Measurement of Organic Solar Cell Parameters

Vasil Jivkov Siderov, Petar Georgiev Georgiev, Ivaylo Tzankov Zhivkov, Georgi Hristov Dobrikov, Rumen Stoyanov Yordanov, Martin Vala and Martin Weiter

Abstract – **Computer controlled voltage source operating in the range of 0÷10 V with up to 16 bit resolution was constructed and tested. The device capabilities were tested by measurement of *I-V* characteristics of organic solar cell.**

The tests performed show clearly that the module constructed could be used for testing of solar cells.

Keywords – **Data Acquisition System, Solar Cell Measurements**

I. INTRODUCTION

Current-voltage (*I-V*) measurements of semiconductor samples prototypes and devices with nonlinear characteristics - photovoltaic cells, light-emitting diodes, field effect transistors, and sensors play an important role [1, 2, 3].

These devices sometimes contain thin films of wide-gap semiconductors or insulators [4], where both ohmic and injection currents [5] could flow applaying voltages from few milivolts to several volts. From the other side the high precision measurements requires a satisfactory resolution to be achieved.

Especially for low-level signals, more sensitive instruments such as electrometers, picoammeters, and nanovoltmeters must be used. In this case some special precautions should be taken to prevent the noise and the influence of parasitic signals generated from sources with piesoelectrical, triboelectrical or electrochemical origin. In this case applaying galvanic insulation between the different modules could significantly reduce the afforementioned effects.

From other side the long time measurement need an atomatisation to be applied. For the purpose of automatiization virtual instrument are constructed consisting of an industry-standard computer or workstation equipped with powerful application software, cost-effective hardware such as plug-inboards, and driver software, which together perform the functions of traditional instruments.

This paper describes a construction and testing of simplified voltage source operating in the range of 0÷10 V with up to 16 bit resolution. The device has additional advantage of computer control and galvanic insulation which makes it proper for low-current measurements of wide-gap semiconductors and insulators.

V. Siderov, M. Vala and M. Wieter are with Brno University of Technology, Faculty of Chemistry, Centre for Materials Research, Purkynova 118, 612 00 Brno, Czech Republic

P. Georgiev, G. Dobrikov and R. Yordanov are with the Department of Electronics, Faculty of Electronic Engineering and Technologies, Technical University - Sofia, 8 Kliment Ohridski blvd., 1000 Sofia, Bulgaria

I. Zhivkov is with Brno University of Technology, Faculty of Chemistry, Centre for Materials Research, Purkynova 118, 612 00 Brno, Czech Republic and with Institute of Optical Materials and Technologies “Acad. J. Malinowski”, Bulgarian Academy of Sciences, Acad. G. Bonchev Str. bl. 101/109, 1113 Sofia, Bulgaria, e-mail: zhivkov@fch.vutbr.cz

II. DEVICE DESCRIPTION

A. Hardware

The voltage source (Fig. 1.) consists of 16 bit digital-to-analog converter (DAC), analog unit, reference voltage, galvanic insulation, microcontroller (μC) and power supply units.

DAC (1) is the fast, low noise DAC8830 chip (Texas Instruments) connected to the 5V high precise ADR02 voltage reference. The unbuffered DAC output is connected to the buffer (OPA376) which belongs to the analog unit (2). The analog unit includes also two operational amplifiers (OP07) which act as a summer and power amplifier, respectively. The summer converts the unipolar (5V) voltage to a bipolar (±5V) one. The power amplifier provides the full range woltage scale of ±10 V and output current up to 24 mA. The power amplifier could be connected to a second stage amplifier providing higher output voltage and current, which is under development.

