3D Counter Electrodes For Dye Sensitized Solar Cells With Improved Performance

G. Syrrokostas[1], K. Govatsi[1], G. Leftheriotis[2] and S.N. Yannopoulos[1]

1.Foundation for Research and Technology Hellas, Institute of Chemical Engineering Sciences (FORTH/ICE-HT), Rio-Patras, P.O. Box 1414, GR-26504, Greece
2. Department of Physics, University of Patras, GR-26504, Rio-Patras, Greece

email: gesirrokos@iceht.forth.gr, sny@iceht.forth.gr

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Introduction

One of the main components of a dye sensitized solar cell (DSSC) is the **platinized counter electrode (CE)**. The role of the counter electrode is to catalyze the reduction of triiodide ions:

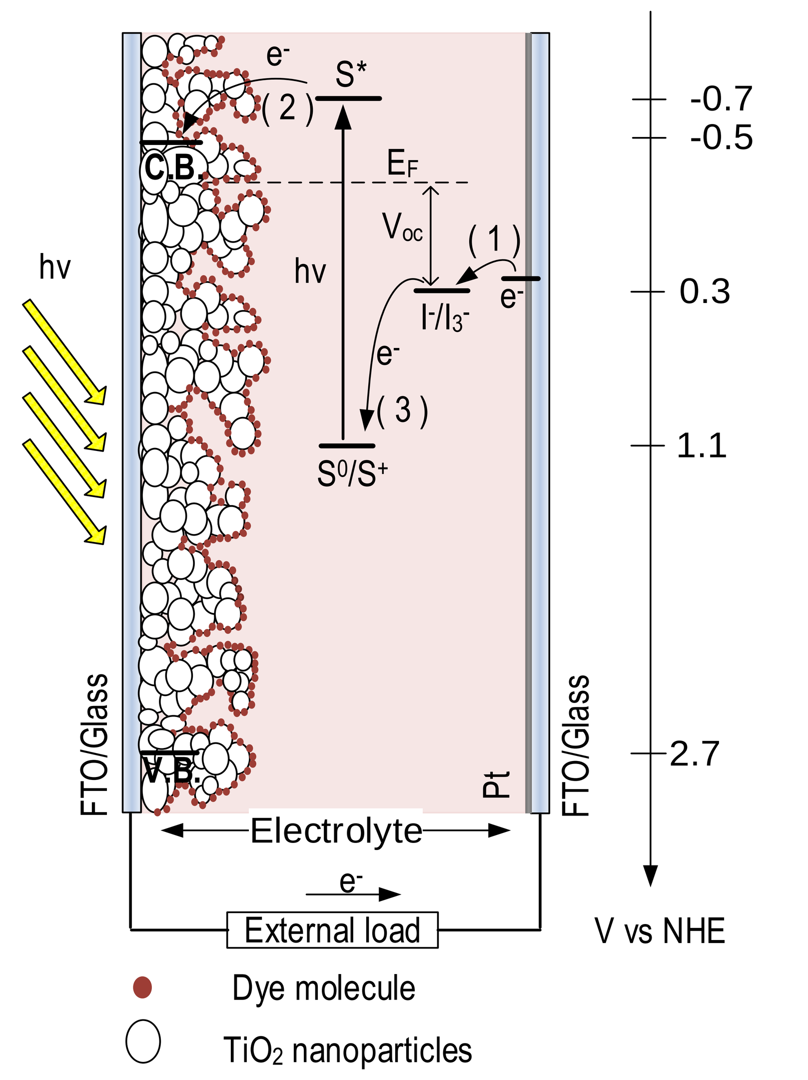
$$I_3^- + 2e^- \xrightarrow{(Pt)} 3I^- \quad \textbf{(reaction 1)}$$

Triiodide ions are produced when the oxidized dye [(due to electron donation to CB of TiO_2 **(reaction 2)]** is reduced by iodide ions according to the reaction:

$$2S^+ + 3I^- \Rightarrow 2S^o + I_3^- \quad \textbf{(reaction 3)}$$

Although these electrodes present very good electrocatalytic properties, high cost and stability issues [1] have to be addressed before implementation in practical applications. By **increment of the surface area where the deposition of Pt takes place**, one can **achieve better utilization of the expensive Pt**. Other materials (carbon based, conductive polymers, transition metal compounds and hybrids) can substitute Pt, but in most cases their stability remains an issue. For these reasons **ZnO NWs arrays with high surface area were used as a 3D scaffold for the evaporation of Pt**.

