$\Delta\theta$ at which this occurs is a function of kinetic factors including the layer thickness, growth temperature, and growth rate. Experimentally, the critical $\Delta\theta$ also depends on the sign of $\Delta\theta$ as can be seen in Figure 9.12. Indium-rich material is under compression. It is generally more difficult (and takes longer) to generate misfit and threading dislocations in compressively strained material compared to material under tension; hence, the difference in strain-relaxation behavior. Intuitively, the critical layer thickness for compressively strained material will generally approach that of tensively strained material as the growth temperature is increased and/or the growth rate is decreased. This behavior is relatively common. Note that this is contrary to the theoretical calculation shown in Figure 9.13(b). This calculation considers only the equilibrium state of the epilayer; the sign of the strain is, therefore, immaterial.

The thickness of the $Ga_xIn_{1-x}P$ top cell for most conditions will be on the order of 1 μm or less. From Figure 9.13(b) this would imply that the critical lattice mismatch should be less than 2×10^{-4} or $|\Delta\theta| \leq 50$ arcsecond. There are several factors that tend to increase or decrease this tolerance limit such as the following:

- Material lattice matched at room temperature is lattice mismatched at growth temperature. This is due to a difference in the thermal expansion coefficients between $Ga_xIn_{1-x}P$ and GaAs (see Table 9.4). For kinetic reasons, it is probably more important that the layers are lattice matched at growth temperature. A layer that is lattice matched at a growth temperature of 625°C will exhibit a lattice mismatch of $\Delta\theta \sim -200$ arcsecond at room temperature [38], or alternatively, a layer that is lattice matched at room temperature, would exhibit a $\Delta\theta = 200$ arcsecond at 625°C. Because it is easier to introduce misfit dislocations at high temperatures, it is probably better to grow the layer lattice matched at the growth temperature. Hence, a ±50 arcsecond tolerance at growth temperature would yield a room temperature tolerance of $-250 < \Delta\theta < -150$ arcsecond.

Table 9.4 Important properties of Ge, GaAs, and GaInP at 298 K

	Ge	GaAs	$Ga_xIn_{1-x}P$	$Al_xIn_{1-x}P$
Atoms/cm^3	4.42×10^{22}	4.44×10^{22}		
Lattice constant [Å]	5.657906 [37]	5.65318 [37]	$= a_{GaAs}$ for $x = 0.516$	$= a_{GaAs}$ for $x = 0.532$
Energy gap [eV]	Indirect 0.662 Direct 0.803 [37]	1.424 [37]	Disordered 1.91 [41]	Indirect 2.34 Direct 2.53 [37]
Density of states				
Conduction band N_C [cm^{-3}]	1.04×10^{19}	4.7×10^{17}		
Valence band N_V [cm^{-3}]	6.0×10^{18}	7.0×10^{18}		
Intrinsic carrier concentration [cm^{-3}]	2.33×10^{13}	2.1×10^{6}		
Linear coefficient of thermal expansion [K^{-1}]	7.0×10^{-6} [37]	6.0×10^{-6} [37]	5.3×10^{-6} [38]	
		6.63×10^{-6} [38]		