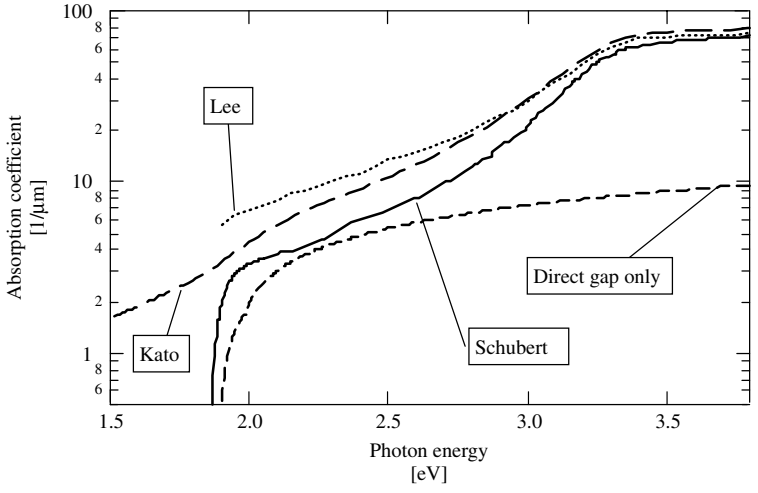

Figure 9.15 Comparison of absorption coefficients of $Ga_xIn_{1-x}P$ published in the literature. The data of Lee *et al*. [59] and Schubert *et al*. [56] are ellipsometric data. The model of Kato *et al*. [57] is a reasonably good fit at high energies, but is a poor fit for sub–band gap photon energies. The curve marked "direct gap only" is a plot of equation (9.22)

where the photon energy E, the band gap energy E_g, and the spin orbit energy Δ_{so} are in units of eV. The value of E_g, of course, varies with the degree of order, η, and the value of Δ_{so} is typically set to 0.1 eV, independent of η. This model reasonably accounts for the absorption associated with the two near-band transitions at E_g and $E_g + \Delta_{so}$ and is useful for deducing the minority-carrier diffusion length from near-gap photoresponse measurements [58]. It is not a good model for adsorption at higher photon energies.

9.6.3.3 Doping characteristics

9.6.3.3.1 n-type dopants

Selenium

The element Se is a commonly used *n*-type dopant in III-V materials and is usually obtained from the decomposition of H_2Se. The doping behavior of H_2Se has been studied by a number of investigators [60–65]. Under most growth conditions, the electron concentration increases with H_2Se flux or partial pressure and then saturates at about $2 \times 10^{19}/cm^3$, depending on T_g. The incorporation of Se also depends on the partial pressure of PH_3 (for GaInP) or AsH_3 (for GaAs). These data best fit an equation of the form

$$n^{-1} = (1 + \alpha P_V)(\beta P_{Se})^{-1} + k^{-1} \tag{9.23}$$

where n is the electron concentration and P_V and P_{Se} are Group V and Se partial pressures, respectively. The coefficients α and β depend on T_g and carrier flow rate (residence time) and, therefore, must be determined for each reactor system. This doping behavior can be derived from a modified Langmuir adsorption model that accounts for the competitive absorption of Se and the Group V species on a fixed number of sites, k, which will depend,