contributing to the enhanced loss. Furthermore, if the interface is rough or textured, the area of the metal is increased contributing to a higher loss. In a good light-trapping cell design, the light at the weaker end of the spectrum can encounter many reflections within the cell. At each reflection, a part of the light incident on the metal will be absorbed instead of being reflected back to the semiconductor. The photon loss due to metal will become a severe problem when the thickness of the cell decreases and the number of passes increases. Minimization of the metal loss is also an important task in the design of the solar cell.

In this chapter, the optical-modeling software, *PV optics*, is used to discuss the optical design of TF-Si cells. We use the example of a single-junction thin-film solar cell illustrated in Figure 8.12. The results of a series of calculations will be presented to provide information on the influence of various features of the cell configuration on the optical properties of the device, which can help select the best configuration for single-junction Si thin-film solar cells. It should be emphasized again that the optical design of the cells is only an optimization process of the cell structure which was itself determined by other design criteria. The results of the optical design can be very different for different structures.

8.3.2 Description of PV Optics

PV Optics is an optical-modeling software developed by Sopori *et al*. at NREL [59]. This software can calculate a variety of optical parameters for multilayer devices operating in air or within an encapsulated module. These parameters include reflectance, transmittance, distribution of absorbed photons in each layer, and integrated absorbance weighted with an AM1.5 spectrum to determine the MACD for each layer. The method is the numerical equivalent to shining a beam of light on the sample that has an arbitrary surface morphology. This beam is split into a large number of beamlets that impinge on a small region of the surface. Each beamlet is permitted to propagate within the sample, and we keep track of its entire path while it undergoes reflection, transmission, and absorption. In this manner, each beamlet bounces back and forth within the sample. The net energy absorbed at each plane within the sample is determined. This procedure is continued for each beamlet until the energy in the beam is reduced to nearly zero. This process yields the net reflection, transmission, and absorption in the device structure. *PV Optics* uses a combination of ray and wave optics to suitably address thin and thick media, and metal optics.

In our calculations, MACD is used to evaluate the ability of the device to absorb photons in the semiconductor layers. It is defined as the current density that could be generated if every photon (in AM1.5 spectrum) absorbed in the semiconductor layer would generate an electron-hole pair and this pair would contribute to current that is collected by the external circuit. Another parameter, metal loss, is used to estimate the amount of photons lost at the semiconductor/metal interface. Metal loss is defined as the current density that could be generated if every photon (in AM1.5 spectrum) lost at the semiconductor/metal interface would generate an electron-hole pair and this pair would result in a current that is collected by the external circuit. Thus, better devices have higher MACD and lower metal loss.

It should be pointed out that a metallic back-reflector requires a careful design, because such a reflector is accompanied by a loss of photon flux caused by free-carrier