the next section, phosphorous diffusion and Al alloying are very effective impurity-gettering methods.

8.3.1 Light-trapping in Thin Si Solar Cells

As pointed out earlier, a thin-film Si solar cell requires highly efficient light-trapping designs to absorb a significant fraction of the incident sunlight and to minimize reflection. Light-confinement approaches have been discussed in detail for wafer-based cells [54]. Here, we will concentrate only on thin cells. A true optical confinement (or light-trapping) implies that once the light is transmitted into a wafer, the structure sustains the light without transmission from the surfaces. In electromagnetic devices, this is referred to as a *guided wave*. In thin dielectric films used as waveguides in integrated optics, the guided waves use total internal reflection and some specific coherent features to achieve this condition. In a solar cell structure, such modes are not possible. The modes of the structure are radiation modes. Thus, light-trapping as used in solar cells is a misnomer. However, it is supposed to imply relative enhancement of optical absorption over the planar configuration. This necessitates two features of the structure: (1) capability of increasing the optical path of the light transmitted into the cell, and (2) making the structure asymmetrical, such that reflectance at two surfaces is different. An additional requirement in a solar cell is to minimize the reflectance of the illuminating sunlight.

Antireflection (AR) coatings and front-side texturing can be used to fulfill this goal. Choosing appropriate materials for AR coatings and designing the configuration of the front-side texture are among the tasks for optical design of solar cells [55]. The only way to enhance light-trapping in a terrestrial (completely illuminated) solar cell is to use rough surfaces/interfaces instead of planar structures. An analysis of light-trapping concepts using thermodynamic equilibrium conditions suggested that a semiconductor slab with rough surfaces can produce an effective increase in the optical path by a factor of $2n^2$, where n is the refractive index of the semiconductor [5]. The shape of the surface/interface of the device will play a critical role in the light-trapping process. Finding the most appropriate surface configuration that can maximize light-trapping is one of the major goals of optical design of the solar cell. Depending on its morphology, a rough surface can be either Lambertian reflective (a random roughness that causes scattering to follow a $(\cos\theta)^2$ distribution) or geometric reflective (textured surface having a feature size larger than the wavelength of light). Only the surface/interface structure that is geometric reflective will be investigated in this chapter. A number of software packages are available for calculating absorption in a solar cell. These include Sun Rays, Texture, and PV Optics [56–58]. Of these, *PV Optics* is the most general and allows investigation of many features as will be shown later.

One of the important issues in a thin-film solar cell that is seldom considered for thick cells is the metallic absorption loss. All solar cells need contacts, and in many cases, contacts may be expected to serve as optical reflectors. For example, a-Si solar cells use Al or Ag as part of the back-reflector. Unfortunately, a metal surface is not totally reflective. Typical reflectance at an air–metal interface may be quite high, ∼90% for Al and 95% for Ag. However, when such a metal is used in a solar cell, the metal loss is enhanced. The reflectance at the semiconductor metal interface is lower than that at the air–metal interface; the light that is transmitted into the metal is absorbed there,