13.3.2 Back Contact

The Mo back contact, used for all high-efficiency devices, is typically deposited by direct current (dc) sputtering. The thickness is determined by the resistance requirements that depend on the specific cell or module configuration. A film with thickness 1 μm will typically have a sheet resistance of 0.1 to 0.2 Ω/□, a factor of 2 to 4 higher resistivity than bulk Mo. Sputter deposition of the Mo layer requires careful control of the pressure to control stress in the film [70] and to prevent problems such as poor adhesion that it might cause. During Cu(InGa)Se_2 deposition, a $MoSe_2$ layer forms at the interface [71]. Its properties are influenced by the Mo film with less $MoSe_2$ forming on dense Mo, sputter-deposited under low pressures [51]. This interfacial layer does not necessarily degrade device performance. Metals other than Mo have been investigated with limited success [72].

13.3.3 Coevaporation of Cu(InGa)Se_2

The highest efficiency devices have been deposited by thermal coevaporation from elemental sources [73]. An illustration of a laboratory system for Cu(InGa)Se_2 coevaporation is shown in Figure 13.9. The process uses line-of-sight delivery of the Cu, In, Ga, and Se from Knudsen-type effusion cells or open-boat sources to the heated substrate. While the evaporation temperatures for each metal will depend on the specific source design, typical ranges are 1300 to 1400°C for Cu, 1000 to 1100°C for In, 1150 to 1250°C for Ga, and 300 to 350°C for Se evaporation.

The sticking coefficients of Cu, In, and Ga are very high, so the film composition and growth rate are determined simply by the flux distribution and effusion rate from each source. The composition of the final film tends to follow the pseudobinary tie-line between $(InGa)_2Se_3$ and Cu_2Se (see Figure 13.4) according to the relative concentration of Cu compared to In and Ga. The relative concentrations of In and Ga determine the band gap of the film, according to equation (13.4), and the effusion rates can be varied over the course of a deposition to change the film composition through its thickness. Se has a

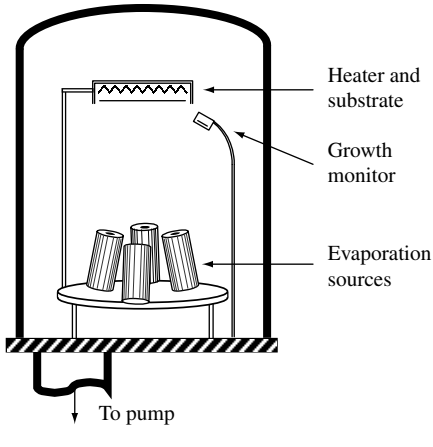

Figure 13.9 Configuration for multisource elemental coevaporation