



CHAPTER II

FUNDAMENTAL KNOWLEDGE AND LITERATURE REVIEW

2.1 Solar cell

Photovoltaic energy conversion

Photovoltaic energy conversion refers to the direct conversion of energy in light into usable electrical energy which may be employed immediately or stored. The basic ingredients for photovoltaic energy conversion are presented schematically in Figure 2.1. These are seen to be a light-induced transition from ground state to excited state, a transport mechanism which conveys away the resulting excited electrons and holes, and a “check valve” of some sort which prevent these photogenerated electrons and holes from flowing backwards and recombining. In such a system the electrons, whose energy has been pumped up by the incoming photons, must go through some external path in order to lose their energy and recombine with the holes. This external path may involve an electrical load or some storage mechanic such a chemical storage.

Figure 2.2, illustrating the mechanism of natural photo synthesis. Again there is a light-induced transition from ground state to excited state(actually two are seen) and a transport mechanism with a check valve. In the energy conversion system devised by nature, the excited electrons and holes are used directly to store energy in chemical bonding(Fonash , 1981).

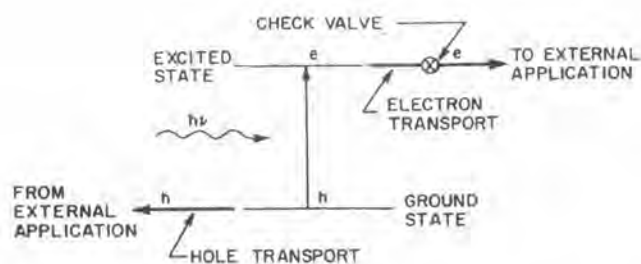


Figure 2.1 Basic features of photovoltaic conversion. The check valve prevent backflow of the excited electrons.

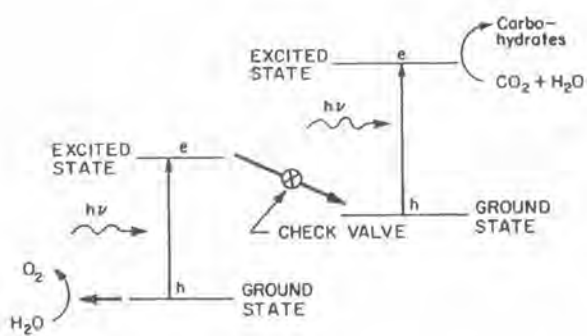


Figure 2.2 Process of nature photosynthesis. Two photosystems are seen to be involved. Again, a check valve is involved to stop backflow.

2.2 Dye sensitized solar cell

A schematic presentation of the operating principles of the DSSCs is given in Figure 2.3. The important part of this system is a mesoscopic oxide semiconductor film, which is placed in contact with a redox electrolyte or an organic hole conductor. The material of choice has been TiO_2 (anatase) although alternative wide band gap oxides such as ZnO , and Nb_2O_5 have also been investigated. Attached to the surface of the nanocrystalline film is a monolayer of the sensitizer. Photo-excitation of the latter results in the injection of an electron into the conduction band of the oxide. The dye is regenerated by electron donation from the electrolyte, usually an organic solvent containing a redox system, such as the iodide/triiodide couple. The regeneration of the sensitizer by iodide intercepts the recapture of the conduction band electron by the oxidized dye. The iodide is regenerated in turn by the reduction of triiodide at the counter-electrode the circuit being completed via electron migration through the external load. The voltage generated under illumination corresponds to the difference between the Fermi level of the electron in the solid and the redox potential of the electrolyte. Overall the device generates electric power from light without suffering permanent chemical transformation.

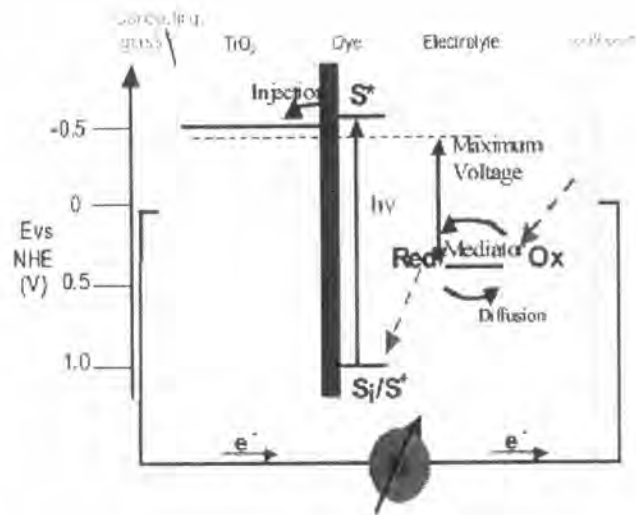


Figure 2.3 Principle of operation of the dye-sensitized nanocrystalline solar cell.

