Influence of post deposition Plasma surface Treatments of TiO_2 Electrodes with respect to DSSC Cell performance

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1. Introduction

Dye-sensitized solar cells (DSSC) based on nanocrystalline TiO_2 were invented by O'Regan and Gratzel in 1991. DSSC are third generation, thin film solar cells. They are photoelectrochemical devices whose operating principle closely resembles the photosynthesis reaction of green plants. There is increasing interest in dye-sensitized solar cells (DSSCs) due to their relatively low cost and ease of manufacture. However, the performance of the DSSC solar cell in many cases is limited by the presence of oxygen vacancy (- Ti^{3+} defects site) along with surface contamination in the TiO_2 electrode. To improve current density and the overall efficiency of the DSSCs surface contamination and surface defects need to be reduced. This study investigated the influence of plasma surface treatments of nanocrystalline TiO_2 films on photovoltaic performance of the corresponding DSSCs. Two surface treatments, PlasmaTreat™ an atmospheric air plasma system and a Microwave (MW) plasma system were used for the first time to study the effect of plasma surface treatment of TiO_2 on DSSC performance.

2. Experimental

The TiO_2 layer was deposited and sintered by SolarPrint™. The plasma surface treatments of TiO_2 layer deposited onto a conducting (FTO) glass substrate were carried out using an air plasma jet system called PlasmaTreat™ and an oxygen plasma using a circumferential antennaplasma (CAP) microwave system.. For the PlasmaTreat™ system, percentage plasma cycle time (PCT) was varied from 20 – 90 and the overall treatment time (from 15 to 45 seconds) was varied for the MW plasma system. The morphological and crystallographic properties of the sintered TiO_2 layer both before and after plasma treatment were investigated using SEM, optical profilometry and X-ray diffraction techniques. Subsequent to the TiO_2 plasma surface treatment, a ruthenium based dye (N719) was applied to the coating on the plasma surface treated coatings. The level of dye adsorption on the treated and non-treated TiO_2 coatings were assessed using UV-Vis spectroscopy. This analysis was performed by desorbing the dye from a fixed area of TiO_2 coated glass in a buffer alkaline solution.

3. Results and Discussion

The performance of each cell was assessed using IV, IPCE and UV-Vis dye adsorption measurement. It can be seen in Figure 1 that the highest efficiency was recorded for TiO_2 samples treated with in the PlasmaTreat™ system using 50% PCT and in the MW system treated for 30 seconds. Compared to control samples, the PlasmaTreat system treated samples using 50% PCT exhibited an

increase of 5.9% Voc, 8.7% increase in Jsc, 19% increase in IPCE and a 19.3% increase in efficiency. Likewise a 30 sec MW plasma treated sample showed a 5.9% increase in Voc, 19.8% increase in Jsc, 30% increase in IPCE and a 22.9% increase in efficiency when compared to control samples.

