act as an antireflection coating, provide resistance to charging, and even provide added thermal control to the spacecraft. In the 1970s, manufacturers began adding a nominal 5% cerium oxide to the cover glasses. This was shown to significantly improve the resistance of the glass to darkening from radiation or ultraviolet light [22]. The protection offered by the cerium also will improve the lifetime of the adhesives that are used to bond the cover glasses. The SOA cover glass is a drawn cerium-doped borosilicate glass. Research today is focused on improving the transmission of the glasses over a wider spectral range to accommodate the development of new MJ devices.

Current methods for calculating damage to solar cells are well documented in the GaAs Solar Cell Radiation Handbook (JPL 96-9). Recently the displacement damage dose (Dd) method has been developed to model radiation degradation. This method is currently being implemented in the SAVANT radiation degradation modeling computer program [23].

The bombardment of cells by charged particles can also lead to dangerously high voltages being established across solar arrays. These large voltages can lead to catastrophic electrostatic discharging events. This is especially true in the case of large arrays and pose significant problems for future utilization of large-area arrays on polymeric substrates. Much work has been done on the grounding and shielding of arrays to mitigate the effects of array charging [24]. Progress in addressing these effects has been made through the development of plasma contactors that ground the arrays to the space plasma.

Solar cell performance is also diminished over time due to neutral particle or micrometeor bombardment. These events account for approximately a 1% decrease in EOL space solar cells performance [25]. These events may also have a correlation to the initiation of discharging events discussed above. Space solar cells and arrays must also be equipped to contend with the plasma environment (radiation and charging). Removed from much of the shielding effects of the Earth's magnetic field, solar cells in space are continually bombarded with high-energy electrons and protons. The radiation damage caused by these particles will degrade solar cell performance and can dramatically limit spacecraft life. This is especially true for mid-Earth orbits (MEO, defined as ∼2000 to 12 000 km) in which cells must pass through the Van Allen radiation belts and thus get a much higher dose of radiation than would be experienced in low-Earth orbits (LEO, defined as <1000 km) or geosynchronous Earth orbits (GEO, defined as 35 780 km). LEO orbits vary in their radiation dose depending on their orientation, with, for example, polar orbits yielding a higher radiation dose than equatorial orbits. Figure 10.3 shows a comparison of equivalent fluence on a silicon solar cell in a variety of orbits. Figure 10.4 shows the dramatic decline in EOL power of cells in MEO orbit [26]. The degradation of cells in space due to radiation damage can be mitigated through the use of cover glasses at the expense of added mass to the spacecraft. Figure 10.5 shows the decline in power density as a function of time over 10 years in an 1853-km, 103° sun-synchronous orbit.

10.2.2 Thermal Environment

There is a considerable range of temperatures and intensities that may be encountered for the space use of photovoltaics. The temperature of a solar cell in space is largely determined by the intensity and duration of its illumination [32]. In a typical LEO, such as the orbit of the ISS, the operating temperature of the silicon solar cells is 55°C when