REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Many researchers have developed and characterized thin film of TiO_2 owing to its wide application in numerous fields. In this chapter, a through survey of literature on various deposition techniques and its characterization studies of TiO_2 film have been done.

2. 1 STUDIES ON THE DEPOSITION OF TiO_2 THIN FILMS

U.M. Patil[29] et al. (2009) have synthesized the nanocrystalline TiO_2 thin films by simple successive ionic layer adsorption and reaction (SILAR) method on glass and fluorine-doped tin oxide (FTO)-coated glass substrate from aqueous solution. The as-deposited film was heat treated at 673K for 2 h in air. The results show that the SILAR method allowed the formation of anatase, nanocrystalline, and porous TiO_2 thin films.

Photocatalytically active TiO_2 thin-films have been deposited on silicon wafers using the Successive-Ionic-Layer-Adsorption-and-Reaction technique by **Sangmoon Park[30] et al. (2006)**. Atomic-force-microscopy images and X-ray diffraction measurements of the TiO_2 films obtained under various annealing conditions showed how changes of the micro-scale surface structure depend on the post-SILAR treatment. Hydro thermally treated TiO_2 films show a higher photocatalytic activity and a much better mechanical stability compared to furnace-annealed films.

H.M. Pathan[31] et al. (2006) have investigated the effect of annealing on the photocatalytic activity of TiO_2 thin films. It was found that the films annealed at 450C exhibited more photocatalytic activity when compared to as-deposited films.

Titanium dioxide (TiO_2) films were deposited fabricated on fluorine doped tin oxide (FTO) coated glass substrate using successive ionic layer adsorption and reaction (SILAR) method by **A.M. More[32] et al. (2009)**. The as-deposited and annealed TiO_2

films were amorphous in nature. The optical band gap values of virgin TiO_2, annealed, methyl violet and rose bengal sensitized TiO_2 were found to be 3.6, 3.5, 2.87 and 2.95 eV, respectively.

M. Stamate[33] **et al. (2005)** analyzed the characteristics of TiO_2 thin films deposited by a d. c. magnetron sputtering method. The optical band gaps of TiO_2 film varied from 3 eV - 3.4 eV as a function of oxygen/argon ratios in the flowing gas between 10% to 50%.

M. M. Hasan[34] **et al.(2008)** studied the characteristics of anatase TiO_2 thin films grown by radio frequency magnetron sputtering on glass substrates at a high sputtering pressure and room temperature. From X-ray diffraction patterns of the TiO_2 films, it was found that the as-deposited film showed some differences compared with the annealed films and the intensities of the peaks of the crystalline phase increased with the increase of annealing temperature. The extinction coefficient was nearly zero in the visible range and was found to increase with annealing temperature. The allowed indirect optical band gap was found to be in the range from 3.39 to 3.42 eV, which showed a small variation. The allowed direct band gap of the films found to increase from 3.67 to 3.72 eV.

Graetzel[35] **et al. (2005)** has successfully demonstrated a dye sensitized photo electrochemical bared on TiO_2 nanoparticles. The TiO_2 nanoparticles was sensitized using Ru(II) complexes.

K. Prabakar[36] **et al. (2010)** prepared nitrogen-sulphur (N-S) doped thin films by sol-gel method. The N-S doped thin films yielded an increased open circuit voltage and short circuit current density.

Low resistance dye-sensitized solar cells (DSSCs) based on all-titanium substrates have been proposed by **Hai Wang**[37] **et al. (2009)**. To minimize the internal resistance of DSSCs, the titanium wires and titanium sheets were used as the substrates of the photoanode and the counter electrode, respectively. The thickness of TiO_2 thin film coated on titanium wire was optimized to achieve a high cell performance. An efficiency of 5.6% for the cell was obtained with a Jsc of 15.41 mA cm^{-2}, Voc of 0.59 V, and FF of 0.62.

Roberto M. Paniago[38] et al. (2008) have prepared TiO_2 film by the sol–gel method or directly by Degussa P25 .The effect of adsorption of the cis-[Ru(dcbH2)2(NCS)2] dye, N3, on the surface of films was investigated. The photo electrochemical parameters was evaluated and rationalized in terms of the morphological characteristics of the films.

Masayuki Okuya[39] et al. (2002) synthesized titaniumdioxide (TiO_2) thin films on glass substrates from titanium (IV)oxy acetylacetonate 2-butanol solution by a spray pyrolysis deposition (SPD) technique. The films consisted of TiO_2 leaflets and showed are oriented with along the (2 0 0) direction The surface area of the film was successfully increased by adding a small amount of aluminum (III) acetylacetonate (AA) in the source solution. A conversion efficiency of 3.2% at AA content of 0.6% was obtained which was attributed to the highest amount of dye anchored on the surface of TiO_2 layer.

