can range from 10^7 cm/s for an unpassivated GaInP emitter to less than 10^3 cm/s for a high-quality AlInP/GaInP interface. A high interface recombination velocity will reduce the photoresponse of the GaInP solar cell, most strongly in the blue portion of the spectral response. To be an effective window layer for an n-on-p cell, the material should have a

- lattice constant close to that of GaInP,
- E_g much larger than that of the emitter,
- large valence-band offset with respect to the emitter to provide a potential barrier for minority holes,
- relatively high electron concentration (on the order of $n \geq 18/\text{cm}^3$), and
- material quality sufficient to produce low-interface recombination velocity.

The semiconductor AlInP has most of the required characteristics. $Al_xIn_{1-x}P$ is lattice matched to GaAs for $x = 0.532$. The indirect band edge of AlInP is 2.34 eV, 0.4 to 0.5 eV larger than that of GaInP. The $Al_xIn_{1-x}P$/GaInP band alignment appears to be Type 1 with $\Delta E_c \sim 0.75\Delta E_g$ and $\Delta E_v \sim 0.25\Delta E_g$ [86]. This implies that it should provide reasonable confinement of the holes in the emitter of an n-on-p device. It is easily doped n-type with either Si or Se. The internal quantum efficiency of a GaInP cell with a good $Al_xIn_{1-x}P$ window layer is greater than about 40% at a photon energy of 3.5 eV. However, there is a strong affinity between the Al in $Al_xIn_{1-x}P$ and oxygen, and oxygen is a deep donor in $Al_xIn_{1-x}P$. Hence, if the reactor chamber or the source materials are contaminated with water vapor or other oxygenated compounds, the quality of the $Al_xIn_{1-x}P$ will suffer. Poor-quality $Al_xIn_{1-x}P$ will degrade the blue response of a GaInP cell and degrade the fill factor (via contact resistance) [8].

9.6.3.4.2 Back-surface barrier

The function of the top-cell back-surface barrier is to passivate the interface between the top-cell base and the tunnel-junction interconnect (TJIC). Also, in some cases, it may help reduce outdiffusion of dopants from the TJIC [87]. The high recombination velocity at this interface will affect both the photoresponse (in particular, the red photoresponse) and the V_{OC}. The V_{OC} effect is shown in Figure 9.8. Note that the magnitude of the effect can be quite large and is also affected by the base minority-carrier diffusion length and thickness. The requirements of a good back-surface barrier layer are similar to those of a front-surface window layer. For an n-on-p cell, it should have a

- lattice constant close to that of GaInP,
- E_g larger than E_g of GaInP,
- large conduction-band offset with respect to GaInP,
- relatively high hole concentration (on the order of $p = 1 \times 10^{18}/\text{cm}^3$),
- relatively good minority-carrier transport properties, and
- high transparency to photons destined for the underlying GaAs cell.

For back-surface fields, initial results from Friedman *et al.* [88] implied that disordered or high-E_g GaInP was the best BSF for a low-E_g GaInP top cell compared to an AlGaInP BSF. This was probably due to oxygen contamination in the AlGaInP layer.