CHAPTER VI

DISCUSSION AND CONCLUSION

In previous chapter, we have shown the numerical results of the diffusivity-mobility ratio calculated by using the expression (4.68) and the empirical expression (3.20). The method of calculation we use follows Sritrakool, Glyde and Sa-yakanit[15] (sub-section 4.3.2) . In this chapter, we would like to conclude the result that we obtained from the previous chapter. Finally some suggestions will be also introduced.

In limit of the Thomas-Fermi approximation, we obtain the diffusivity-mobility ratio for n-type heavily doped semiconductors (4.68)

$$\frac{D}{\mu} = \frac{n}{2e}\left[\rho(E)\Big|_{E=E_f} + \sum_{i=1}^{\infty} a_i (k_B T)^{2i} \frac{\partial^{2i}\rho(E)}{\partial E^{2i}}\Big|_{E=E_f}\right]^{-1},$$

and we can derive it in extremely degenerate case as (4.76)

$$\frac{D}{\mu} = \frac{\pi\hbar^2}{em^*}\left(\frac{\pi}{3}\right)^{1/3} n^{2/3},$$

which is identical to that derived by Van Cong and Dabiais result in (3.22).

In the present model of heavily doped GaAs, the screening of the impurity charges is calculated within the Thomas-Fermi approximation leading to (4.30)

$$v(\vec{r}-\vec{R}) = -\frac{e^2}{\varepsilon_0|\vec{r}-\vec{R}|}\exp\{-Q|\vec{r}-\vec{R}|\}.$$

The Thomas-Fermi approximation is generally valid for smooth potentials varying slowly in space. Specifically in this case it is valid if the root mean square of impurity potential fluctuation is small compared to the Fermi energy measured away from the conduction band edge (4.36)

$$\xi_Q^{1/2} \leq E_f - E_C.$$

This limits the present calculation to higher net carrier concentrations so that Fermi energy is large. In this event the Fermi energy must lie high up in the conduction band.

Considering the diffusivity-mobility ratio for n-type heavily doped semiconductors (4.68). Usually, the first term in the parenthesis dominates the second term so that the diffusivity-mobility ratio mainly depends on the density of states at $E = E_f$. The precise position of Fermi energy then depends mainly on the density of conduction band states and a little on a fewer states in the band tail. It is for this basic reason that the diffusivity-mobility ratio depends very little on the band tail density of states used.

Table 7 lists the minimum net carrier concentrations, N_d-N_a, for which the Thomas-Fermi approximation holds base on the limit $\xi_Q^{1/2} \leq E_f - E_C$. To reduce the Fermi energy below this limit we must abandon the Thomas-Fermi approximation and (4.30) in favor of more sophisticated screening such as discussed, for example, by Herbert *et al.*[16] This would require re-evaluating the band tail density of states since none of the expressions discussed here base on (4.30) would be valid.

When the net carrier concentration is high and Fermi statistics rather than Boltzmann statistics must be used, the electrons are said to be degenerate. The concentration above which the electrons are degenerate is approximately [14]

$$N_{deg} = \left(\frac{\pi}{3}\right)\left(\frac{8m^* k_B T}{\hbar^2}\right)^{3/2}$$

using $m^* = 0.072\, m_0$ this given

$$N_{deg} = \begin{cases} 2.3\times10^{15}\,cm^{-3} & : \; T = 10K \\ 4.8\times10^{16}\,cm^{-3} & : \; T = 77K \\ 3.7\times10^{17}\,cm^{-3} & : \; T = 300K \end{cases}$$

Since N_{deg} less than N_{min} in Table 7. , the electrons are always degenerate here. It is for this reason that the empirical diffusivity-mobility ratio which is based on the degenerate, parabolic band density of states, gives little different result from the diffusivity-mobility ratio for n-type heavily doped semiconductors

We have neglected any possible band tailing to the valence band when the GaAs is compensated. This band tailing will have little effect on Fermi energy. Also the holes enter the screening length in the form

$$Q^2 = Q_e^2 + Q_h^2$$

and since $N_a \leq N_d/2$ the acceptor impurities should not affect Q^2 greatly.