Photo-excitation of the sensitizer (S) is followed by electron injection into the conduction band of an oxide semiconductor film. The dye molecule is regenerated by the redox system, which itself is regenerated at the counter-electrode by electrons passed through the load. Potentials are referred to the normal hydrogen electrode (NHE) The energy levels drawn match the redox potentials of the standard N3 sensitizer ground state and the iodide/triiodide couple (Gratzel, 2006).

2.3 Carbon nanotubes

Carbon nanotube has been recognized as a very promising good material due to its excellent properties in optical, mechanical and electrical aspects. Iijima is the first research who discovered a morphology from his experiment in 1991. He discovered microtubules of graphitic carbon with outer diameters of 4-30 nm and a length of up to 1 μm in figure 2.4 (Iijima, 1991)

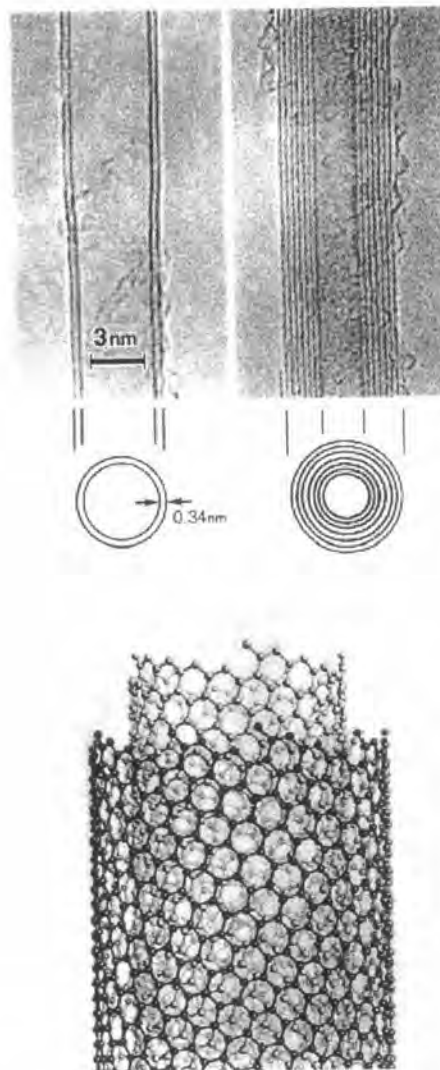


Figure 2.4 Multi-wall carbon nanotubes discovered by Iijima.(Iijima, 1991).

The carbon nanotubes(Figure.2.4) range in length from a few tens of nanometers to several micrometers, and in outer diameter from about 2.5 nm to 30 nm. At high resolution the individual layers making up the concentric tubes can be imaged directly, as in Figure. 2.5 It is quite frequently observed that the central cavity of a nanotube is traversed by graphitic layers, effectively capping one or more of the inner tubes and reducing the total number of layer in the tube, reducing the number of concentric layers from six to five(Harris, 1999).

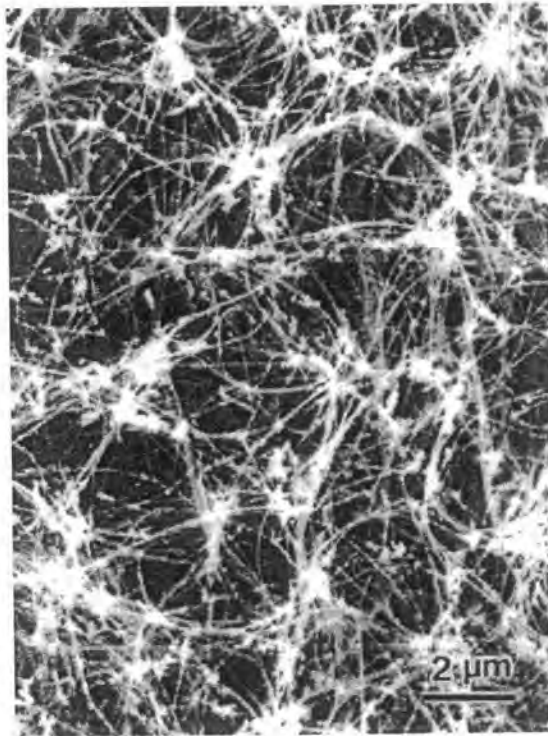


Figure 2.5 A typical micrograph of SEM of as-grow
Multi-wall carbon nanotubes.

