Effect of microwave exposure on the photo anode of DSSC sensitized with natural dye

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Abstract

Dye Sensitized solar cells (DSSC) are also referred to as dye sensitised cells (DSC) or Graetzel cell are the device that converts solar energy in to electricity by the photovoltaic effect. This is the class of advanced cell that mimics the artificial photosynthesis. DSSC fabrication is simple and can be done using readily available low cost materials that are nontoxic, environment friendly and works even under low flux of sunlight. DSSC exhibits good efficiency of ~ 10-14 %. This paper emphasis on the study of enhancing the efficiency of DSSC by exposing the photo anode to microwave frequency. Effect of duration of microwave exposure at 2.6 GHz on energy efficiency of solar cell is studied in detail. The SEM analysis and dye desorption studies of the photo anode confirms an increased solar energy conversion efficiency of the DSSC.

Key words: Dye sensitized solar cells, Microwave, Natural dyes, and SEM analysis.

1. Introduction

DSSC is widely regarded as the most promising third generation of photovoltaic cells which can achieve an efficiency of 15% [1]. Efforts are there to increase the efficiency of these cells by incorporating nanofibers [2], different mesostructured [3] and Nanostructures [4]. BHQ Dang et al [5] studied the effect of incorporation of carbon into TiO2 photoanode by the use of microwave plasma processing which showed up to 72% improvement in the maximum power density (Pd-max) as compared to the TiO2 anode, onto which no carbon is added. Shimizu et al introduced the surface modification for film dye sensitized solar cells (film DSSCs) using atmospheric pressure microplasma as a damage less surface treatment process. The photoconversion efficiency is improved by about 0.3%-0.6% after O2 or Ar micro plasma treatment [6]. Present work studies the
effect of photo voltaic parameters after exposure with microwave frequency at 2.6GHz on the photo anode of DSSC using Alizarin red, a natural dye.

2. Experimental Analysis

2.1. Materials used

For photo anode Fluorine doped tin oxide-coated glass substrate (FTO) having resistance 10Ω/cm², and Degussa P25 TiO₂ Nano powder, Acetone, Methanol, Alizarin Red S is used and for counter electrode using the same glass substrate and Hydroxychloroplatinic acid is used.

2.2. Device Fabrication

Fabrication of photo anode

The conducting glass substrates (FTO) are cleaned and rinsed with deionized water and 2-propanol and then soaked in propanol for 12 h. The FTO substrates are air dried prior to film deposition. The TiO₂ colloidal solution is prepared by grinding the TiO₂ (Degussa P25) powder with 2 ml of distilled water and acetylacetone for 30 min. Finally, 8.0 ml of distilled water and 0.1 ml of Triton X-100 are added with continuous mixing for 10 min, and is coated over the FTO by doctor blade technique. Coated substrate is annealed at 80°C for 1 hr. After cooling, the substrate is sintered at 450°C for 30 min and again cooled [7]. Prepared films are exposed to microwave frequency of 2.6GHz using a monopole antenna. These films are exposed to 5 minutes, 10 minutes and 15 minutes in the near field of the antenna at Amrita-Keysight Advanced Wireless lab. Near fear field exposure ensures that maximum radiation is received by the film. The monopole antenna has its resonance at 2.6GHz with Omni-directional radiation characteristics as shown in figure 1 and figure 2. The gain is ~ 2dBi for the antenna in the operating range. The experimental arrangement for exposing the film with microwave is shown in figure 3. Now the microwave exposed TiO₂ coated FTO glass plates are dipped overnight in 0.3 mM Alizarin red S dye which will acts as the photo anode for DSSC.
Figure 1. Reflection Characteristics of the monopole antenna

Figure 2. Radiation Characteristics of the monopole antenna
Preparation of Electrolyte

For the preparation of Lithium Iodide (LiI) electrolyte, 100 ml of acetonitrile is added into a beaker. Then 15.9672 mg of 1 butyl 3 methyl imidazolium iodide, 1.3385 g of Lithium Iodide, 1.1816 g of Guanidium thiocyanate, 1.269 g of Iodine (I₂) and 6.7605 g of 4-ter butyl pyridine are added and sonnicated for 15 min [8].

Fabrication of Counter electrode

For the platinum cathode, Chloroplatinic acid is spin coated over cleaned FTO glass plate. After drying, the film is annealed for 1hr at 80°C in the oven. Further the film is sintered for 30 minutes at 150°C in electronic muffle furnace.

Assembling of the Device

A sandwich like structure is made with photo anode and platinum cathode at the two ends and the liquid electrolyte at the centre. This device characterized.

