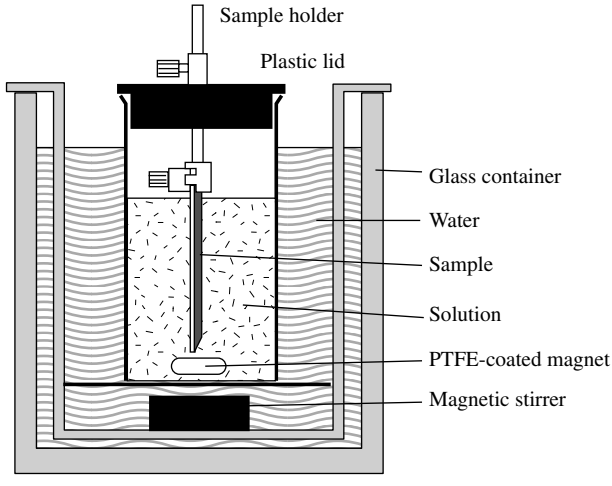

Figure 13.11 Typical laboratory apparatus for chemical bath deposition of CdS

temperature. A typical arrangement, incorporating a water bath for more uniform temperature, is shown in Figure 13.11. Scale-up of the CBD process for manufacturing will be discussed in Section 13.6.1.

The growth of CdS thin films by CBD occurs from ion by ion reaction or by clustering of colloidal particles. Depending on the bath condition, the resulting CdS lattice structure may be cubic, hexagonal, or a mixture [120]. Under typical conditions used for Cu(InGa)Se_2 solar cells, the relatively thin CdS layers grow ion by ion, resulting in dense homogeneous films [121] with mixed cubic/hexagonal or predominantly hexagonal lattice structure [51, 122, 123]. The films consist of crystallites with a grain size of the order of tens of nanometers [122].

Compositional deviation from stoichiometry is commonly observed. In particular, films tend to be sulfur-deficient and contain substantial amounts of oxygen [124, 125]. In addition to oxygen, significant concentrations of hydrogen, carbon, and nitrogen have also been detected in device quality films [126]. The concentration of these impurities has been correlated to a reduction of the optical band gap and the amount of cubic CdS in relation to hexagonal CdS [127].

13.4.2 Interface Effects

The interface between the Cu(InGa)Se_2 and the CdS is characterized by pseudoepitaxial growth of the CdS and intermixing of the chemical species. Electronic band alignment will be discussed in Section 13.5.3. Transmission electron microscopy has shown that chemical bath–deposited CdS layers on Cu(InGa)Se_2 films exhibit an epitaxial relationship at the interface with (112) chalcopyrite Cu(InGa)Se_2 planes parallel to the (111) cubic or (002) hexagonal CdS planes [51, 123]. The lattice mismatch is very small for pure $CuInSe_2$ with a (112) spacing of 0.334 nm as compared to a spacing of 0.336 nm for (111) cubic and (002) hexagonal CdS. In Cu(InGa)Se_2 the lattice mismatch increases with the Ga content. $CuIn_{0.7}Ga_{0.3}Se_2$ and $CuIn_{0.5}Ga_{0.5}Se_2$ have (112) spacing of 0.331 nm