consequently, low photon-to-current conversion efficiencies. Additionally, the organic dyes that were used had a narrow absorption range in visible light, which also contributed to low solar cell performance. Thus, to improve light-harvesting efficiencies and cell performance, researchers used two approaches: developing photoelectrodes with larger surface areas that could adsorb large amount of dye and synthesizing dyes with broader absorption ranges. Significant improvements in the performance of a dye-sensitized solar cell (DSSC, or Grätzel cell) have been mainly due to the development of high-performance nanoporous TiO_2 thin-film electrodes that have a large surface area capable of adsorbing a large amount of photosensitizer, and due to the synthesis of new Ru complex photosensitizers capable of absorbing in the wide visible and near-IR region from 400 to 800 or 900 nm.

Ru bipyridyl complexes are suitable photosensitizers because the excited states of the complexes have long lifetimes and oxidized Ru(III) has long-term chemical stability. Therefore, Ru bipyridyl complexes have been studied intensively as photosensitizers for homogeneous photocatalytic reactions and dye-sensitization systems. An Ru bipyridyl complex, bis(2,2′-bipyridine)(2,2′-bipyridine-4,4′-dicarboxylate)ruthenium(II), having carboxyl groups as anchors to adsorb onto the semiconductor surface, was synthesized and single-crystal TiO_2 photoelectrodes sensitized by the Ru complex were studied in 1979 to 1980 [3, 4].

Recent drastic improvements in the performance of DSSC have been made by Grätzel and coworkers at the Swiss Federal Institute of Technology (EPFL). They achieved a solar energy efficiency, η, of 7 to 10% under AM1.5 irradiation using a DSSC consisting of a nanocrystalline TiO_2 thin-film electrode having a nanoporous structure with large surface area, a novel Ru bipyridyl complex, and an iodine redox electrolyte [5, 6]. They also developed a Ru terpyridine complex that absorbs in the near-IR region up to 900 nm as a photosensitizer for a nanocrystalline TiO_2 photoelectrode: the resulting cell obtained $\eta = 10.4\%$ under AM1.5 with a short-circuit photocurrent density, J_{SC}, of 20.5 mA cm^{-2}, an open-circuit voltage, V_{OC}, of 0.72 V, and a fill factor (*ff*) of 0.70 [7, 8].

The DSSC is an attractive and promising device for solar cell applications that have been intensively investigated worldwide, and its PV mechanism is well understood [9–18]. Recently, commercial applications of the DSSC have been under intensive investigation. The cost of commercially fabricating DSSCs is expected to be relatively low because the cells are made of low-cost materials and assembly is simple and easy. In this chapter, we describe the DSSC, including its structure, component materials, characteristics, working mechanism, preparation, and long-term stability, and discuss the improvement of its performance and commercial applications.

15.1.2 Structure and Materials

The schematic structure of the DSSC constructed by the Grätzel group is shown in Figure 15.1. The composition of the DSSC is described in this section.

15.1.2.1 Transparent conducting oxide-coated glass substrate

Transparent conducting oxide (TCO)-coated glass is used as the substrate for the TiO_2 photoelectrode. For high solar cell performance, the substrate must have low