Table 12.2 Ranges of RF-PECVD deposition conditions for a-Si:H films with optimal properties. These numbers are empirical, not fundamental limits, and represent current results at the time of publication

Range	Pressure [Torr]	RF power density [mW/cm^2]	Substrate temperature [C]	Electrode spacing [cm]	Active gas flow^a [sccm/cm^2]	H_2 dilution R^b
Upper	2	100	350	5	0.02	100
Medium	0.5	20	250	3	0.01	10
Lower	0.05	10	150	1	0.002	0

^{a}Flows of active gases, such as SiH_4, GeH_4, or Si_2H_6, for each unit area of the deposition area (electrode + substrate + chamber walls)
^{b}Hydrogen dilution R, defined here as the ratio of hydrogen and active gas flows (e.g. H_2/SiH_4)

controlled within certain ranges desirable for high-quality a-Si growth. Typical ranges of parameters for a-Si are summarized in Table 12.2.

The pressure range is usually between 0.05 and 2 Torr. Lower pressure is desirable for making uniform deposition, and higher pressure is more desirable for preparing microcrystalline silicon films. Most researchers use a pressure between 0.5 and 1 Torr for a-Si deposition. The RF power should be set at around 10 to 100 mW/cm^2 for a capacitively coupled reactor. Below 10 mW/cm^2, it is difficult to maintain a plasma. Higher power is desirable for higher deposition rate. However, above 100 mW/cm^2, the rapid reactions in the gas can create a silicon polyhydride powder that contaminates the growing Si film. This problem can be mitigated by using very low pressure or strong hydrogen dilution.

The substrate temperature is usually set between 150 and 350°C. At lower substrate temperature, more H is incorporated in the film. As expected from Figure 12.10, this increases the band gap of a-Si:H slightly [51, 75]. However, lower substrate temperature (<150°C) exacerbates silicon polyhydride powder formation unless high hydrogen dilution is used. At higher substrate temperature, less hydrogen is incorporated and the band gap is somewhat reduced. These effects are attributed to the thermal enhancement of the surface diffusivity of adatoms during growth; presumably at higher temperatures the silicon network is more ideal and binds less hydrogen. Researchers exploit the substrate temperature effect on the band gap in device making. Wider band gap materials are useful in the top component cell of a triple-junction solar cell [76, 77]. Narrower band gap a-Si is useful as the top cell *i*-layer of an a-Si/a-SiGe tandem cell. However, at temperatures higher than 350°C the quality of the material degrades; this effect is attributed to loss of hydrogen passivation of dangling bonds.

The electrode spacing in an RF glow discharge reactor is usually set between 1 and 5 cm for a-Si deposition. Smaller spacing is more desirable for a uniform deposition, while with a larger spacing it is easier to maintain a plasma. The flow rate that is required is determined by deposition rate and the area of the reactor plates. Some of the silicon atoms in the gases directed into the chamber are deposited onto the substrates or the chamber walls; the remainder gets pumped to the exhaust. Manufacturers may prefer conditions that lead to higher gas utilization (lower gas flows and higher RF power). But this compromises the quality of a-Si films deposited near the downstream area when a linear flow scheme