One of the organic dyes, merocyanine dye, also gave good long-term stability in a preliminary test using a sealed cell under continuous AM1.5 irradiation with a 420-nm cutoff filter, although organic dyes are generally considered to be unstable compared to metal complexes. We obtained stability of cell performance for approximately 1500 h, corresponding to a turnover number of more than 10 million (Table 15.3).

These results strongly indicate that the DSSC shows sufficient physical and chemical stability during the period of illumination. Nevertheless, stability tests at high temperatures and high humidity must be carried out for outdoor applications.

15.4.2 Module Fabrication and Other Subjects for Commercialization

The sheet resistance of TCO substrates (i.e. SnO_2) is relatively high, making the DSSCs resistance-limited if they are larger than about 1 cm^2. Increased sheet resistance of the TCO substrate on scale-up of the DSSC leads to loss of efficiency, especially fill factor. Therefore, scale-up of the DSSC using a modular approach has been investigated [168, 169]. A module consists of several interconnected basic cells with two TCO substrates coated with TiO_2 or platinum, including the electrolyte inside. The electrolyte contains iodine and iodide, which dissolve metal materials, dissolved in an organic solvent. Therefore, standard conductors like silver will not work or has to be protected by sealing materials. In addition, for having an organic solvent in such a system, one must seal the system carefully also at the outside. To seal the modules, an inert material, glass frit, even for interconnections has been used [168]. An efficiency of 7% was achieved using a module consisting of 12 interconnected cells with a total area of 112 cm^2 (7.6% for a 3-cm^2 cell and 8% for a 1-cm^2 cell) [168]. A continuous process for the fabrication of a monolithic series connecting DSSC modules using laser scribing has been proposed by Kay and Grätzel (Figure 15.16) [13].

Recently, polymer substrates instead of glass have been utilized in constructing DSSCs, expanding possible commercial applications [170–174]. Polymer substrates allow roll-to-roll production, which can achieve high throughput. When a polymer film is used as a substrate, aqueous TiO_2 paste without organic surfactants is sintered at relatively low temperatures, approximately 150°C being sufficient to produce mechanically stable TiO_2 films. Sommeling *et al.* at ECN used an ITO-coated poly(ethylene terephthalate) (PET) film as a substrate and prepared a plastic DSSC [170–172]. A cell performance with a J_{SC} of 15 μA cm^{-2}, V_{OC} of 0.48 V, and *ff* of 0.67 was obtained at an illumination intensity of 250 lux. This performance is sufficient to power indoor appliances such as watches and calculators. Under AM1.5 irradiation, a V_{OC} of 0.7 V and J_{SC} of 2 mA cm^{-2} were obtained.

Recently, the DSSC has been used for educational demonstration of solar energy–to–electricity conversion because of its simple fabrication [15, 175]. One can purchase DSSC kits including all components, TCO-coated glass, TiO_2 electrodes, blackberries (i.e. dye), and electrolyte solution [176, 177] and easily demonstrate an artificial photosynthetic process. For detailed studies, one can purchase other materials, including Ru complex photosensitizers, TiO_2 paste, and sealing materials from Solaronix S. A. [178].