9.6.8 Materials Availability

A question of interest for all solar cell technologies is the availability of the component materials required for very large scale, long-term production of the cell. Predicting the long-term availability of such natural resources as gallium, indium and germanium is very difficult. This issue has been studied periodically over the years, including a recent thorough work by Andersson [115]. It appears that the material whose availability constrains production for the GaInP/GaAs/Ge structure may prove to be germanium. If so, one approach would be to forfeit the relatively small additional contribution of the Ge third junction by using the two-junction GaInP/GaAs structure grown on GaAs. Also, reuse of the substrate by liftoff of the active junctions may prove practical. In any case, high-concentration operation of these cells makes the best use of their constituent materials.

9.7 TROUBLESHOOTING

The standard procedures for measuring light and dark I-V curves and QE curves are described in Chapter 16. Here, we describe additional techniques for characterizing materials and devices. The symptoms of common problems are tabulated in Table 9.5.

9.7.1 Characterization of Epilayers

When working with alloys like GaInP, rocking-mode X-ray diffraction is very helpful toward confirming that the desired lattice constant (alloy composition) was realized (see above).

A modified Polaron profiler (available from Bio Rad) can measure the carrier concentration, band gap, and minority-carrier diffusion length of an epilayer [58, 116]. The sample is mounted in a special holder that allows the formation of front and back contacts in a fraction of the time that is required by a typical solid-state device. An ohmic contact is made to the back of the wafer by passing a surge of current (something like a spot weld). A junction is formed between the epilayer and an aqueous electrolyte (e.g. 0.1 M HCl). The capacitance–voltage ($C-V$) characteristics of this junction provide a measure of the carrier concentration as a function of depth. In a finished device, the carrier concentrations of the individual layers can be checked by profiling (etching) through the structure in the electrochemical cell, or by using selective etches to uncover the layer(s) of interest. $C-V$ measurements on a processed single-junction device (rather than on an aqueous-semiconductor junction) tend to give lower dissipation factors because of lower series resistance, but only give information about the lightly doped side of the junction. Thus, it can be difficult to ascertain whether the emitter is underdoped by a $C-V$ profile on the solid-state device. Although a Polaron profiler is designed to measure the doping level of each layer as a multilayered stack is etched, etch profiles of a multijunction solar cell require considerable skill and some luck. Nonuniform etching can distort the results, especially if the material has some defects. Also, some layers may be completely depleted. Often, a Polaron profiler gives the best information when the etching is partly done by the profiler and partly by applying selective etches *ex situ*. (See Section 9.6.7.) A (dilute) mixture of ammonia and hydrogen peroxide etches GaAs, but stops at GaInP and AlInP,