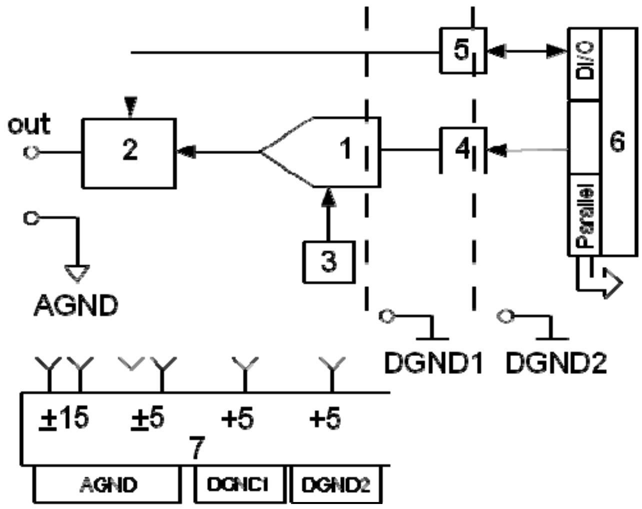

Fig. 1. Block Diagram of the Solar Cell Measurement Setup: 1 – DAC; 2 – Analog Unit; 3 – Voltage Reference; 4, 5 – Galvanic Insulation; 6 – Microcontroller; 7 – Power Supply

The galvanic insulation of the DAC (4) is implemented by the specialised chip ISO7241, which is proper to separate the serial peripheral interface (SPI), while the digital I/Os (5) are separated by conventional optocouplers. SPI interface transmitts the data from the μC to DAC in one direction. Therefore the SPI consists only of two clock and data lines. The additional chip select pin not only servs to select a specific slave devace, but also initiates the measurement. Galvanic insulation module improves the performance of the device, especially for low current measurements. The microcontroller (μC) (6), controls the voltage source and gets the data from the main processor via parallel 8 bit interface. The parallel interface includes typical “data ready” (DR) and “data acknowledge” (DA) lines which provides the handshaking. The power supply provides three separate grounds (ANGND, DGND1, DGND2), which decreases the noise in the system and prevents the parasitic influence between the modules and external devices.

B. Software

Block-diagram of the μC firmware is presented in Fig. 2. It consists of the main part and the hardware driven interrupt service routine. The main part of the program implements the device initialization and configuration and starts and endless loop which is related to other tasks of the module. Upon an external interrupt request initiated by the main processor (non-presented in the block diagram), the data and commands presented on the 8 bit parallel bus are

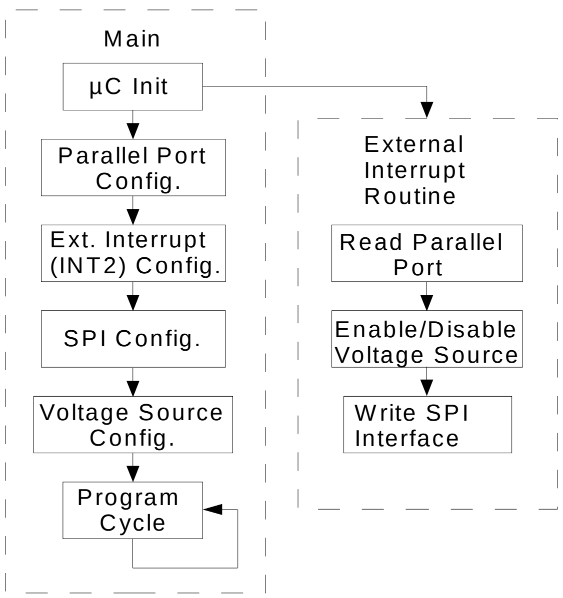

Fig. 2. Block diagram of the μC software

read and delivered to the periphery by the interrupt service routine. The interrupt line stays active during the whole stage of the data transmission and plays a role of DR signal. After the slave device accepted the data it emits the DA signal, which notifies the master device to finishes the measurement. The received through the parallel interface data could either rearrange the digital pins of the μC or sends a 16 bit data trough the SPI interface, The 16-but data are sent trough the interface in two bytes. The device performance was tested by measurement of current-voltage (*I-V*) characteristics of organic solar cell samples.