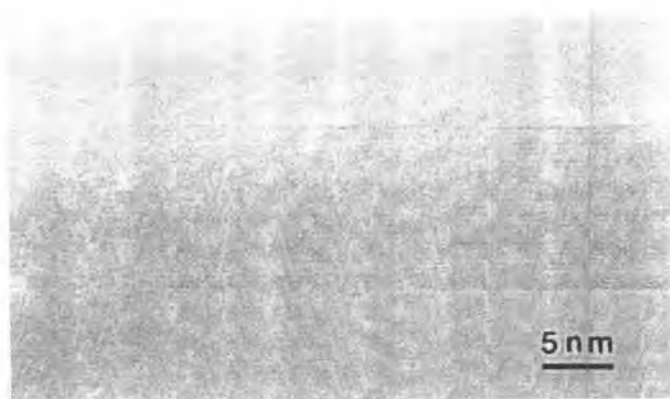


Figure 2.6 The central cavity of a nanotube is traversed by graphitic layers

(An example of HRTEM of and as-grown MWNTs.

The inner diameter of the MWNTs is approximately 1.0 nm, while the outer diameter is near 11.2 nm.(Ando et al., 1999).

Electrical conductivity of individual purified MWNTs

Y. Ando et. al.,(1999) prepared multiwall carbon nanotubes(MWNTs) and investigated physical properties, showed the electrical conductivity of individual purified MWNTs using a two-probe method. Figure 2.7.

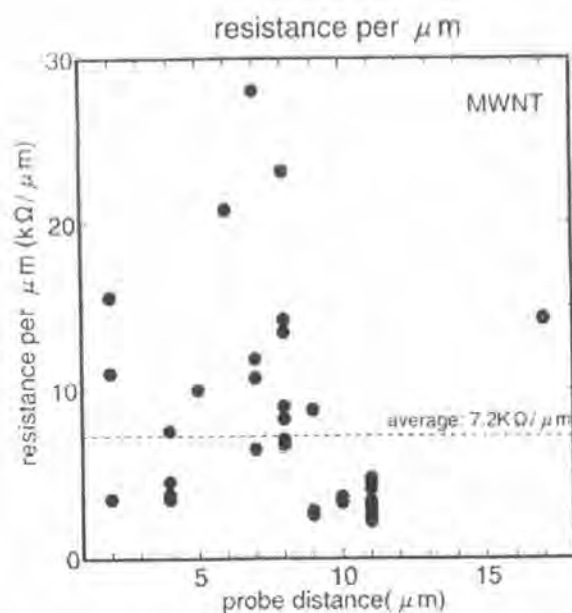


Figure 2.7 The resistance per unit length (1 mm) of individual purified MWNTs.

(Ando et al., 1999)

It was reported that resistance per unit length (1mm) along the long axis of purified MWNTs would be dependent upon probe diameter. The current-voltage curves of four individual purified MWNTs, whose lengths were 4, 6, 9 and 10 mm, respectively, at a high applied voltage are shown in Figure 2.8. The electrical conductivity measurements of individual purified MWNTs indicated that the purified MWNTs obtained using this method possessed an electrical conductivity of approximately $1.85 \cdot 10^3 \text{ Scm}^{-1}$, and could conduct an enormous current density of more than 10^7 Acm^{-2} (Ando et al., 1999)

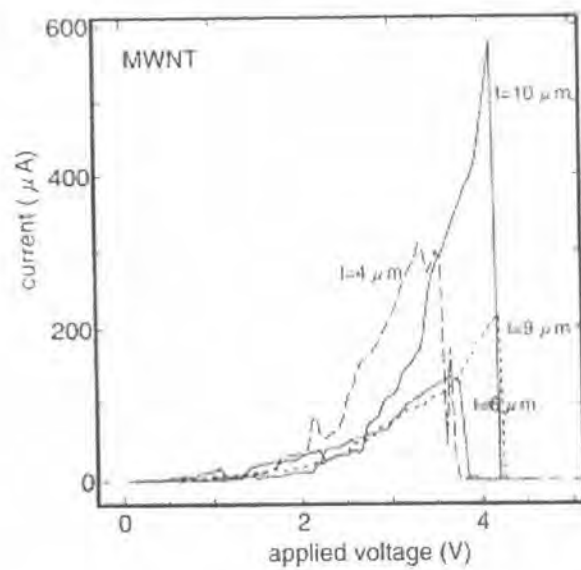


Figure 2.8 The current-voltage curves of four individual purified MWNTs at high voltage. The length of four MWNTs was 4, 6, 9 and 10 μm . (Ando et al., 1999)

