

SOLAR CELL BASED ON CuInS₂ AND TiO₂ NANOCRYSTALS

T. Nyari^a, Sz. Papp^b, L. Körösi^b, R. Bănică^{a,c}, M. Paulescu^d, I. Hrianca^d, I. Dékány^b

^a*INCEMC—Condensed Matter Res. Inst. Timisoara, Str. Plautius Andronescu 1, 300224 Timisoara, Romania*

^b*Department of Colloid Chemistry, University of Szeged, Aradi Vertanuk tere 1, 6720 Szeged, Hungary*

^c*Faculty of Ind. Chem. and Env. Eng, Politehnica Univ. Timisoara, P. Victoriei 2, 300006 Timisoara, Romania*

^d*Faculty of Physics, West University of Timisoara, Bd. V. Parvan 4, 300223 Timisoara, Romania*

Abstract

In this paper a completely inorganic nanostructured 3D solar cell based on hydrothermally obtained CuInS₂ nanocrystals and TiO₂ nanocrystals is presented. I-V measurements under artificial and direct sun light illumination has been used to demonstrate the functionality of the device as a photovoltaic element.

Keywords: solar cells, CuInS₂, bulk heterojunction

1. Introduction

Solar cells based on heterogeneous nanostructures are in the top of present solar energy conversion research [1, 2]. Due to its direct band gap near 1.5 eV, high absorption coefficient ($\alpha \sim 10^5 \text{ cm}^{-1}$) and photoconductivity [3], CuInS₂ is one of the most suitable absorbers for thin film solar cells. There are some recent reports on CuInS₂ nanocrystals use in organic or inorganic matrices for developing cheap solar cells [4, 5]. In our previous research [6, 7], hydrothermal techniques for the one step synthesis and crystallization of CuInS₂ nanocrystals has been developed. In this work, a completely inorganic nanostructured 3D solar cell based on hydrothermally obtained CuInS₂ nanocrystals and TiO₂ nanocrystals has been constructed aiming to demonstrate the functionality of the device as a photovoltaic element.

2. Solar cell construction

The schematic structure of the constructed solar cell is presented in figure 1.

Glass support preparation

Glass plates covered with ITO (indium thin oxide) transparent conductor were used as support and contacts. Before utilization, the supports were cleaned by repeated sonication in ethanol and acetone with an ultrasonic cleaning bath, then left to dry at room temperature.

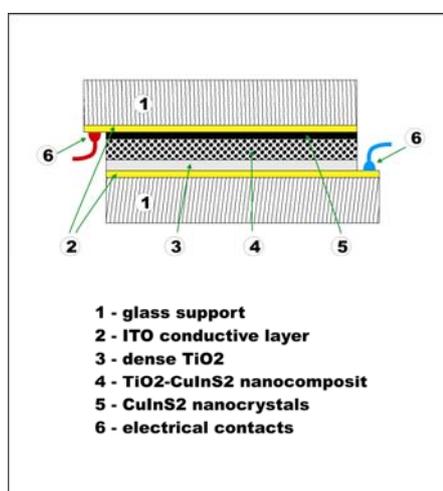


Fig. 1 Schematic structure of the solar cell

Dens TiO₂ film preparation

First, a paste comprising TiO₂ nanocrystals (Degussa P25), distilled water and acetic acid by mixing the components in an agate mortar has been prepared. A piece of ITO covered glass support was protected on two sides with adhesive tape (for contacts) and the paste was deposited on the free surface by doctor blading. After drying in air, the TiO₂ film was sintered for densification in air at 450°C for 50 minutes in a furnace. The temperature-time diagram of sintering process is presented in figure 2.

