was applied. Also, the increased perimeter area of the top cell sometimes affects the dark current.

Underlying junctions may be investigated by first chemically removing the upper junctions. In this case, the underlying junction will respond to a wider spectral range.

It is also useful to be able to characterize two-terminal multijunction cells. The shape of the I-V curve of a series-connected multijunction cell is dominated by the characteristics of the junction that generates the smallest photocurrent. (This concept can be understood by reviewing Figure 9.5 above.) The I-V curve for each junction can be measured by adjusting the spectrum so that that junction has the smallest photocurrent. Using these measurements, the estimated individual junction I-V curves can be derived mathematically, as described in Reference [120]. An example is given below. From the individual I-V curves, one can calculate the I-V curve for the multijunction cell under an arbitrary spectrum. For some samples, the J_{SC} values may be measured by reverse biasing the cell beyond the breakdown points of the junctions [121].

9.7.4 Evaluation of Morphological Defects

Careful examination of the devices with a microscope can identify many problems, especially when the device is forward biased so that it emits light, or when an optical beam–induced current (OBIC) image is available. GaInP junctions emit red light that is usually visible to the naked eye. GaAs emission may be observed with an infrared (IR) imaging device. If the emission shows dark or bright spots, these can usually be correlated with a morphological defect, giving an explanation to the problem. Also, metal (e.g. a contact pad) that extends to the very edge of the pad may touch a layer that is nearby and short the device. This failure mode can sometimes be detected by microscopic examination.

9.7.5 Device Diagnosis

In general, a low J_{SC} may be evaluated from the energy dependence of the photocurrent loss. It is useful to measure and model the internal QE. The external QE measurements are described in Chapter 16. The internal QE is modeled according to equations (9.2–9.8) (Figure 9.16) and is determined experimentally from

$$QE_{\text{Internal}} = QE_{\text{external}}/(1 - \text{Reflectivity}) \tag{9.28}$$

Accurate knowledge of the absorption coefficient is essential to successfully model the QE. The absorption coefficients of GaAs and GaInP were discussed above.

Figure 9.17(a) compares the QE of a typical GaInP cell QE (solid line) with what would be expected if there were no loss in the AlInP window (top curve) or a poor collection in the emitter (bottom curves). Although window absorption losses can easily be distinguished from emitter losses, the similarity of the two lower curves demonstrate the difficulty of distinguishing poor front-surface recombination from poor emitter material quality. However, it is somewhat easier to differentiate poor base material quality from poor rear passivation using a series of devices with variable base thickness. A cell with a