Table 6.4 Single-furnace performance metrics for ribbon technologies under development and in commercialisation

Method/ parameter	Pull speed [cm/min]	Width [cm]	Throughput [cm^2/min]	Furnaces per 100 MW[a]
WEB	1–2	5–8	5–16	2000
EFG Octagon	1.65	8 × 12.5	165	100
STR	1–2	5–8	5–16	1175
SF	[b]	15–30	[b]	[b]
RGS	600–1000	12.5	7500–12 500	2–3

[a]Furnace data are taken from Reference [58], where throughput is normalised for comparison purposes to an overall yield of 90% and cell efficiency of 15% for all processes
[b]Pulling rate parameters for the SF process are not available

to ribbon technology. Superior electronic quality is generally achieved at the expense of throughput in bulk crystal growth from the melt.

A summary of performance metrics for ribbon technologies currently under development is given in Table 6.4. A critical driving parameter in technology development of ribbon methods for large-scale manufacture and commercialisation is the productivity per furnace. Productivity governs the capital cost of installed capacity and direct labour costs, which constitute significant barriers to ongoing commercialisation on a large scale for all ribbon technologies.

6.5.3 Manufacturing Technology

Table 6.4 shows that development of ribbon technologies is proceeding along two distinct paths. WEB and STR rely on low furnace cost to remain competitive in wafer costs. Development of SF and RGS technologies is focused on achieving superior throughput per furnace.

Scaling of ribbon factories significantly beyond the manufacturing levels practised now, for example, 100 MW, poses different challenges for technology development in these two cases. The low throughput ribbon furnace (WEB, STR) requires a simple and low-cost furnace design, a high level of automation and low infrastructure costs. In contrast, high reliability and uptime of furnaces and the growth process are most critical for the high throughput technologies SF and RGS. EFG technology development is moving in a direction that is trending towards the middle of these two extremes.

Examples of commercial installations and equipment now in manufacturing for EFG and STR technologies are shown in Figure 6.26. Figure 6.26(a) pictures a group of furnaces in the EFG octagon manufacturing line, with a high bay area to accommodate the 5.4-m octagon growth lengths. EFG wafers of 10-cm width and of 10- or 15-cm lengths are standard products and are cut from the octagon tubes using high-speed lasers (not shown). More detail on this technology is given in Reference [59].

Single ribbon furnaces for the growth of 8-cm-wide ribbon of the STR manufacturing line are shown in Figure 6.26(b). Ribbon sections up to a meter long are scribed