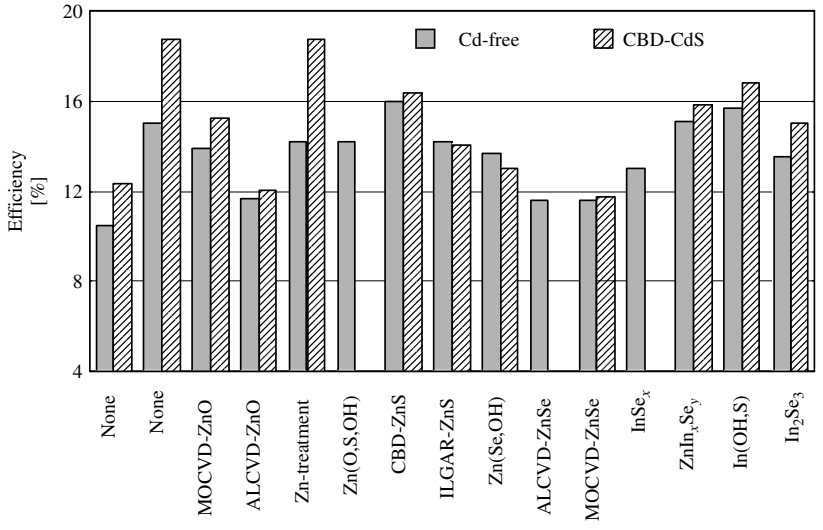

Figure 13.13 The efficiency of Cu(InGa)Se_2 solar cells with a selection of Cd-free junction-formation methods together with corresponding values of Cu(InGa)Se_2 cells with chemical bath–deposited CdS

Cu(InGa)Se_2 surface, which would reduce the recombination in a shallow *n*-type emitter, and possibly also serve to protect the junction and near-surface region during subsequent deposition of the transparent contact materials.

13.4.5 Transparent Contacts

The early Cu(InGa)Se_2 devices used CdS doped with In or Ga as front-contact layers in addition to the CdS buffer layer. Short wavelength light (<520 nm) was absorbed near the surface in the thick CdS layer and did not generate any photocurrent. When chemical bath deposition allowed CdS buffer layers to be thin enough such that it no longer limited the short wavelength collection in the Cu(InGa)Se_2, photocurrent could be gained by increasing the band gap of the contact layer. Since the contact layer must also have high conductivity for lateral current collection, the obvious choice is a transparent conducting oxide (TCO), a class of materials used in such devices as displays and low-emission coatings on window glass panes. There are three main materials in this class: SnO_2, In_2O_3:Sn (ITO), and ZnO. SnO_2 requires relatively high deposition temperatures that restrict the potential in Cu(InGa)Se_2 devices that cannot withstand temperatures greater than 200 to 250°C after CdS is deposited. ITO and ZnO can both be used, but the most common material is ZnO, favored by potentially lower material costs. A good overview of TCO thin-film materials can be found in Reference [153].

The most commonly used low-temperature deposition method for TCO films is sputtering. ITO layers are routinely fabricated on an industrial scale using dc sputtering. Industrial practice is to use ceramic ITO targets and to sputter in an Ar:O_2 mixture. Typical sputter rates range between 0.1 to 10 nm/s, depending on the application [154].

Sputtering of doped ZnO films is not as developed as is sputtering of ITO. Nevertheless, it is the preferred method for depositing the transparent front contact on Cu(InGa)Se_2