Ribbon cell processing, nevertheless, needs to recognise the unique growth constraints of all of the techniques. As noted above, a common material characteristic for ribbon materials historically has been the compromised as-grown bulk electronic quality, dictated by the development of desired high-throughput growth configurations. This strategy has its base in a commercial demand for very low cost wafers that must compete at relatively low volumes with already established dominant products based on single-crystal Cz wafers or directionally solidified and cast ingots. As-grown ribbon diffusion lengths most often are less than 100 μm. To obtain the maximum cell efficiency on this ribbon, with higher dislocation densities and contaminating impurities than in competitor wafers, a solar cell processing strategy was devised early in the history of ribbon technology development that incorporates special bulk lifetime upgrading steps. For example, bulk lifetime upgrading via aluminium alloying and hydrogen is particularly effective for EFG material [69, 70]. Another approach is to use plasma-enhanced chemical vapour deposition (PECVD) of silicon nitride to generate hydrogen for passivating the silicon bulk [71].

6.5.5 Ribbon/Foil Technology – Future Directions

Ribbon/foil wafer production is poised to move on to face a new round of challenges in the construction of large (50–100 MW) manufacturing facilities for crystalline silicon ribbon wafers. The RGS foil technology, with the greatest potential of all ribbon methods for cost reduction on the basis of a high throughput per furnace, is entering a pilot demonstration phase. This process faces challenges in process and equipment development before it can enter high-volume manufacturing of wafers. In the next pilot phase, we may expect that RGS will demonstrate a consistent material quality sufficient for improving cell efficiency to greater than 12% from the current 10 to 11%; process control capable of reproducibly producing a low stress, regular structure, with a shaped 12.5-cm-wide wafer suitable for high-yield cell processing at about a 300-μ thickness and a reliable prototype furnace with melt replenishment to enable continuous production, which will gain full benefit from the high throughput growth concept.

The future focus of WEB and STR ribbon development is on process automation and capital cost reduction for furnaces and infrastructure based on a concept of a low throughput (per furnace) process. Production will probably grow to between 1 and 10 MW for each of these approaches over the next several years. Process parameters that will be practised in this next round of manufacturing equipment expansion for both of them are narrowed down to a single ribbon per furnace concept with similar throughput parameters – a ribbon width of about 8 cm and a pull speed in the 1 to 2 cm/min range. The WEB ribbon technology is embarking on its pilot expansion with a unique process for the growth and manufacturing of solar cells at a 100-μm wafer thickness. STR is expanding its manufacturing with a 300-μm-thick wafer. Although wafer bulk quality is demonstrated on an R&D level to be capable of achieving 15 to 16% cell efficiencies for STR, and over 17% for WEB, quality and cell efficiency levels on a multi-megawatt scale are yet to be established. Both approaches will attempt to demonstrate the cost-effectiveness of operating on a multi-MW level in the next few years. R&D directions, which would appear to have the most potential for the reduction of wafer material costs for these techniques, are growth of wider ribbons and more ribbons per furnace.