3. Result and Discussion

3.1. Thickness of the electrode

The thickness of the photo electrodes are studied using ellipsometer. In null ellipsometry, the compensator is kept at 45° and changed Analyser and Polarizer angle to obtain minimum
intensity. Analyser (A1) and Polarizer (P1) is rotated from rotate from 0˚ to 90˚we get null intensity at a particular angle (say, P1=41 & A1=8). Similarly, rotate Polarizer (P2) from 270˚ to 360˚ and Analyser (A2) from 90˚ to 180˚ we obtain null intensity. This data is used to calculate the refractive index of the materials (TiO$_2$ specified as n$_1$ and air specified as n$_2$). The thickness of the different electrodes are calculated and tabulated in the Table 1. All the photo electrodes fabricated is found to have nearly equal thickness. These electrodes are used for analysing the effect of microwave exposure.

**Table 1.** Thickness studies of various photoanodes using ellipsometer.

| Photoanodes          | P1 | A1 | P2 | A2 | n1  | n2  | Thickness (nm) |
|----------------------|----|----|----|----|-----|-----|----------------|
| **Without microwave exposure** | 41 | 8  | 297| 143| 2.62| 1.00| 104            |
| **With 5 minutes microwave exposure** | 41 | 8  | 297| 143| 2.62| 1.43| 104            |
| **With 10 Minutes microwave exposure** | 44 | 3  | 306| 142| 2.6 | 1.6 | 108            |
| **With 15 Minutes microwave exposure** | 51 | 3  | 317| 148| 2.6 | 1.6 | 112            |

3.2. **SEM analysis of the photoanode**

Using Scanning Electron Microscopy (SEM) performance of the photo electrode is analysed. As mentioned in Table 1, four types of devices with different exposure time of microwave are studied. The SEM images of these four types of photo anodes with microwave exposure at 2.6GHz is presented in figures 4,5,6 and 7. From images, maximum growth of TiO$_2$ is observed for the sample exposed for 10 minutes.
Figure 4. SEM images of photo anode without microwave exposure

Figure 5. SEM images of photo anodes after 5 minutes microwave exposure
3.3. Current- Voltage Characteristics

The J-V characteristics of the fabricated devices obtained from Keithly IV meter are shown in figure 8. The short circuit current ($J_{SC}$) and Fill Factor are found to be influenced by microwave exposure even through the open circuit voltage ($V_{OC}$) remain same for the device with and without microwave exposure. The efficiency is also affected by the microwave exposure. A maximum enhancement in performance is observed for the device that has been exposed to microwaves for 10 minutes. The absorption spectra are also implies that the high absorption is achieved, when exposed to 10 minutes of microwave frequency which leads to higher efficiency of the device.
Figure 8. V-I Characteristics of the fabricated device

Table 2. Photovoltaic parameters of the assembled device.

| Device                      | J_{SC} (A/cm^2) | V_{OC} (V) | FF   | Efficiency(%) |
|-----------------------------|-----------------|------------|------|---------------|
| Without microwave exposure  | 0.000249        | 0.76       | 0.614| 0.116         |
| 5 minutes microwave exposure| 0.000252        | 0.76       | 0.668| 0.127         |
| 10 minutes microwave exposure| 0.000346      | 0.76       | 0.595| 0.144         |
| 15 minutes microwave exposure| 0.000259      | 0.76       | 0.635| 0.124         |
3.4. Absorption spectra of desorbed dyes

The reason for the high efficiency of the device exposed to 10 minutes of microwave exposure can be understood by carrying out dye desorption studies. The dye sensitized film is dipped in 5 ml, 1 molar NaOH solution for 1hr, and after 1hr the dye got desorbed in the solution.

![Absorption spectra of desorbed dyes](image)

Figure 9. Absorption spectra of the desorbed dyes

The absorption spectra of the desorbed dye are shown in figure 9. From the absorption spectra of desorbed dye it is clear that high absorption is obtained for the photo anode exposed to microwaves for 10 minutes. This implies that when the photo anode is exposed with microwave of frequency of 2.6GHz for 10 minutes, maximum dye is adsorbed and thereby increasing the efficiency of the device.

4. Conclusion

This paper demonstrates a method to improve the efficiency of dye sensitized solar cell by exposing the photo anode to microwave radiation. A fixed frequency of 2.6GHz is exposed to same type of photo anode for three different time intervals to compute the best exposure time at the frequency for maximum porosity. The effect of microwave radiation exposure is found to produce enhancement in the electrode characteristics as observed in SEM analysis and current voltage characteristics. The absorption of desorbed dye once again authenticates microwave exposure as a good tool for enhancing the efficiency and absorption of dye. It is observed that the 10minutes microwave exposed photo anode assembled device have got the higher efficiency of 0.144%. This higher efficiency is due to the
higher dye absorption. The whole device has a constant open circuit voltage as 0.76V and short circuit current changed with different exposure time of microwave radiation. Further work has to be done to understand the chemistry behind this increase in efficiency. Future work also holds in finding best suited frequency for further improvement in properties.

Acknowledgment
Dr. K.S. Sreelatha and I. Jinchu are here by acknowledging KSCSTE – SRS Project (004/SRSPS/2014/CSTE) for giving financial support to this work.

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