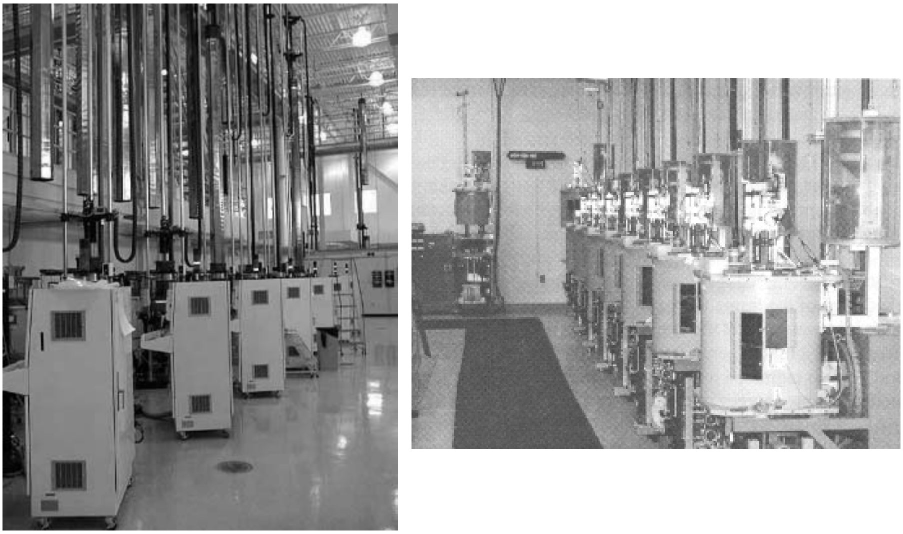

(a) (b)

Figure 6.26 Manufacturing crystal growth equipment in commercialisation for (a) EFG and (b) STR technology

from the ribbon while it is growing, and then further cut into wafers of 10-cm length prior to processing.

WEB, SF and RGS ribbon technologies all are in various stages of R&D and pilot demonstrations leading to commercialisation. SF is perhaps the closest to successfully scaling up the technology, as a wider (20 cm) and higher throughput furnace is reaching the final demonstration phase. WEB is basing its expansion to a 1- to 2-MW pilot operation on a single ribbon furnace for producing 5-cm-wide wafers. RGS is moving towards the use of 12.5-cm-wide ribbon in which high sustained throughput technology and consistent high material quality needs to be demonstrated.

6.5.4 Ribbon Material Properties and Solar Cells

Except for WEB, all the growth processes produce multicrystalline ribbon. WEB ribbon grows with (111) crystallographic faces (see Figure 6.21). It typically does not have any grain boundaries, but has a single multiple-twin boundary located about mid-way through the ribbon thickness. Each (111) surface is made up of a single grain, and the dislocation density is the lowest of any ribbon, 10^3 to $10^4/cm^2$.

For the other two vertical ribbon growth cases, EFG and STR, extraneous crystals are generated most often at the sides of the ribbon (i.e. octagon tube corners) and propagate along the growth axis of the ribbon. These crystals form elongated grains often many centimetres in length along the growth axis, and which extend through the ribbon thickness. In EFG, the grains are interspersed with numerous twin boundary arrays. The grains at the ribbon edge in STR are generally smaller than in the centre. Because the meniscus near each string is concave downward, the grains nucleated at the string can