9.6.3 GaInP Solar Cells

9.6.3.1 Lattice matching

One of the major advantages of the monolithic GaInP/GaAs/Ge solar cell is that it is composed of semiconductors that are all closely lattice matched. The fabrication of such a monolithic structure is achieved by the generic process of heteroepitaxy, the specific process being MOCVD. Close lattice matching makes the job of heteroepitaxy much easier, especially for chemically similar materials such as AlGaAs on GaAs. The heteroepitaxy of lattice-mismatched materials is generally more difficult. The lattice mismatch is accommodated by nucleation and by propagation of dislocations in concentrations that depend on the amount of mismatch and the thickness of the individual layers. These dislocations are often centers for nonradiative recombination, in effect limiting the minority-carrier lifetime or diffusion length, and ultimately the efficiency of the device.

The lattice constant of the semiconductor alloy $Ga_xIn_{1-x}P$ is linearly related to the composition x by

$$a_{Ga_xIn_{1-x}P} = xa_{GaP} + (1-x)a_{InP} \tag{9.18}$$

where $a_{GaP} = 0.54512$ nm and $a_{InP} = 0.58686$ nm are the lattice constants of GaP and InP, respectively (see Table 9.3). An epitaxial layer of $Ga_xIn_{1-x}P$ on GaAs with $a_{GaAs} =$ 0.565318 nm will be lattice matched to GaAs at 25°C for $x = 0.516 = x_{LM}$. The quality of a thin, epitaxial $Ga_xIn_{1-x}P$ layer is relatively good for small variations of x around x_{LM}. This case is shown in Figure 9.12, in which a broad-spectrum photocurrent from an electrolyte/$Ga_xIn_{1-x}P$ junction is plotted as a function of $\Delta\theta$ (see Section 9.7.1). The quantity $\Delta\theta$ is measured by double-crystal X-ray rocking-curve diffraction and is a measure of x [35]. If the thickness of the $Ga_xIn_{1-x}P$ layer is less than the x-dependent critical thickness, then

$$\Delta\theta = \tan\theta_B \left(\frac{xa_{GaP} + (1-x)a_{InP} - a_{GaAs}}{a_{GaAs}}\right)\left(\frac{1 + [\nu_{GaP}x + \nu_{InP}(1-x)]}{1 - [\nu_{GaP}x + \nu_{InP}(1-x)]}\right) \tag{9.19}$$

Table 9.3 Lattice constants, force constants, and Poisson ratios for selected III-V binary compounds. Values from Reference [37]

Material	Lattice constant [nm]	C_{11} [10^{10} N/m^2]	C_{12} [10^{10} N/m^2]	Poisson ratio, ν
AlP	0.546354			
GaP	0.54512	14.12	6.25	0.307
		14.05	6.203	0.306
InP	0.58686	10.22	5.76	0.360
InP		10.11	5.61	0.357
$Ga_xIn_{1-x}P$ [$x = 0.516$]				0.333
GaAs	0.565318	11.81	5.32	0.311
		11.91	5.951	0.333
InAs	0.60583	8.329	4.526	0.352
Ge	0.5657906	12.89	4.83	0.273
		12.40	4.13	0.250