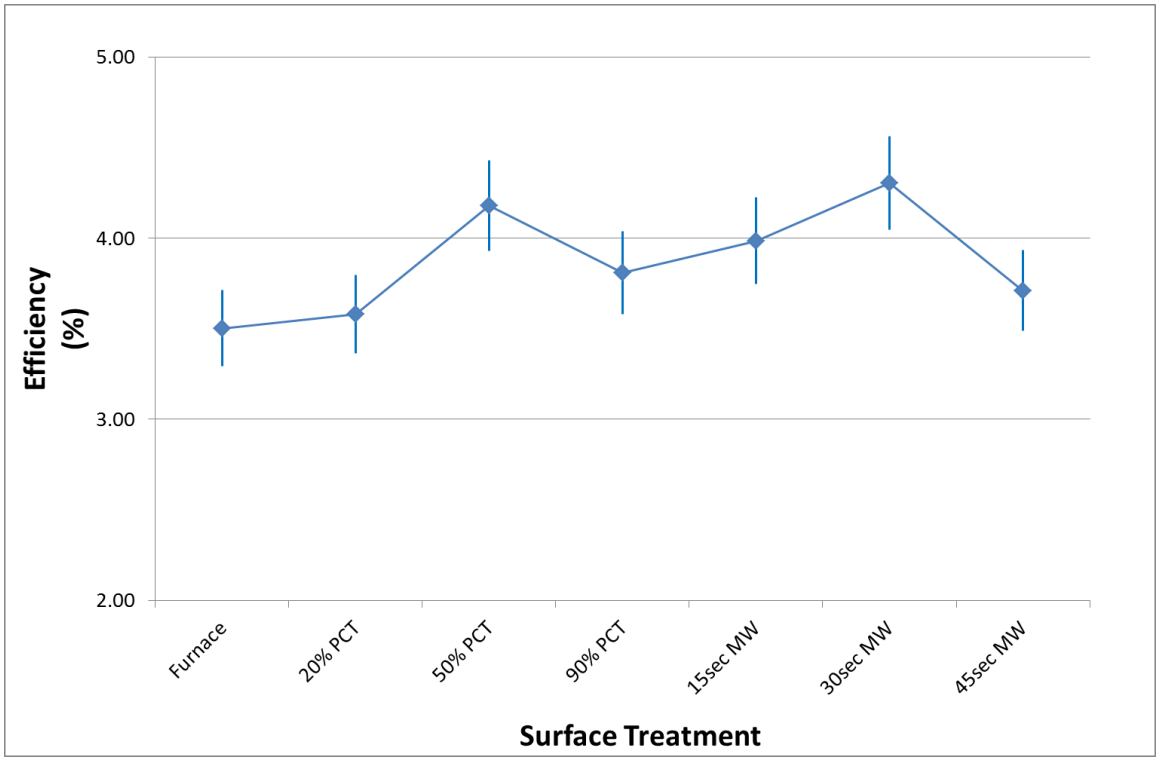

Figure 1 Efficiency of corresponding DSSC cells after various surface treatments

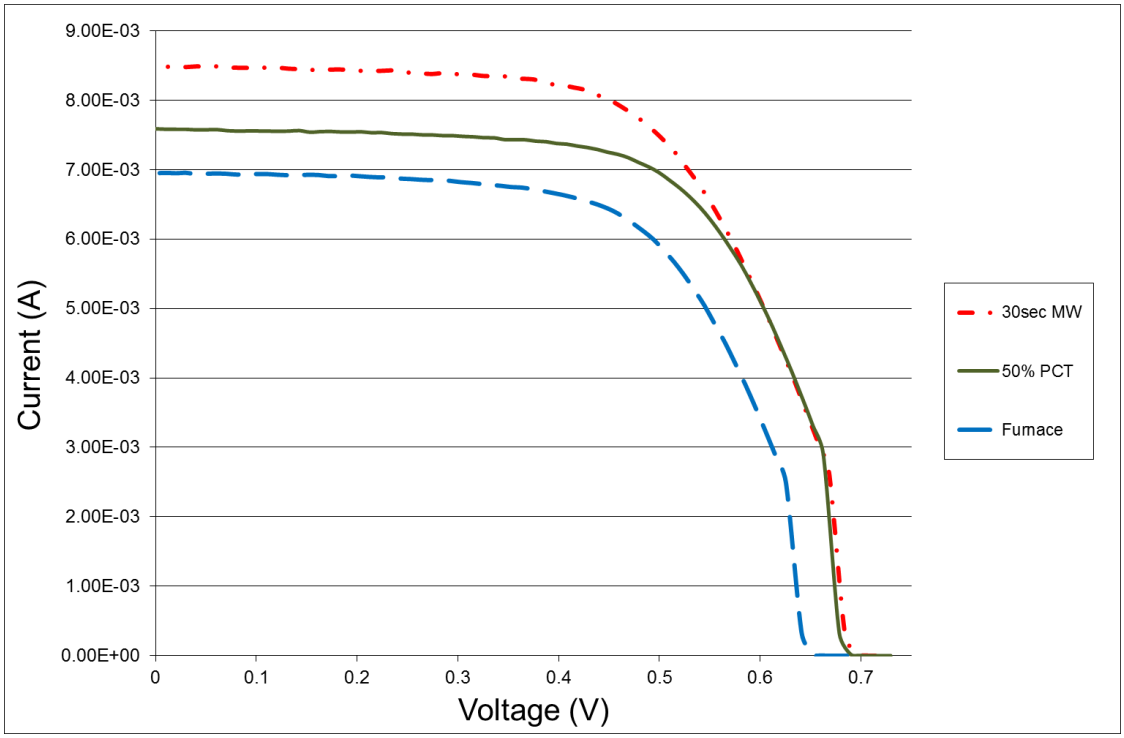

Figure 2 Current/Voltage curves of two best performing samples as compared to furnace treated samples

