Practical back mirrors that are fully compatible with the cell electrical design, can be implemented, such as those schematized in Figure 7.4. A metal can make a good reflector, but Al, especially after heat treatment, gives low reflectance. The Si-oxide-metal structure in Figure 7.4(c) can present a high reflectance by capitalizing on interference effects [65].

At the front, the metal mirror is not applicable because the ray paths must be kept open for the entering light. Still, high front reflectance can be achieved because of total internal reflection [61]. Rays striking the surface at angles larger than the critical air-Si one are totally reflected. Texturing one or both surfaces with macroscopic or microscopic features serves this purpose by tilting the rays. Even in the case of geometric texturing with well-defined surface orientations, after a few internal reflections, the direction of rays inside the wafer is randomly distributed: this is the lambertian case, useful analytic approximation to light-trapping. Bifacial structures in Figure 7.4 can, for the same reason, be very efficient at confining the light [66].

Light-trapping increases the effective thickness of the wafer for absorption. In the geometrical optics regime, it has been shown that for one-side isotropic illumination the maximum enhancement factor (though perhaps not realizable) is 4 $(n_{\mathrm{Si}}/n_{\mathrm{air}})^2$, that is, each ray traverses 50 times the cell thickness before escaping [67]. The corresponding enhancement in photogeneration will be lower because of the competition of the absorption by free carriers at long wavelength.

Light-trapping is essential for thin cells. Even in the thick PERL design it can suppose around 1 mA·cm^{-2} enhancement in short-circuit current with respect to the case where the internal reflectances were zero.

7.3.7 Performance Comparison

For illustration purposes, Table 7.3 collects relevant parameters of the Auger-limited ideal Si solar cell [30], the best one-sun PERL cell [36] and a typical screen-printed, industrial cell on Cz-Si. The different concepts behind each set of data must be accounted for when comparing the figures. For instance, the ideal cell is assumed as being isotropically illuminated, while measurements are made for near-normal incidence.

Table 7.3 Cell performance (25°C, AM1.5 Global 0.1 W·cm^{-2})

Cell type	Ideal (calculated)	PERL (measured)	Industrial (typical)
Size (cm^2)	–	4	100
Thickness (μm)	80	450	300
Substrate resistivity (Ω·cm)	Intrinsic	0.5	1
Short-circuit current density, J_{SC} (A·cm^{-2})	0.0425	0.0422	0.034
Open-circuit voltage, V_{OC} (V)	0.765	0.702	0.600
Fill factor, *FF*	0.890	0.828	0.740
Efficiency, η (%)	28.8	24.7	15.0