Working principle of a DSSC



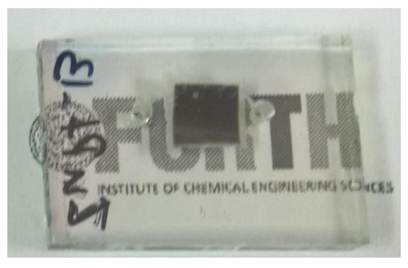
Methodology

Three kinds of Pt CEs were prepared and evaluated using cyclic voltammetry.

- **By electrodeposition,** using as aqueous solution of 0.002M H_2PtCl_6, at a constant voltage of -400 mV for 200s.

- **By evaporation of Pt wire on conductive glass substrate (SnO_2:F) or else FTO**

- **By evaporation of Pt wire on ZnO NWs arrays [2]**



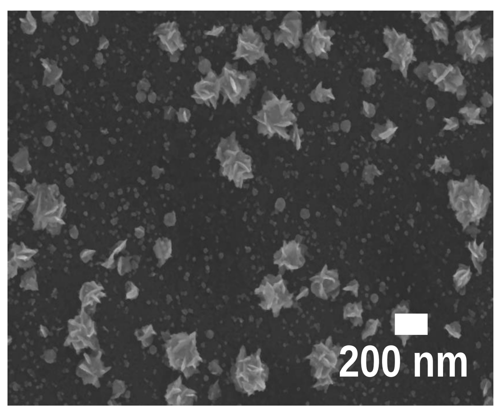
Then the corresponding devices were prepared and J-V curves were recorded, using a solar simulator, fitted with an AM 1.5G filter [3].

Results

A) Morphology

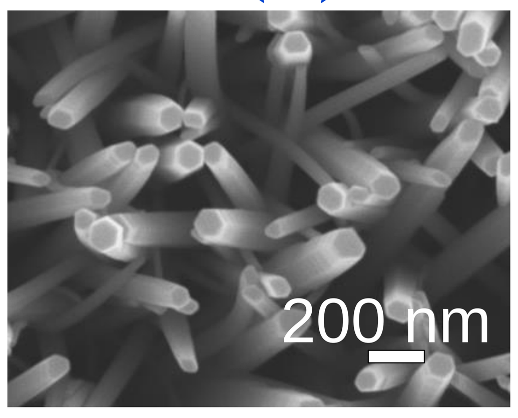
Scanning microscope (SEM) images of two CEs prepared by electrodeposition on FTO/glass substrate and by evaporation on ZnO NWs arrays.

