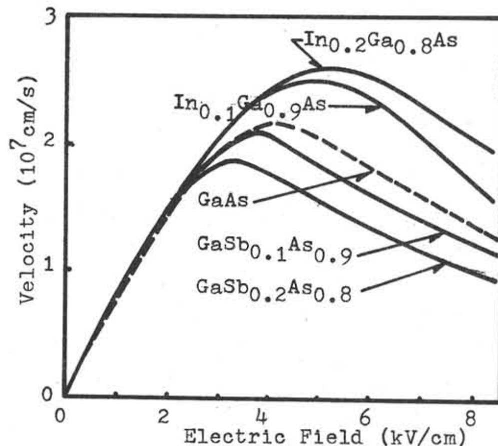

Fig.3