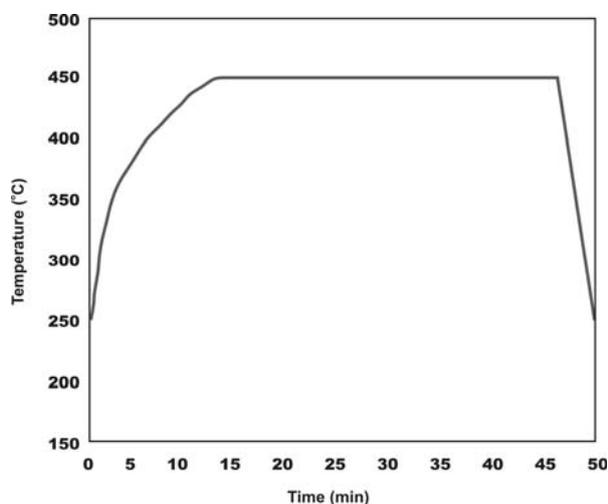


Fig. 2 Temperature-time diagram of TiO₂ sintering process

CuInS₂/TiO₂ nanocomposite film preparation

A nanocomposite paste has been prepared by mixing suitable amounts of TiO₂ nanocrystals (Degussa P25), CuInS₂ nanocrystals (synthesized previously by a hydrothermal method) and solvent. Then the nanocomposite film has been realized by depositing the paste on top of the dense TiO₂ layer using the same technique, followed by drying at 80°C in an oven.

Counter electrode preparation

On another piece of ITO covered glass a very thin layer of CuInS₂ nanocrystals has been realized following the procedures as above.

Cell assembly

The as obtained two electrodes were put face to face and pressed to form a good contact, then the assembly has been fixed with adhesive tape. The as obtained cell, ready to be measured, is presented in figure 3.

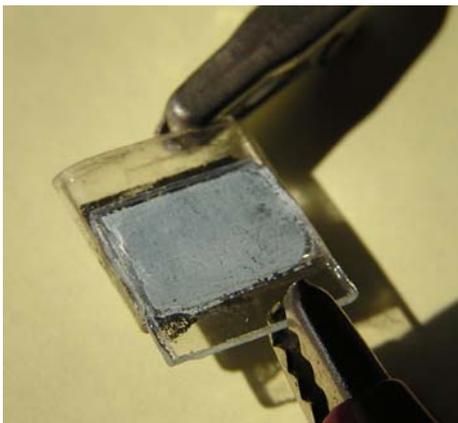


Fig. 3 Solar cell ready to the measurements

3. Solar cell test

The performances of a solar cell (I-V characteristic and efficiency) are strongly dependent on the illumination conditions (spectral distribution and power of used light) and the ambient, especially temperature. For realistic and comparable performance data to be obtained, measurements are made usually in standard conditions using solar simulators [8, 9].

This was not the case here, because of the preliminary nature of our experiments aimed only to demonstrate the functionality of the device as a photovoltaic cell. So, two types of I-V measurements were made: under artificial light and under direct sun light (indoor) irradiation, respectively. The cell has been illuminated from the TiO₂ electrode side.

In the first case, we used a measurement set-up (figure 4a, b) comprising:

- halogen lamp (L) powered by an adjustable voltage source (E) delivering 10A;

- water filter (F) 24 mm thick – to simulate the AM1.5G solar spectrum;
- ZMG001 pyranometer – for the measurement of light flux density
- VOLCRAFT M-3650B voltmeter – for the measurement of V_{OC} ;
- MAVO-35 microammeter – for the measurement of I_{SC}

The cell has an active area of 0.5 cm^2 , and the measured V_{OC} and I_{SC} values under illumination are in the range of 150-200 mV and 1-2 μA , respectively.