Electrodeposition



Distinct nanoparticles covering only a part of the substrate

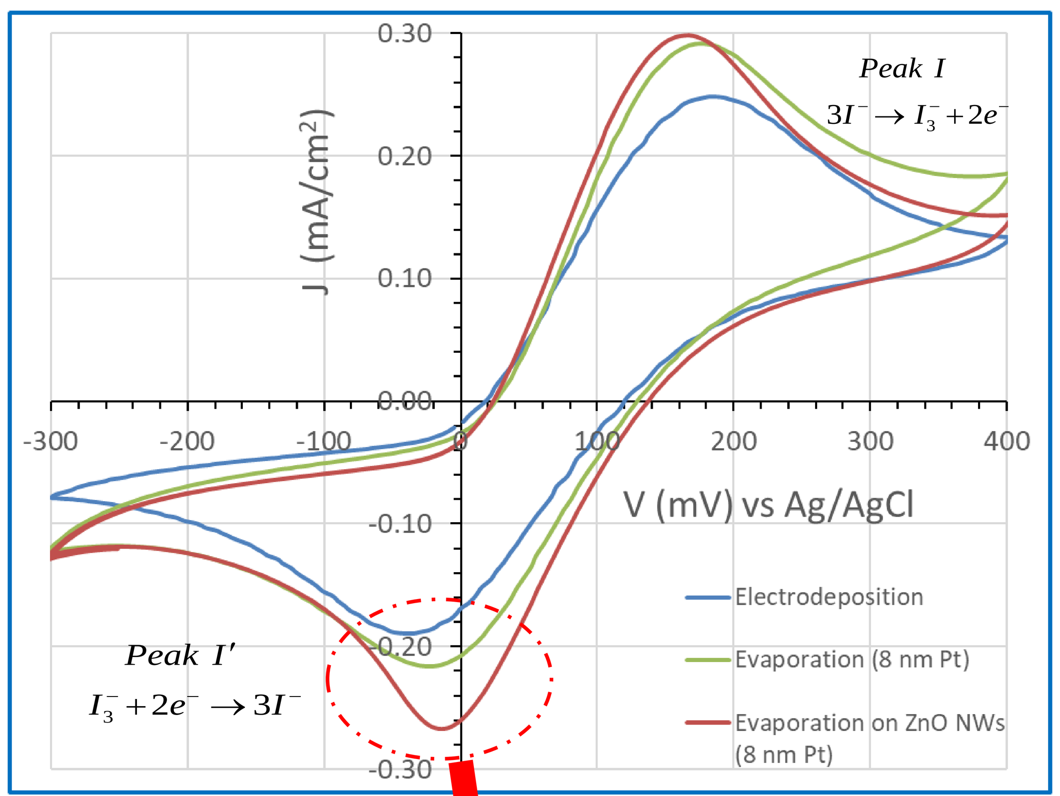
Evaporation of Pt on ZnO NWs (3D)



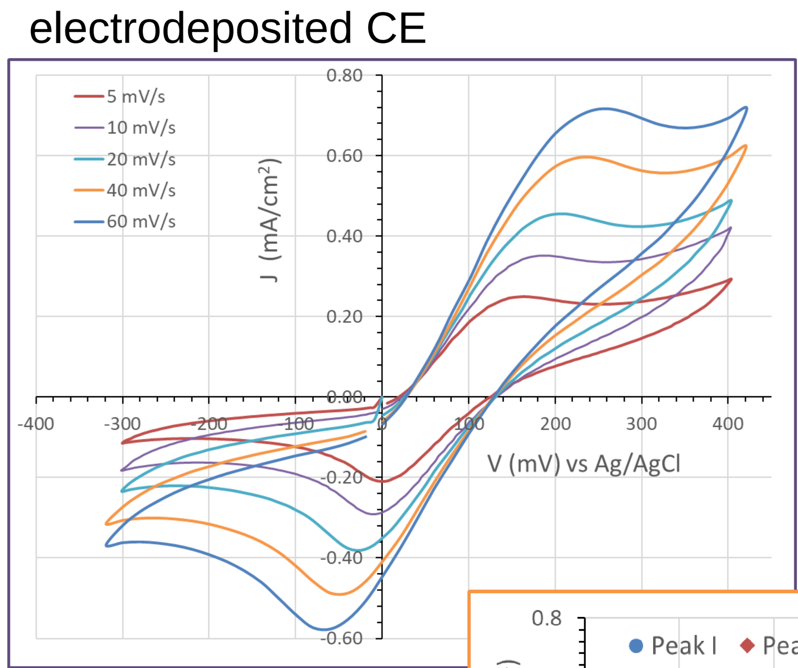
Uniform coverage of the NWs with a thin Pt layer

B) Cyclic Voltammograms

Typical cyclic voltammograms of the prepared CEs in an electrolyte containing the iodide/triiodide redox couple (10 mM KI, 1 mM I_2, 0.1 M $LiClO_4$ in propylene carbonate)



