Thus, the increased high-injection lifetime (see equation 3.40) offsets the reduced ambipolar diffusion coefficient.

It is crucial that the front surface of a back-contacted cell be well passivated, so we will assume that $S_F = 0$. We will further assume that optical generation is uniform throughout the base region. At open circuit, with these assumptions, $d^2p/dx^2 = 0$ and therefore

$$V_{OC} = \frac{2kT}{q} \ln\left[\frac{G(\tau_n + \tau_p)}{n_i}\right]. \tag{3.169}$$

The short-circuit current (with $p \simeq 0$ at the back of the cell) is

$$I_{SC} = qAL_aG \sinh(W_B/L_a) \tag{3.170}$$

which, when $L_a \gg W_B$, becomes

$$I_{SC} = qAW_BG. \tag{3.171}$$

3.5.7 *p-i-n* Solar Cells

The p-i-n solar cell takes advantage of the fact that in many semiconductor materials, especially direct band gap semiconductors (i.e. large absorption coefficient), most of the electron–hole pairs are created very near the surface. If an intrinsic (undoped) layer is placed between the (very thin) n and p regions, the depletion region thickness is the most significant fraction of the total solar cell thickness, as illustrated in Figure 3.27. Carrier collection is now aided by the electric field in the depletion region, which helps offset the low lifetimes in some materials, such as amorphous silicon (see Chapter 12). The I–V characteristic of a p-i-n solar cell can be described with minor modifications to the previously derived expressions. The most significant modification is to equation (3.129) where the depletion width is now written as

$$W_D = \chi_N + W_I + \chi_P \tag{3.172}$$

where W_I is the thickness of the intrinsic layer. Since χ_N and χ_P are very thin, short-base approximations are in order for equations (3.127) and (3.128). Also, there is no BSF ($S_{BSF} \to \infty$).

3.5.8 Detailed Numerical Modeling

While analytic solutions such as those discussed thus far in this chapter provide an intuitive understanding of solar cell performance and are therefore very important, they are limited in their accuracy due to the many simplifying assumptions that must be made in order to obtain them. It is rather straightforward to solve the semiconductor equations numerically without the need to make so many simplifications. Several computer codes have been written that solve the semiconductor equations for the explicit purpose of modeling solar cells – PC-1D [23], AMPS [24], ADEPT [25], and its predecessors [16, 26, 27], for example. The basic design of these computer programs is very similar. The semiconductor