

substrate, followed by sequential deposition of CdS and the TCO. Novel schemes have also been demonstrated for fabricating *substrate* configuration cells by transferring the entire cell from a disposable superstrate to a substrate (see, for example, Reference [25]). Superstrate polycrystalline CdTe/CdS heterojunction thin-film solar cells were first demonstrated in 1969 by Adirovich *et al.* in a superstrate design with evaporated CdTe on a CdS/SnO₂/glass superstrate, yielding an efficiency >2% [26]. This was followed in 1972 by Bonnet and Rabenhorst, who, in their paper for the 9th European Photovoltaic Specialists Conference, described a 5 to 6% efficient substrate design CdS/CdTe/Mo made by chemical vapor-deposited CdTe and vacuum-evaporated CdS films [27]. This paper delineated the fundamental issues that still influence the development of highly efficient CdTe/CdS thin-film solar cells: (1) the role of Cu in *p*-type doping of CdTe; (2) the controlling role of doping efficiency in CdTe; (3) the effects of abrupt versus graded CdTe–CdS junctions; (4) the effects of active versus passive grain boundaries; and (5) the formation of low-resistance contacts to *p*-type CdTe.

Development of thin-film CdTe/CdS solar cell fabrication processes during the 1980s and 1990s was advanced by refinements in device design, postdeposition treatments, and formation of low-resistance contacts rather than by refinements in specific deposition methods. This is primarily due to the relatively high chemical stability of CdTe compared to the elemental and compound precursors used to prepare it. Thus, numerous film-fabrication techniques have been used to deposit CdTe for moderate- to high-efficiency solar cells, and eight of these are reviewed in this chapter. Surprisingly, CdTe/CdS solar cells having conversion efficiency from ~10 to ~16% have similar photovoltaic behavior. Electrical analysis suggests that device operation is primarily limited by Shockley–Read–Hall recombination in the space charge region [28].

In spite of tolerance to the deposition technique, two enigmatic aspects of processing high-efficiency thin-film CdTe/CdS solar cells persist, that is, the use of superstrate device configuration, with CdTe deposited onto CdS, and the need for processing step(s) that expose the CdTe and CdS films to Cl and O. During the 1980s, significant gains in performance were obtained by empirical optimization of superstrate fabrication processes with respect to processing variables such as the CdTe deposition temperature, postdeposition heat treatment, growth or treatment chemical environment, and CdTe contact formation. For example, the Matsushita Battery Industrial Company reported that for screen-print/sintered CdTe cells, it was critical to control the CdCl₂, O, and Cu concentrations in the structure by adjusting the slurries and the temperature–time sequences of the sintering step [29]. The Monosolar electrodeposition process was optimized to the 10% efficiency level by addition of Cl to the CdTe plating bath and the use of a so-called “type-conversion junction formation” postdeposition treatment to electrically activate the cell [30]. The group at Kodak achieved the 10% efficiency level with close-space sublimation-deposited CdTe by optimizing the CdTe deposition temperature and the oxygen content in the deposition ambient [31]. A turning point for thin-film CdTe cell performance, with a collateral benefit for processing tolerance, was the application of a postdeposition air-heat treatment of CdTe/CdS structures coated with CdCl₂ [32, 33]. Combining the “CdCl₂ treatment” with advancements in low-resistance contact formation led to the achievement in 1993 of a >15% efficient cell with CdTe deposited by close-space sublimation [34]. Refinements in window-layer processing [35] and employing vapor CdCl₂ treatments [36] have led to additional improvements. The record efficiency