ABSTRACT

Nanocrystalline TiO$_2$ thin films have been prepared using titanium isopropoxide precursor by sol-gel dip coating method. The prepared TiO$_2$ thin films were annealed at 400°C, 450°C and 500°C. The structural properties have been studied using x-ray diffraction method, high resolution transmission electron microscope (HRTEM) and Raman spectra. The annealed films have been observed to be nanocrystalline in nature and crystallinity has been found to be improved on annealing. The grain size is found to lie in the range of 11 to 28 nm. The high resolution transmission electron microscope (HRTEM) images showed lattice fringes corresponding to (101) plane of anatase phase of TiO$_2$. The Raman spectra of the nano crystalline TiO$_2$ films have vibrational peaks at 143 cm$^{-1}$, 197 cm$^{-1}$, 396 cm$^{-1}$, 519 cm$^{-1}$ and 638 cm$^{-1}$. The absence of overlapping broad peaks shows that the material is well crystallized, with low number of imperfect sites. These peaks are unambiguously attributed to the anatase phase TiO$_2$.

The optical properties have been studied using transmittance spectra. The optical band gap determined using the transmittance spectra revealed that the band gap decreased from 3.73 to 3.61eV on annealing. The photoluminescence spectra of TiO$_2$ thin films showed a visible broad luminescence band in the region of 387 to 485nm.

TiO$_2$ thin films have been sensitized using natural dye extracts of blue pea, red rose, table rose, red cabbage and leaves of solanum nigrum and eclipta alba. The natural dye sensitized TiO$_2$ has been used as photo electrode in dye sensitized solar cells. The characteristics of the fabricated dye sensitized solar cells have been studied. The extracts have various flavonoids
like cyanidin-3-(sinapoyl) diglucoside-5-glucoside, ternatin, cyanidin-3-glucoside, solasodine, solanine and luteolin-7-O-glycoside. The intensity of light absorption has been enhanced due to the interfacial Ti–O coupling between the dye molecules and the TiO$_2$ molecules. It is generally accepted that the chemical adsorption of the dye takes place due to the condensation of alcoholic-bound protons with the hydroxyl and carboxyl groups present on the surface of the nano structured TiO$_2$ thin films.

The structure of the fabricated sandwich type solar cell is ITO/TiO$_2$/dye/Pt electrode. The solar cell fabricated using TiO$_2$ film sensitized with red cabbage dye extract exhibited a power conversion efficiency of 0.73 % with a short circuit current density ($J_{sc}$) of 4.38 mA/cm$^2$, open circuit voltage ($V_{oc}$) of 0.47 V and fill factor (FF) of 0.36. The solar cell fabricated using TiO$_2$ film sensitized with blue pea dye extract exhibited a power conversion efficiency of 0.67 % with a short circuit current density ($J_{sc}$) of 4.16 mA/cm$^2$, open circuit voltage ($V_{oc}$) of 0.45 V and fill factor (FF) of 0.35.

The solar cell fabricated using TiO$_2$ film sensitized with red rose dye extract exhibited a power conversion efficiency of 0.81 %, with a short circuit current density ($J_{sc}$) of 4.57 mA/cm$^2$, open circuit voltage ($V_{oc}$) of 0.485 V and fill factor (FF) of 0.36. The solar cell fabricated using TiO$_2$ film sensitized with table rose dye extract exhibited a power conversion efficiency of 0.67 % with a short circuit current density ($J_{sc}$) of 4.23 mA/cm$^2$, open circuit voltage ($V_{oc}$) of 0.46 V and fill factor (FF) of 0.35.
The solar cell fabricated using TiO$_2$ film sensitized with solanum nigrum dye extract exhibited a power conversion efficiency of 0.77 % with a short circuit current density ($J_{sc}$) of 4.46 mA/cm$^2$, open circuit voltage ($V_{oc}$) of 0.48 V and fill factor (FF) of 0.36. The solar cell fabricated using TiO$_2$ film sensitized with eclipta alba dye extract exhibited a power conversion efficiency of 0.60 % with a short circuit current density ($J_{sc}$) of 4.04 mA/cm$^2$, open circuit voltage ($V_{oc}$) of 0.43 V and fill factor (FF) of 0.34.

The photo current density–voltage (J–V) characteristics of N719 dye sensitized TiO$_2$ nanocrystalline thin film based solar cell exhibited a short circuit current density ($J_{sc}$) of 8.11 mA/cm$^2$, an open circuit voltage ($V_{oc}$) of 0.584V, a fill factor (FF) of 0.676 and an overall power conversion efficiency ($\eta$) of 3.21%.

Even though the efficiencies obtained for the natural dye sensitized TiO$_2$ solar cells are not comparable with the efficiency of commercial solar cells, the study shows the potential of natural dye to be used as sensitizer, and may be an initiative for more focused research in this direction.