Table 13.1 Selected properties of $CuInSe_2$

Property		Value	Units	Reference
Lattice constant	*a*	5.78	Å	[28]
	c	11.62	Å	
Density		5.75	g/cm^3	[28]
Melting temperature		986	C	[29]
Thermal expansion	(*a* axis)	8.32×10^{-6}	1/K	[30]
coefficients at 273 K	(*c* axis)	7.89×10^{-6}	1/K	
Thermal conductivity at 273 K		0.086		[30]
Dielectric constant	Low frequency	13.6 ± 2.4		[31]
	High frequency	8.1 ± 1.4		
	Electrons	0.09		[30]
Effective mass [m_e]	Holes (heavy)	0.71		[30]
	Holes (light)	0.092		[30]
Energy gap		1.02	eV	[30]
Energy gap temperature coefficient		-2×10^{-4}	eV/K	[30]

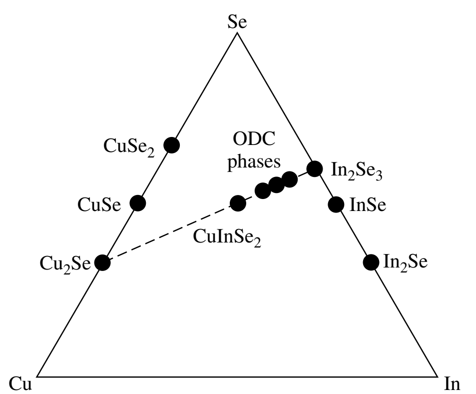

Figure 13.4 Ternary phase diagram of the Cu–In–Se system. Thin-film composition is usually near the pseudobinary Cu_2Se–In_2Se_3 tie-line

the composition 25% Cu. At higher temperatures, around 500°C, where thin films are grown, the phase field widens toward the In-rich side. Typical average compositions of device-quality films have 22 to 24 at.% Cu, which fall within the single-phase region at growth temperature.

$CuInSe_2$ can be alloyed in any proportion with $CuGaSe_2$, thus forming Cu(InGa)Se_2. Similarly, the binary phase In_2Se_3 at the end point of the pseudobinary tie-line can be alloyed to form $(InGa)_2Se_3$, although it undergoes a structural change at $Ga/(In + Ga) = 0.6$ [33]. In high-performance devices, $Ga/(In + Ga)$ ratios are typically 0.2 to 0.3.

One of the central characteristics of Cu(InGa)Se_2 is its ability to accommodate large variations in composition without appreciable differences in optoelectronic properties.