effects. This must be balanced with contact resistance. Etching off of the passivating layer before metallization is usually needed (not in screen-printed cells). To maintain low sheet resistance and diminish recombination at the metallized fraction, the emitter is deep (around 1 μm). Note that the collection of carriers near the surface implies that the emitter is thin in terms of the minority-carrier diffusion length ($w < L$) and so it is very sensitive to surface recombination. Recombination is further reduced, by making the contact window narrower than the finger width, as illustrated in Figure 7.3 [51].

Control of both the surface concentration and the depth of the emitter, is achieved by depositing, in a thermal step, the desired amount of phosphorus or boron (predeposition) and then diffusing it into the substrate (drive-in) during subsequent furnace steps. The MIS solar cell, on the contrary, uses no diffusion for the *n* region, which is electrostatically induced by charges on top of the surface [20].

The J_0 of the emitter is the average, weighted by the contacted area, of the J_0 of contacted and noncontacted portions.

7.3.3.3 Selective and point emitters

A further improvement involves making separate diffusions for the different regions since the requirements are so different (Figure 7.3c) [52]: a heavily doped and thick region under the contacts, a thin and lowly doped region under the passivating layer. These structures, known as “selective emitters”, come at the expense of more complicated processing usually involving photolithographic delineation and alignment of the diffusions (not in LGBG cells to be seen later).

If a very low SRV is possible, it would be best to have no emitter at all since doping always degrades bulk lifetime (Figure 7.3d). Examples are the back point-contact solar cell and the point-emitter design with bifacial contact [53], originally designed for concentration but capable of very high one-sun efficiency as well.

With localized contacts, surface recombination decreases with the penalty of an increase in transport losses in the substrate: deeper gradients for minority carriers, or increased series resistance for majority carriers, because of current crowding near the contacts. The trading is more favorably solved as the contact size shrinks [54]. Light and/or localized diffusions also have the drawback of decreased gettering action.

7.3.3.4 Industrial cells

Screen printing drastically affects the design of the emitter: it must be very highly doped to decrease the high-contact resistance and not very shallow so that it is not perforated during paste firing, which would short-circuit the junction [55]. Besides, the wide metal lines must be placed well apart; and in order to keep shading losses moderate, the emitter lateral conductance must be high, which also advises deep and highly doped regions. These characteristics are good to decrease recombination at the contacts, but are far from optimum at the exposed surface.

Industrial phosphorus emitters, typically, feature surface concentrations over 10^{20} cm^{-3} and 0.4-μm depth, and result in a sheet resistance around 40 Ω. As already