

Low Temperature Synthesis of Nanocrystalline Anatase Films for use in Dye Sensitized Solar Cells

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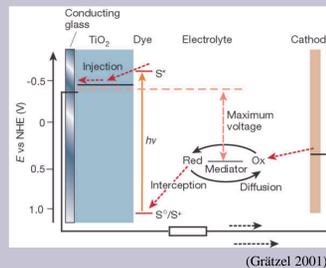
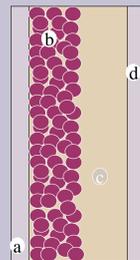
Introduction and Background

Dye Sensitized Solar Cell

The dye sensitized solar cell was first introduced in 1991 by Grätzel et al. This type of cell is fundamentally different from traditional solar cells in that it separates charge generation and charge transport. These functions are performed in the same region of material in traditional solar cells, resulting in a major obstacle to cost reduction. In the dye cell, recombination is not such a concern as it is in traditional solar cells, so material restrictions (e.g. high purity and few grain boundaries) are relaxed.

The basic components of the dye sensitized solar cell

- transparent conducting electrode
- porous, nanocrystalline, wide bandgap semiconductor with a monolayer of sensitizing dye adsorbed to surface
- electrolyte
- counter electrode



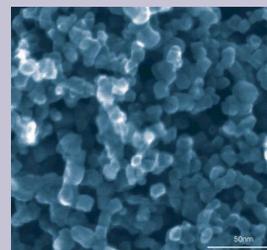
The basic way that the dye cell works is indicated schematically to the left. The organometallic dye absorbs a photon, which excites an electron into a higher energy state. The excited electron is rapidly injected into the wide bandgap semiconductor where it percolates through to the anode.

Anatase (TiO₂) Film

A high resolution SEM of a good microstructure for the dye sensitized solar cell is shown here.

The ideal semiconductor for this type of cell includes the following characteristics:

- Nanocrystalline (very high surface area)
- High porosity (average pore diameter ~20nm)
- Good connectivity between crystallites
- Good connectivity between film and electrode



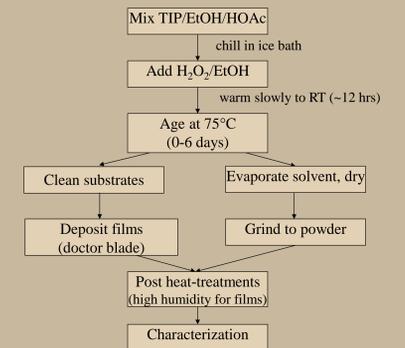
(Grätzel 2001)

Project Objectives

The primary objective of this project is to develop and investigate a low temperature route to anatase (TiO₂) films that would be suitable for use in the dye sensitized solar cell. Ideally, the processing temperature should be low enough to allow deposition on polymer substrates. Properties desirable in the anatase film include high surface area, high porosity, and good electrical connection between crystalline particles and between the film and the electrode.

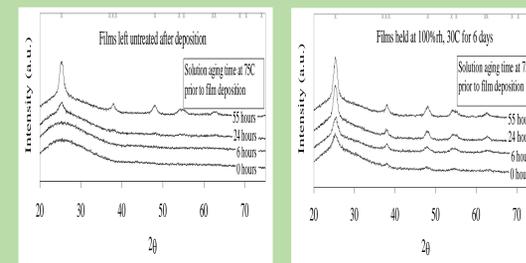
Experimental Procedure

Films were made using a sol-gel process with titanium isopropoxide (TIP), ethanol, acetic acid, and hydrogen peroxide. They were deposited through a doctor blade technique at various stages after gelation had been reached. The chemical system used to make the starting solutions in this work is based on a paper by Uekawa et al (2002).



Experimental Results

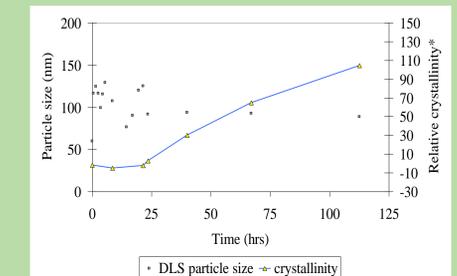
Comparison of untreated and high-humidity films



Dynamic light scattering (DLS) was used to evaluate particle size in solution during the crystallization process. The particles rapidly increased to roughly 100nm and remained there throughout crystallization. No notable changes were seen during this time, although there appears to be less scatter in the data after crystallization has occurred.

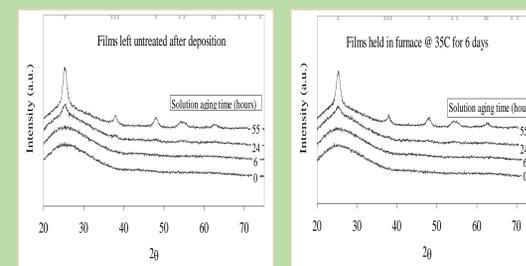
*Relative crystallinity is calculated from XRD (for comparison only) from the height and width of the (101) peak, compared to the same numbers for an amorphous film (=0) and a film fired at 500°C for one hour (=100).

Particle size and crystallinity during solution aging



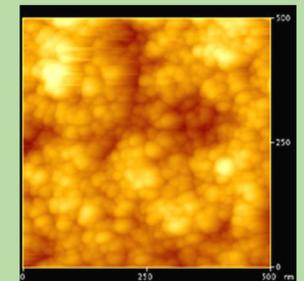
Aging of deposited films at moderate temperature (30°C) and very high humidity (~100%rh) results in increased crystallinity, as can be seen in these x-ray diffraction patterns. Even the previously amorphous films (0 and 6hrs) show small crystalline peaks after treatment.

Comparison of untreated and low-humidity films



Films show no increase in crystallinity when heated at mild temperatures without high humidity. The XRD plots above are for films deposited at various solution aging times. Films fired at 35°C for 6 days showed no change in crystallinity compared to films left in ambient conditions.

At right is an AFM image from an anatase film aged in a high humidity environment. Particles appear mostly spherical with average size roughly 20-40nm. (Image is 500nm in x-y directions, z scale bar on right of image 200nm.)



Conclusions

- The method described above is a viable means of obtaining nanocrystalline anatase films at low temperature.
- The anatase films crystallize after deposition at low temperature only in a high humidity environment.
- Particle size in solution remains constant (~100nm) during the crystallization process

Acknowledgements

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References

- Grätzel, M. (2001). "Photoelectrochemical cells." *Nature* **414**: 338-344.
 Uekawa, N., J. Kajiwara, et al. (2002). "Low Temperature Synthesis and Characterization of Porous Anatase TiO₂ Nanoparticles." *Journal of Colloid and Interface Science* **250**: 285-290.