Role of Optics in Optimizing Photoelectrochemical Activity of Semiconductor Anodes

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***Abstract*—Absorption of light and resulting photoelectrochemical efficiency of photoanodes can be increased by application of appropriate optical focusing and lensing methods. Control experiments were performed with titania photoanodes and a halogen lamp as light source. Short pass and long pass optical filters (Melles-Griot SPF-400 and LPF-400) were used to study the spectrum wavelength dependence on photoelectrochemical efficiency of photoanodes. Short pass and long pass optical filters removed visible and ultraviolet portions of the light respectively. A Fresnel lens was used to focus the light impacting the TiO2 photoanodes. The application of Fresnel lens increased the photocurrent by approximately 70%. The irradiance of the light incident in each method was measured and correlated with photocurrent generated.**

I. Introduction

CURRENT methods of generating hydrogen using solar energy are becoming more accepted as possible candidates for large scale hydrogen production. The main concern is the efficiency of the conversion and the scalability of the system. Using plasma treated TiO_2 photoanodes has been shown as a viable process for creating a photocurrent capable of producing hydrogen in this photoelectrochemical (PEC) process[1]. By applying methods used for solar cells to improve efficiency by concentrating light through systems of lenses[2], this photoelectrochemical process can be made more efficient, and create a larger photocurrent. Due to differences in photoconversion of TiO_2 over visible and ultra-violet light[1], long and short pass filters were used to block each ultra-violet and visible light, showing the contributions of each wavelength range in the PEC process.

II. Setup and Methods

The experimental system consists of a glass cell containing the TiO_2 photoanode, Pt cathode and a reference electrode (Ag/ AgCl) in an electrolyte (KOH). A halogen lamp was used as a light source in all the experiments and photocurrent was measured using a potentiostat (Princeton Applied Research Potentiostat/Galvanostat Model 283). Tests were performed each with a control using no light source, the light source and no other optical devices, light source with a Fresnel lens, light source and a long pass optical filter, light source and short pass optical filter, and combinations of the Fresnel lens, long pass and short pass optical filters.

The first experiment performed with no light source and external light blocked from the PEC cell was used as control for the later experiments. This was followed by a test using only the light source incident on the photoanode, then a trial using a Fresnel lens with the light source. The next trials were performed with the light source and a long pass filter, and light source with short pass filter. Final trials were completed using the light source with Fresnel lens and a long pass filter, and then Fresnel lens and a short pass filter. In each test the same TiO_2 photoanode was used.

III. Results and Discussion

The data shown in fig. 1 shows the relation of the control dark current to the trials with the light source and the Fresnel lens. In this trial we were able to see a signifiacnt increase in photocurrent density due to the use of the Fresnel lens. The maximum value of the photocurrent density using light source only was 0.503 mA/cm^3. With the application of Fresnel lens, the photocurrent density increased to 0.792 mA/cm^3.

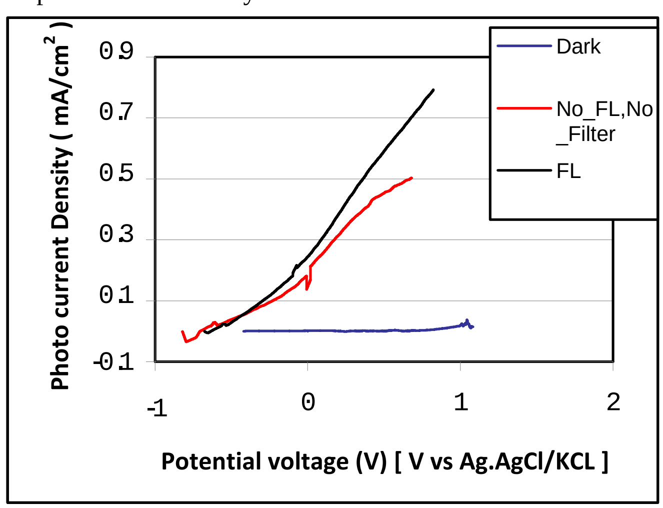

Fig. 1. Photocurrent density of TiO_2 photoanode. The plot shows dark current, current with light source, and with light source and Fresnel Lens.