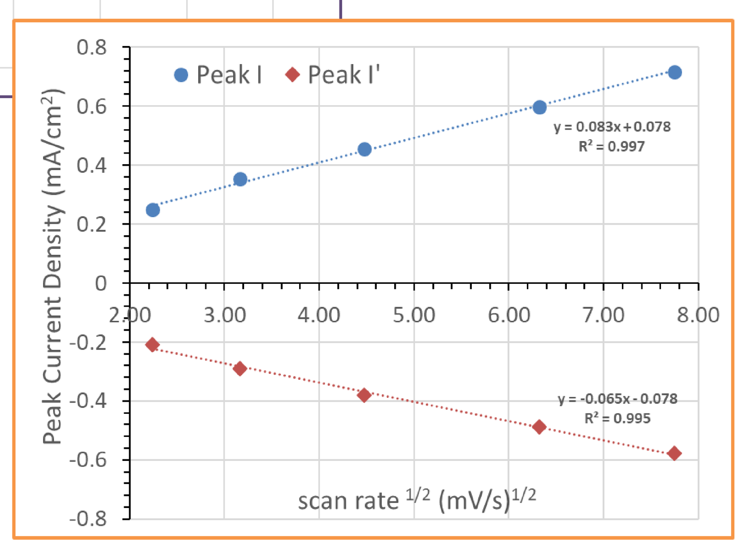
25% and 40% increment in the peak current density for the 3D CE compared to the evaporated and the electrodeposited CE



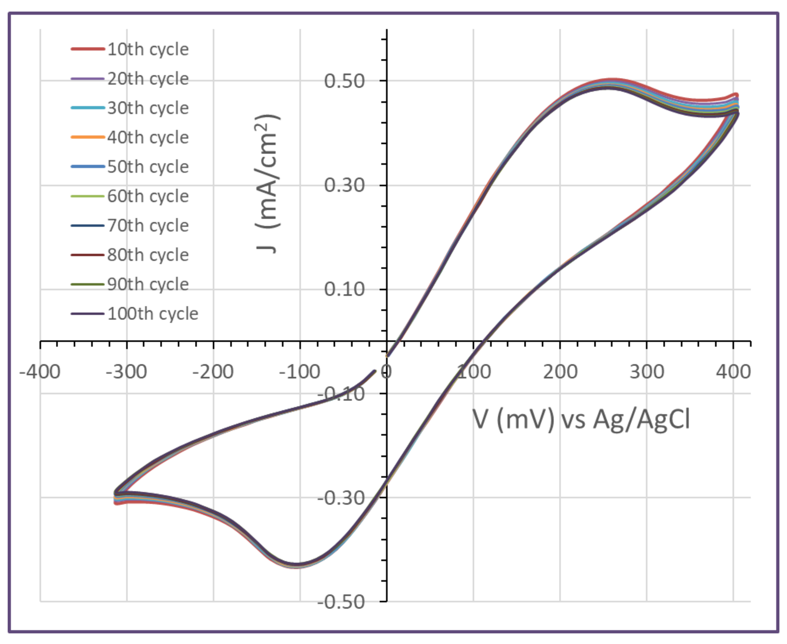
CV curves at different scan rates for a 3D CE

The linear relation shows:

a) Diffusion controlled reactions [4]
b) Efficient depletion of the electroactive species even at high scan rates [4]



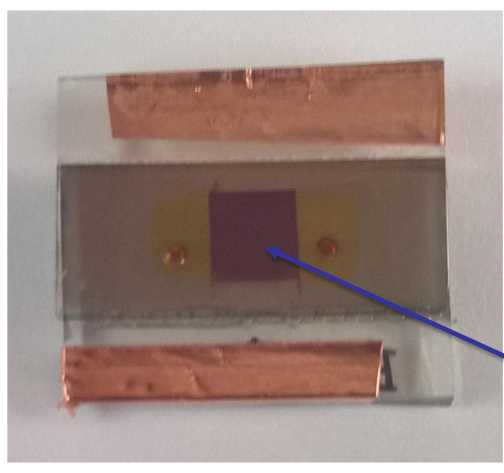
C) Stability under successive cycling



No degradation was observed, even after ***100 successive cycles*** *(scan rate:30 mV/s)*

