materials. Resistivity, price and availability considerations make silver the ideal choice as the contact metal. Copper offers similar advantages, but it does not qualify for screen printing because subsequent heat treatments are needed during which its high diffusivity will produce contamination of the silicon wafer.

Screen printing compares very unfavorably with vacuum evaporation in the first three requirements. It has been already commented how this affects the cell design and leads to a significant efficiency gap between laboratory and commercial cells. But throughput and cost compensate for it.

Screen printing will be described in more depth in the following section. It is used to stick a paste containing silver powder to the front face of the wafer in the comblike (fingers plus bus bars) pattern. Automatic screen printers are available that are capable of in-line, continuous operation with high throughput. These machines accept wafers from packs, cassettes or a belt line, place them with sufficient accuracy under the screen and deliver the printed wafers to the belt line. The paste is a viscous liquid due to the solvents it contains; these are evaporated in an in-line furnace at 100 to 200°C. The dried paste is apt for subsequent processing.

8. *Back contact print and dry*: The same operations are performed on the backside of the cell, except that the paste contains both silver and aluminum and the printed pattern is different.

   Aluminum is required because silver does not form ohmic contacts to p-Si, but cannot be used alone because it cannot be soldered. The low eutectic temperature of the Al-Si system means that some silicon will be dissolved and then recrystallize upon cooling in a p-type layer.

   Though in principle a continuous contact will give better electrical performance (lower resistance), most commercial wafers feature a back contact with a mesh structure: apart from paste-saving considerations, this is preferred to a continuous layer because the different expansion coefficients would produce warp of the cell during the subsequent thermal step.

9. *Cofiring of metal contacts*: A high-temperature step is still needed: organic components of the paste must be burnt off, the metallic grains must sinter together to form a good conductor, and they must form an intimate electric contact to the underlying silicon. As Figure 7.6 shows, the front paste is deposited on an insulating layer (the AR coating) and the back contact on the parasitic n-type rear layer.

   Upon firing, the active component of the front paste must penetrate the ARC coating to contact the n-emitter without shorting it: too mild a heat treatment will render high contact resistance, but too high a firing temperature will motivate the silver to reach through the emitter and contact the base. In extreme situations, this renders the cell useless by short-circuiting it. In more benign cases, small shunts appear as a low shunt resistance or dark current components with a high ideality factor that reduces the fill factor and the open-circuit voltage.

   The back paste, in its turn, must completely perforate the parasitic back emitter to reach the base during the firing.

   In order to comply with these stringent requirements, the composition of the pastes and the thermal profile of this critical step must be adjusted very carefully.

10. *Testing and sorting*: The illuminated $I-V$ curve of finished cells is measured under an artificial light source with a spectral content similar to sunlight (a sun simulator)