alkoxides, such as isopropoxide and butoxide, has usually been used to produce high-performance solar cells [16, 76]. Generally, the anatase phase rather than rutile phase of TiO_2 is more suitable for electrodes [77]. Preparation involves the following steps:

1. Precipitation by hydrolysis of Ti alkoxides using 0.1 M HNO_3.
2. Peptization by heating at 80°C for 8 h, followed by filtering.
3. Hydrothermal growth by autoclaving at 200 to 250°C for 12 h.
4. Sonication with an ultrasonic bath.
5. Concentration with an evaporator.

Precipitation involves controlled hydrolysis of a Ti alkoxide, such as Ti isopropoxide. To obtain monodispersed particles of the desired size, the hydrolysis and condensation kinetics must be controlled. Ti-alkoxides suitably modified with acetic acid or acetyl acetonate yield colloids having a large surface area (>200 $m^2\,g^{-1}$) and smaller particle diameter (5–7 nm) [16, 76]. Peptization results in the segregation of the agglomerates to primary particles, after which the large agglomerates are removed by filtration. Autoclaving of the colloidal TiO_2 solution leads to growth of the primary particles to 10–25 nm and also to some extent increases the anatase crystallinity present. At higher autoclaving temperature, more growth of particles and rutile formation occur, particularly at temperatures above 240°C. Electrodes prepared using colloids autoclaved at or below 230°C are transparent, while those made from colloids autoclaved at higher temperatures are translucent or opaque. After autoclaving, the precipitates are redispersed using an ultrasonic processor equipped with a Ti-horn (e.g. Sonics & Materials Inc., 400–600 W [78]). The colloidal solution is then concentrated at 45°C using a rotary evaporator to reach desired concentration of approximately 11 wt% TiO_2.

15.2.2 Preparation of the TiO_2 Electrode

The TiO_2 thin film is usually prepared by one of the two methods:

(a) Doctor blade technique

To increase the porosity of the film, 0.02 to 0.07 g of polyethylene glycol (PEG, molecular weight 20 000) is added as a binder to 1 mL of the concentrated colloidal TiO_2 solution (TiO_2, 11 wt%). If a commercial powder such as P25 is used, the powder is dispersed by grinding with water, a particle stabilizer such as acetylacetone, and a nonionic surfactant such as Triton X [6]. The colloidal TiO_2 solution is spread on a TCO substrate and then sintered at 450°C for 30 min under air. The resulting TiO_2 film is transparent.

(b) Screen printing

The TiO_2 colloid is separated from acidified water, washed carefully, and then mixed with EC as a binder and α-terpineol as a solvent in ethanol, yielding an organic TiO_2 paste after evaporating ethanol. The paste is printed on a TCO substrate using a screen printing machine and then sintered at 500°C for 1 h under air. The film thickness is easily controlled in screen printing by the selection of paste composition (i.e. wt% of TiO_2 nanoparticles in the paste), screen mesh size, and repetition of printing.