2.4 Literature Reviews

In order to grasp the present status of solar cell research which has been conducted so far, some literature has been surveyed and summarized as follows,

T.Y. Lee *et al.*,(2007) fabricated a dye sensitized solar cells using TiO_2 coated multi-wall carbon nanotubes(TiO_2 -CNTs). CNTs introduced to dye sensitized solar cells to improve solar cell performance through reduction series resistance. TiO_2 -CNTs were obtained by Sol-Gel method. Compared with a conventional TiO_2 cell, the TiO_2 -CNTs composite(0.1 wt%) shows an approximately 50% increasing in conversion efficiency, which is attributed to an increase in short circuit current density (J_{sc}). The enhancement occurs due to improvement in interconnectivity between the TiO_2 particles and the TiO_2 -CNTs in the porous TiO_2 film.

N. Viriya-empikul *et al.*,(2008) reported that the length of titanate nanotube within range of 30-200 nm can be controlled by applying sonicating pretreatment of titania precursor in hydrothermal synthesis. Without sonication, the length of TNTs synthesized in the hydrothermal process became much shorter due to hindered effort of lower diffusivities of titania precursors. A mechanism of TNTs length control with sonification pretreatment was proposed by taking account of the reaction rate of the rolling of titania precursor sheets under the hydrothermal condition enhanced by higher diffusion.

S. Ngamsinlasathian *et al.*,(2006) fabricated the electrode of dye sensitized solar cells by surfactant-assisted templating method using tetraisopropyl orthotitanate modified with acetylacetone and laurylamine hydrochloride as template. This mesoporous titanium dioxide cells, film thickness 3.5 μm , exhibited higher short circuit photocurrent density and solar energy conversion due to high anatase phase content, which helps facilitate electron transport and high surface area. But the thickness of transparent MP-TiO₂ film was usually limited to less than 5 μm , since film tends to crack. The 5 % P25(a typical commercial titania powder) was added to mesoporous TiO₂ improving the cell performance up to 8.06%.

Y. Yan *et al.*,(2003) prepared the composite titanate/anatase nanocomposites consisting of titanate nanotubes and leaf-like anatase TiO₂ nanoparticles by hydrothermal treatment on titanate nanotubes in HNO₃ pH 6 under vigorous magnetic stirring. Their surface area is around 120 m²/g. The composite was found to show significantly enhanced activity toward photocatalytic decolorization RhB under visible light illumination in comparison with pure titanate nanotubes, anatase TiO₂, and even commercial Degussa P25.

G. An *et al.*,(2007) successfully prepared the composite between anatase TiO₂ and multi-wall carbon nanotubes(MWCNTs) by depositing anatase TiO₂ nanoparticles on multi-wall carbon nanotubes by hydrolysis titanium isopropoxide in supercritical ethanol. The composite showed significant increment in photoactivity of phenol under visible light irradiation more than pure TiO₂.

K. Lee *et al.*, (2008) investigated fabrication of DSSCs at low temperature 150 °C by adding MWCNTs in range 0.1-0.5 wt% of TiO₂. MWCNTs were oxidized in acid mixture of H₂SO₄/HNO₃ under ultra sonication produced MWCNTs with terminal -COO groups for good contact around TiO₂ nanoparticles. With 0.1 wt% of MWCNTs/TiO₂, the DSSC had the highest cell performance and longest electron lifetime in the TiO₂ electrode.

G. Kim *et al.*, (2006) synthesized titanate nanotubes by hydrothermal process from Degussa P25 in NaOH 10 M. They were used to fabricate electrode of DSSCs by electrophoretic deposition (EPD) method at 40 V and annealing increase from 450 to 550 °C. The solar cell corresponding to EPD titanate nanotubes annealed at 500 °C shows showed higher efficiency than doctor-blade method at same temperature annealing.