Following this test, the long and short pass optical filters were used with the light source. The data from these tests is shown in fig. 2. From fig. 2, we can see contributions from each visible and ultra-violet light as the short pass filter will block visible light and allow ultra-violet through, and the long pass will block ultra-violet light. Total photocurrent for the trial with the short pass filter was 0.184 mA/cm^2 and 0.136 mA/cm^2 for the long pass filter. It is shown that the ultra-violet portion of the spectrum contributes more to the total photocurrent, as with TiO_2.

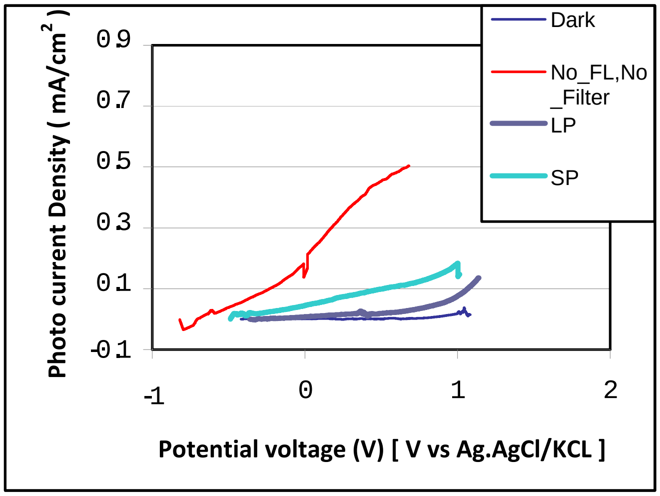

Fig. 2. Graph showing data comparing no light photocurrent with only light source, light source and long pass filter, and light source and short pass filter.

The Fresnel lens was then used with the long pass and short pass filters to show individual increases for each portion with increased light intensity. Data from this is shown in fig. 3. The results from this test show an increase in photocurrent in both the long pass and short pass filter when using the Fresnel lens. The maximum current density values for the Fresnel lens with the short pass filter was 0.281 mA/cm^3 and for the Fresnel lens with long pass filter 0.257 mA/cm^3. This shows the same results as without the Fresnel lens, with the ultra-violet portion contributing more to the total photocurrent.

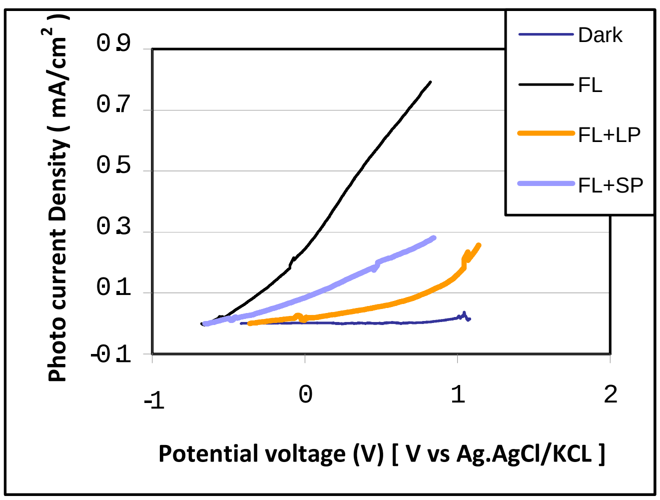

Fig.3. Graph comparing no light photocurrent with light source and Fresnel lens, and long and short pass filters with the Fresnel lens.

The values of the short and long pass filters have cutoff wavelengths at around 400 nm. Although this is the general region of ultra-violet and visible light, the filters do not have a sharp curve for transmittance at this region, blocking some light in the near UV range in the case of the short-pass filter, and in the long pass filter, blocking some light above the 400 nm range. This does account for discrepancies in the total photocurrent from both portions of the spectrum when viewed separately.

It can be concluded that the use of a Fresnel lens significantly increased the photocurrent density of the sample in both visible and ultra-violet portions of the spectrum. Further work is required to optimize the optics for harnessing solar energy in photoelectrochemical hydrogen production

Acknowledgement

The financial support for this study was provided by US Department of Energy Grant (DE-FG36-06GO86054) and Arkansas Science and Technology.

References

[1] R. Sharma, “Enhancement of the photoelectrochemical conversion efficiency of nanotubular TiO_2 photoanodes using nitrogen plasma assisted surface modification,” *Nanotechnology, Volume 20,2009*

[2] A. Rabl, “Comparison of Solar Concentrators.” *Sol. Energy*, Journal Vol. 18.2, Jan. 1976