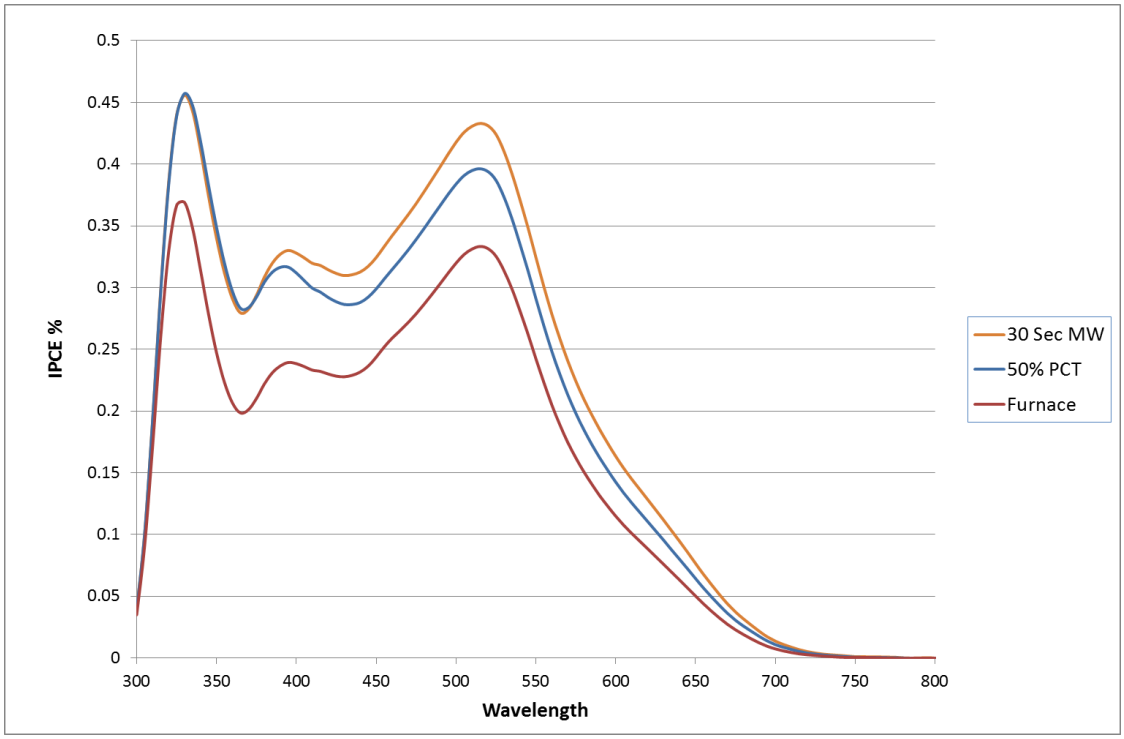

Figure 3 IPCE measurements of two best performing samples as compared to furnace treated samples

4. Conclusion

This study demonstrated that MW and PlasmaTreat™ processes could be used as a means of post deposition plasma surface treatment of TiO_2 electrode for improving overall DSSC cell efficiency. A 22.9% and 19.3% improvement of efficiency was observed for MW and PlasmaTreat™ samples respectively. A possible explanation for the enhanced level of efficiency after plasma activation is the increased level of dye adsorption as confirmed by UV-Vis spectroscopy, reduction of oxygen deficiency site and removal of aqueous and organic contaminants from the TiO_2 surface. Detailed characterization studies of the plasma treated TiO_2 electrodes are currently ongoing to find out the mechanism behind the increase in DSSC cell efficiency.