D) Dye Sensitized Solar Cells

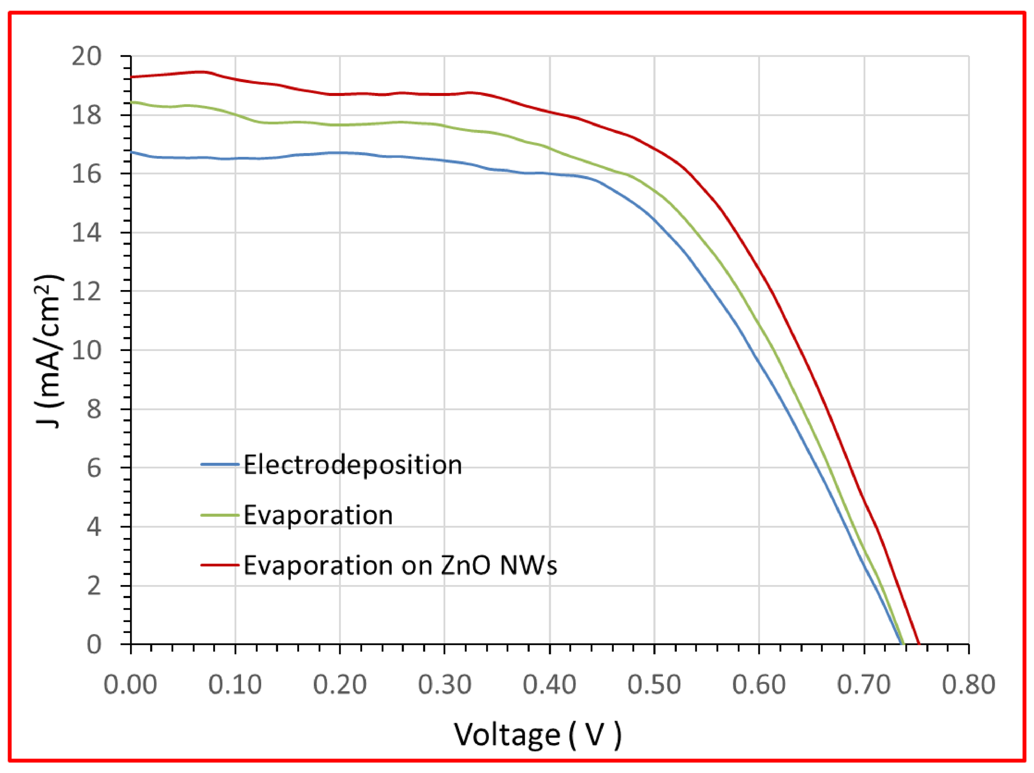
A typical device



Anode: TiO_2 nanoparticles
Dye: N719
Electrolyte: HPE (Dyesol)
Cathode: Pt (electrodeposition)

Dye sensitized TiO_2 nanoparticles

J-V curves for devices using the three kinds of CEs



Photovoltaic properties of DSSCs using the three kinds of CEs

Counter electrode	Voc (V)	Jsc (mA/cm²)	FF	Efficiency %
Electrodeposition	0.739	16.8	0.58	7.2
Evaporation	0.74	18.4	0.57	7.8
Evaporation on ZnO NWs	0.756	19.3	0.59	8.6

10.2% and 19.5% increment for the 3D CE compared to the evaporated and the electrodeposited CEs

Conclusions

- ZnO NWs arrays can be used as a 3D scaffold for the evaporation of Pt to prepare CEs with high surface area, for DSSCs.
- The prepared 3D electrodes exhibited **a 25% and 40% increment in peak current density for triiodide reduction**, compared to evaporated and electrodeposited CEs.
- The electrocatalytic properties were studied by CV experiments at different scan rates and under successive cycling, showing no degradation even after 100 successives cycles.
- The resulting devices showed a **10.2% and 19.5% increment in efficiency**, compared to evaporated and electrodeposited CEs.
- The improvement in the properties of the 3D CEs is attributed to the enhancement in the surface area for the deposition of Pt, due to the presence of ZnO NWs arrays.

References

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Acknowledgments

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