Table 8.5 Grain-enhancement methods for already-deposited amorphous or fine-grain Si films. Temperature >600°C cannot be applied to low-cost glass substrates

Method	Processing temp. [°C]	Processing time	Metal contamination
CVD growth	1000	>10 h	No
Annealing	500	20–40 h	No
ZMR	1200	Quick	No
MIC	<500	Quick	Severe
LIC	>1000	Quick	No

LIC – laser induced crystallization; MIC – metal induced crystallization

in such a frequency range leads to higher deposition rates. See Chapter 12 for a more complete discussion of a-Si materials and deposition techniques.

It is known that typical, low-temperature (<400°C) CVD methods generally yield fine-grain (<0.1 μm) Si films. The solar cells fabricated on such films exhibit shunting, low V_{OC}, and poor carrier collection. Thus, it is imperative that a fine-grain (or amorphous) Si film on a glass or some other low-cost substrate be grain-enhanced by a low-temperature process. Table 8.5 gives a summary of the grain-enhancement techniques currently used in thin-film μc-Si formation. The grain enhancement involves the movement of GBs in an attempt to minimize the overall energy. A simple approach for accomplishing this is to perform a high-temperature anneal. However, high temperature (>600°C) processing is not compatible with low cost substrates like glass. The processing temperature can, however, be significantly lowered by a suitable choice of film properties and processing conditions.

8.3.5 Methods of Grain Enhancement of a-Si/μc-Si Thin Films

The grain-growth phenomenon in a crystal is caused by the material's effort to minimize its excess Gibbs free energy from the presence of GBs by minimizing the total grain-boundary area. GBs are a higher energy, nonequilibrium condition compared to a single-crystal structure. Thus, any technique that applies sufficient energy to mobilize GBs will cause grain enhancement.

(a) Annealing

When an a-Si film deposited on glass substrate is subjected to a thermal anneal for an extended period of time, crystallization of the film occurs leading to an increase in the grain size. The thin film remains in the solid phase during the whole process, which is why this kind of process is also called *solid-phase crystallization*. The grain enhancement in this process results from a movement of GBs activated by the heating. An increase in the time or temperature, or both, can further promote the grain growth. The major drawback of the thermal annealing process is that it requires a long time. A typical annealing process will take 20 to 40 h [75]. The annealing time can be reduced somewhat if a surface-textured substrate or doped a-Si layers are used. These methods accelerate the