Dye-sensitized solar cells based on a tantalum (Ta)-doped TiO_2 thin film prepared by the hydrothermal method showed a photovoltaic efficiency of 8.18%, which was higher than that of the undoped TiO_2 thin film (7.40%) by **Haotian Yanga[40] et al. (2010)**. They have reported that the positive shift of the flat band potential improves the driving force of injected electrons from the LUMO of the dye to the conduction band of TiO_2. The increased electron density caused by the Ta-doped TiO_2 was found to improve the fill factor of the solar cell. They have also found that the increased electron density accelerates the transfer rate of electrons in the Ta-doped TiO_2 thin films by comparison to undoped films.

TiO_2 thin-film electrode for a dye-sensitized solar cell was fabricated by **Ru-Yuan Yang[41] et al. (2008)**. It contained a nanocrystalline TiO_2 layer that was sandwiched between an ITO (indium tin oxide) substrate and a layer of TiO_2/dye composite particles. A nanocrystalline TiO_2 layer and a layer of TiO_2/dye composite particles were subsequently fabricated in that order on the ITO substrate. This layer of the TiO_2/dye composite particles markedly increased the short-circuit photocurrent from 0.2 μA (conventional DSSC) to 4 μA (DSSC with a layer of TiO_2/dye composite particles) because of the improved coverage of the TiO_2 surface by the powder of Copper phthalocyanine dye.

M.F. Hossain[42] **et al. (2008)** prepared nanocrystalline TiO_2 for DSSCs by reactive sputtering. The films were sensitized with the dye solution of chlorophyllin sodium copper salt in water. They have reported that the amount of dye incorporated in the films is highly dependent on the microstructure of the film.

Huizhi Zhou[43] **et al. (2011)** have identified twenty natural dyes, extracted from natural materials such as flowers, leaves, fruits, traditional Chinese medicines, and beverages,as sensitizers to fabricate dye-sensitized solar cells (DSCs). The photoelectrochemical performance of the DSCs based on these dyes showed that the open circuit voltages (V_{oc}) in the range of 0.337 to 0.689 V, and the short circuit photocurrent densities (J_{sc}) in the range of 0.14 to 2.69mAcm$^{-2.}$ Specifically, a high V_{oc} of 0.686V was obtained from the dye extracted from mangosteen pericarp sensitizer. The conversion efficiency of the DSC sensitized by the ethanol extract of mangosteen pericarp was 1.17%.

Dye sensitized solar cells (DSSCs) were fabricated using anthocyanin dye by **M. H. Buraidah**[44], **et al. (2011)**. The study was designed towards increasing the efficiency of the DSSC. DSSC using 26.9 wt.%chitosan-22wt.%NH4I(+2.2wt.% I2)-48.9wt. % IL solid electrolyte, black rice anthocyanin with Pt counter electrode showed Jsc of 172 μA cm^{-2} and V_{oc} of 195mV. The black rice DSSC using 11wt. % (chitosan:PEO, wt. ratio 30:70)-9wt. % NH4I-80wt. % BMII gel electrolyte exhibited J_{sc} of 1213 μA cm^{-2}, V_{oc} of 400mV, *FF* of 0.47, and η of 0.23%. DSSC fabricated using red cabbage anthocyanin exhibited the best performance with the fill factor of 0.39, J_{sc} of 3503 μA cm^{-2}, V_{oc} of 340mV, and an overall conversion efficiency of 0.46%.

Nerine J. Cherepy[45] **et al. (1997)** have investigated photoelectrochemical cell utilizing flavonoid anthocyanin dyes extracted from blackberries, along with colloidal TiO_2 powder, is shown to convert sunlight to electrical power at an efficiency of 0.56% under full sun.

The extract of Eugenia jambolana Lam, was used as a natural sensitizer for TiO_2 in photoelectrochemical solar cells. Photogenerated current and voltage as high as 2.3 mA and 711 mV, respectively were obtained by **Christian G. Garcia**[46] **et al. (2003)**.

The photovoltaic field Dye-Sensitized Solar Cell (DSSC) is one of the most promising methods for a high-performance solar cell in the next generation, since it is fabricated by a simple manufacture process at relatively low cost by **V.Senthilnathan**[47] **et al. (2010)**. It involves the novelties introduced in the instrumentation of the apparatus and the characterisations (XRD, SEM & AFM) of the prepared thin films for the fabricated DSSC. The thin films are prepared and tested for its DSSC performance. The efficiency of assembled DSSC is 0.24%.

