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Thin-film Silicon Solar Cells

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8.1 INTRODUCTION

Because silicon (Si) is an indirect band gap material, it is generally perceived that the thickness of Si required to absorb usable sunlight should be larger than $(\alpha_{\text{bandedge}})^{-1}$, where α_{bandedge} is the absorption coefficient for wavelength (λ) of light corresponding to the near-bandedge. Using this simple rule of thumb, on the basis of absorption due to a single pass of light, and using the mid-point of the bandedge ($\lambda = 1.05$ μm), one gets $\alpha^{-1} \sim 700$ μm. This implies that the wafer thickness for sufficient absorption of the solar spectrum is >700 μm. This is quite a large thickness for a Si wafer and is not desirable for commercial production of solar cells for two reasons: the wafer cost can be very high and its effectiveness for collection of photogenerated carriers will be small because it is difficult to have a minority-carrier diffusion length (MCDL) comparable to such a large wafer thickness. Thus, for practical reasons, wafer thickness must be less than this value. Furthermore, detailed models that take into account surface characteristics and the multireflections within the wafer show that absorption can be greatly enhanced; thus, the need for such a thick wafer is diminished. Later in this chapter, we will show that by employing an appropriate structure, a very thin layer of Si can offer a high degree of absorption of the solar spectrum – nearly as much as a thick wafer. The physics and modeling capabilities for analyses of solar cell structures have taken two decades to develop and have been responsible for the majority of the improvements in Si solar cell efficiency.

As an introduction, it is necessary to have a general understanding of the requirements for a thin-film Si solar cell and the problems that emerge when the thickness of a Si solar cell is reduced. Clearly just reducing the cell thickness will result in reduced absorption, and thus, a reduced photocurrent. To get a quantitative feel of such a reduction in the photocurrent, consider a planar solar cell. Figure 8.1 is a plot of maximum achievable current density (MACD) generated by a planar solar cell, with an optimum antireflection (AR) coating, for different values of the cell thickness. These calculations are

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