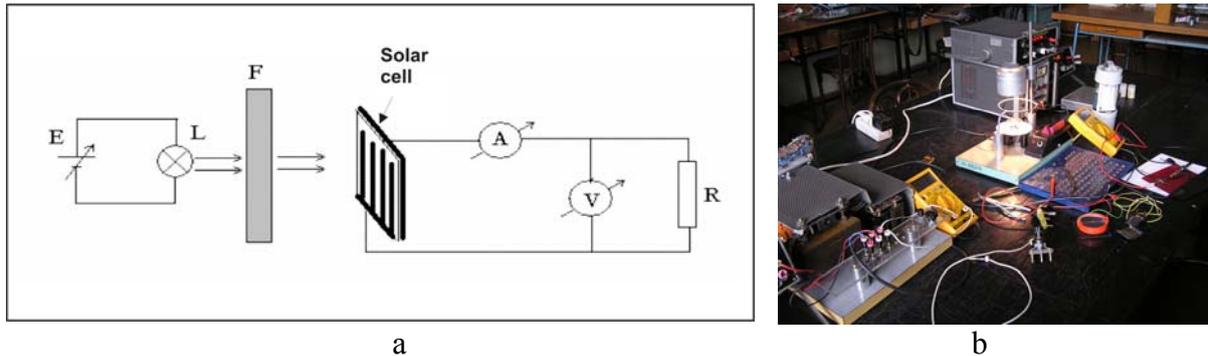


Fig. 4 I-V measurements set-up

Under sun light (indoor) irradiation, the current and voltage measurements has been made in three cases: in the dark, under direct sun light (indoor) and under concentrated sun light (indoor, using a magnifying glass), corresponding to figure 5a, b and c, respectively. One can observe that V_{OC} under direct sun light illumination (case b) is about 4 times that of the dark value (a) and under concentrated illumination is about 14 times the (a) value. The measured photocurrents were in the range of μA . These poor photocurrent values may be explained by the very simple and rough procedure of cell preparation, the possible contamination, poor contacts etc.

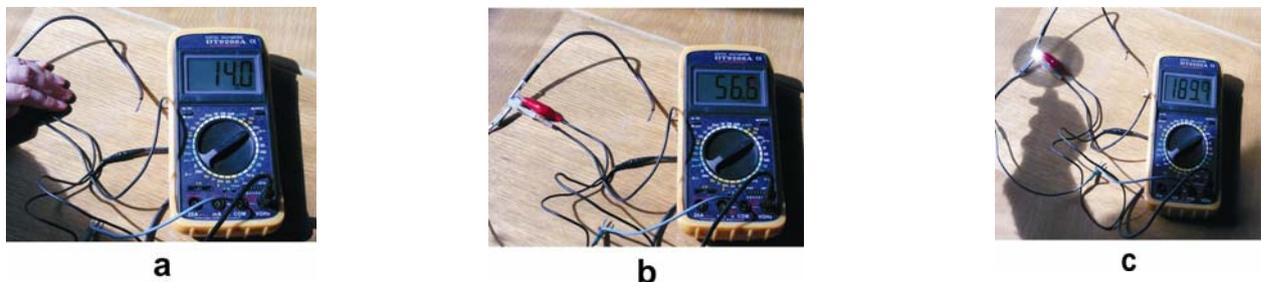


Fig. 5 I-V measurements (a) in the dark, (b) under direct sun light (indoor) and (c) under concentrated sun light (indoor, using a magnifying glass)

4. Conclusions

In summary, a completely inorganic nanostructured 3D solar cell based on hydrothermally obtained CuInS₂ nanocrystals and TiO₂ nanocrystals has been constructed. The functionality as photovoltaic element of this device architecture has been demonstrated. Further research will be done for the improvement of device performances by developing the existing and new thin layer deposition techniques and careful preparation of the devices.

Acknowledgements

Financial support from MATNANTECH and COPBIL research programs of the Romanian Ministry of Education and Research is gratefully acknowledged.

References

- [1] “A Vision for Photovoltaic Technology” - Report by the Photovoltaic Technology Research Advisory Council, Directorate-General for Res. Sustainable Energy Systems, EUR 21242, 2005
- [2] A. J. Nozik, NCPV and Solar Program Review Meeting Proceedings 2003, NREL/CD-520-33586, 422
- [3] Shay J.L., Wernick J.H., *Ternary Chalcopyrite Semiconductors: Growth, Electronic Properties and Applications*, Pergamon Press, New York, 1975
- [4] Arici E. *et al.*, Adv. Funct. Mater., 13 (2003) 165
- [5] Lenzmann F. *et al.*, Thin Solid Films 451 –452 (2004) 639–643
- [6] T. Nyari, R. Băieș, P. Vlăzan, I. Grozescu, Sz. Papp, I. Dékány, P. Barvinschi, Analele Universitatii de Vest din Timisoara - Seria Fizica, 44 (2003) 224-227
- [7] T. Nyari, P. Barvinschi, R. Baies, P. Vlazan, F. Barvinschi, I. Dékány, Journal of Crystal Growth, 275 (1-2) (2005) e2383-e2387
- [8] Paulescu M, Schlett Z (2001) Conversia fotovoltaica a energiei solare, Ed. Mirton, Timisoara.
- [9] Paulescu M, Schlett Z (2002) A new semiconductor-based pyranometer In proc. TIM-02, Timisoara, pp.132-138.