**Table 9.1** Record solar cell efficiencies. Unless otherwise specified, the cells were fabricated from single crystal materials and the measurements were two-terminal [12]

| Cell | Efficiency [%] | Area [$cm^2$] | Intensity [suns] | Spectrum | Description |
|---|---|---|---|---|---|
| GaAs | $25.1 \pm 0.8$ | 3.9 | 1 | Global | Kopin, AlGaAs window |
| GaAs (thin film) | $23.3 \pm 0.7$ | 4.0 | 1 | Global | Kopin, 5-mm |
| GaAs(poly) | $18.2 \pm 0.5$ | 4.0 | 1 | Global | Res. Triangle Inst. (RTI) Ge substrate |
| InP | $21.9 \pm 0.7$ | 4.0 | 1 | Global | Spire, epitaxial |
| GaInP/GaAs | 30.3 | 4.0 | 1 | Global | Japan Energy |
| GaInP/GaAs/Ge | $28.7 \pm 1.4$ | 29.93 | 1 | Global | Spectrolab |
| Si | $24.7 \pm 0.5$ | 4.0 | 1 | Global | UNSW, PERL |
| GaAs | $27.6 \pm 1.0$ | 0.13 | 255 | Direct | Spire |
| GaInAsP | $27.5 \pm 1.4$ | 0.08 | 171 | Direct | NREL, ENTECH cover |
| InP | $24.3 \pm 1.2$ | 0.08 | 99 | Direct | NREL, ENTECH cover |
| GaInP/GaAs/Ge | $32.4 \pm 2.0$ | 0.1025 | 414 | Direct | Spectrolab |
| GaAs/GaSb | $32.6 \pm 1.7$ | 0.053 | 100 | Direct | Boeing, four-terminal mechanical stack |
| InP/GaInAs | $31.8 \pm 1.6$ | 0.063 | 50 | Direct | NREL, three-terminal, monolithic |
| GaInP/GaAs | $30.2 \pm 1.4$ | 0.103 | 180 | Direct | NREL, monolithic |
| Si | $26.8 \pm 0.8$ | 1.6 | 96 | Direct | Sunpower, back contact |

of 30.3% [11]. The current record solar cell efficiencies for this device, along with the record efficiencies of other multijunction devices, are given in Table 9.1.

In 1994, it was discovered that the GaInP/GaAs tandem cells had very good radiation tolerance for operating in space. Kurtz and coworkers published results for a GaInP/GaAs cell with $\eta = 19.6\%$ (AM0) after irradiation with 1-MeV electrons at a fluence of $10^{15}/cm^2$, [10] a standard radiation dose used to compare various solar cells. This efficiency was higher than the beginning-of-life efficiency of an unirradiated Si solar cell. These attributes soon attracted the attention of the commercial sector. Production of GaInP/GaAs solar cells (on Ge substrates) began in 1996, and the first GaInP-/GaAs-powered satellite was launched in 1997. Today, the production capacity for these tandem cells is about 0.5 MW/year.

This chapter discusses the principles and operation of multijunction solar cells fabricated from III-V semiconductor compounds and alloys, with a particular emphasis on the GaInP/GaAs tandem cell. III-V semiconductors have several characteristics that make them especially suitable for solar cells. A wide selection of these materials is available with direct band gaps, and therefore, high absorption coefficients, in the ~1- to 2-eV range of interest for solar cells; GaAs, with a band gap of 1.42 eV, and $Ga_{0.5}In_{0.5}P$, with a band gap of 1.85 eV, are especially important examples. Both $n$- and $p$-type doping of these materials are generally straightforward, and complex structures made from these materials can be grown with extremely high crystalline and optoelectronic quality by high-volume growth techniques. As a result, III-V cells have achieved the highest single-junction efficiencies. Although these *single-junction* efficiencies are only slightly higher than the impressive efficiencies achieved by the best silicon cells, the ease of fabricating