Natural pigments containing anthocyanins extracted at different temperatures from petrocarpus erinaceus (African rosewood) have been investigated as possible sensitizers for TiO_2 by **Kelvin Alaba Aduloju**[48] **et al. (2011)**. Photocurrent densities ranging from 1.11 to 2.15 mA/cm^2 were obtained with photovoltages ranging from 390 to 431 mV. The overall efficiency and fill factor of these cells varied from 0.23 to 0.51 and 0.50 to 0.57 respectively. Among the dyes extracted at different temperature at 323K gave the best-photosensitized effect.

M. Malekshahi Byranvand[49] **et al. (2010)** have employed natural pomegranate juice for sensitization of nanocrystalline TiO_2. Photovoltaic parameters like short circuit current (ISC), open circuit voltage (VOC), fill factor (FF) and overall conversion efficiencies (η) of the fabricated cell were 3.50mA, 600mV, 60% and 1.26 % respectively under 100 mW/m^2 illumination.

A.R. Hernández-Martínez[50] et al. (2012) have performed dye-sensitized solar cells (DSSC) based five natural dyes extracted from *Festuca ovina*, *Hibiscus sabdariffa, Tagetes erecta*, *Bougainvillea spectabilis*, and *Punica granatum.*The best performance was obtained for *Punica Granatum* with a solar energy conversion efficiency of 1.86%, with a current density J_{SC} of 3.341 mA/cm^2 using an incident irradiation of 100 mW/cm^2 at 25 °C.

Giuseppe Calogero[51] et al. (2008) employed the dyes extracted from Sicilian orange and egg plants peels as sensitizers for TiO_2 films band DSSC and obtained maximum efficiency for Sicilian orange dye (0.66%).

The bougainvillea flowers, red turnip and the purple wild Sicilian prickly pear fruit juice extracts have been investigated as natural sensitizers of TiO_2 films by **Giuseppe Calogero[52] et al. (2010)**. The yellow orange indicaxanthin and the red purple betacyanins are the main components in the cocktail of natural dyes obtained from these natural products. The best overall solar energy conversion efficiency of 1.7% was obtained, under AM 1.5 irradiation, with the red turnip extract, that showed a remarkable current density (Jsc = 9.5 mA/cm^2) and a high IPCE value (65% at λ = 470 nm).

Kartika Sari [53] et al. (2011) have explained the characterization of optical properties from the extracts of *Sansevieria Trifasciata* as a dye-sensitized solar cell. The characterization results showed a wide absorption spectrum in nearly all UV and visible regions. Absorbance peak is observed at wavelength λ = 411 nm and λ = 665 nm which shows the content of chlorophyll, anthocyanin and carotene in the extract of the *Sansevieria Trifasciata*. The maximum absorbance value in the study is 3.996. This is indicative of the extract can be used as dye sensitized solar cells.

H. Changa[54] et al. (2010) have studied the application of spinach extract, ipomoea leaf extract and their mixed extracts as the natural dyes for a dye-sensitized solar cell (DSSC). The experimental results of current–voltage curve, the photoelectric conversion efficiency of the DSSCs prepared by natural dyes from ipomoea leaf extract was 0.318% under extractilon temperature of 50 °C and pH value of extraction fluid at 1.0.

Dye-sensitized solar cells (DSSCs) have been fabricated using natural dyes extracted from rosella, blue pea and a mixture of the extracts by **Khwanchit Wongchareea**[55] **et al. (2007)**. The light absorption spectrum of the mixed extract contained peaks corresponding to the contributions from both rosella and blue pea extracts. The cell sensitized by the rosella extract alone showed the best sensitization effect. The energy conversion efficiency (the cells consisting of rosella extract alone, blue pea extract alone and mixed extract was 0.37%, 0.05% and 0.15%, respectively.

Paulo Sergio Calefi[56] **et al. (2007)** have investigated TiO_2 films with the organic dye cyanidin extracted from black mulberry (*Morusnigra*) by the sol-gel method and the film was deposited on glass substrates by dipcoating. Using ultraviolet-visible spectroscopy, observed a shift from the maximum absorption band at 545 nm for the dye's ethanol solution to 595 nm for the film, indicating interaction of the cyanidin with the TiO_2. A SEM analysis confirmed the high density of the films.

Nafarizal Nayan[57] **et al.** reported an over all efficiency of 0.22% for the DSSC in which the photoelectrode (TiO_2) was sensitized with the natural dye obtained from dragon fruits. They have successfully showed that the DSSC using dragon fruit as a dye sensitizer is useful for the preparation of environmental friendly and low-cost DSSC.