III. Solar Cell Sample Testing

A. Experimental conditions

The device performance was tested by measurement of *I-V* characteristics of organic solar cell samples.

The samples were prepared in the clean room class C, to prevent the dust and particles from disrupting the thin layer. The clean lab is equipped with MB-200B MBRAUN gloveboxes (M. Braun Inertgas-Systeme GmbH, Garching, Germany). Oxygen sensitive materials were stored and manipulated exclusively in the nitrogen gloveboxes, where also most of device fabrication step took place.

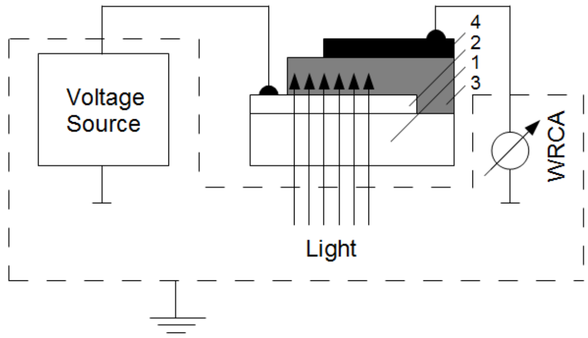

Fig. 3. Block Diagram of the Solar Cell Measurement Setup. Sample Configuration: 1 – Glass Substrate; 2 – Transparent ITO Anode; 3 – Active Organic Film; 4 – Al Cathode

Zinc Phthalocyanine (ZnPc) OF (see Fig. 3) (3) of 100 nm thickness were deposited onto indium tin oxide (ITO) electrode (2) of commercially pre-patterned Ossila substrates in the vacuum system from thermally heated sources at evaporation temperatures of about 500 ºC and deposition rate of 2.0 Å/s through the active area deposition mask. The deposition rate was controlled by quartz crystal microbalance. After deposition of the active composite layer, the samples were taken out in nitrogen atmosphere, the mask was changed and vacuum deposition of aluminum was performed. The aluminum cathode (4) of 150 nm film thickness was thermally evaporated in 1×10^{-6} mbar at a deposition rate of 1 Å/s.

Finally the structures were encapsulated by epoxide resin, which was hardened for 30 minutes under UV lamp irradiation. After that the samples were removed from the glovebox and provided with contacts for electrical measurements.

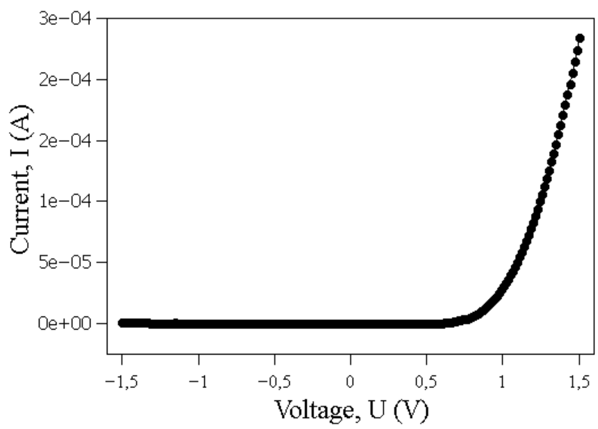

Fig. 4. Typical dark current-voltage solar cell diode

The setup for electrical measurement (Fig. 3) consists of originally developed Wide Range Current Amplifier (WRCA) and the constructed voltage source. Dark *I-V* characteristics were measured in both directions of the voltage scale. The photoconductivity of the samples was measured under exposure of a standard light produced by solar simulator LS0916 LOT Oriel class AAA. It provides defined light source according to standard AM 1.5. Incident light intensity was about 1000 mW.cm^{-2} and was controlled by calibrated reference silicon cell RR200O from ReRa systems (ReRa Solutions BV; Nijmegen, Netherlands). For the studied samples, the exact irradiation of 953 mW.cm^{-2} was measured.

B. Results and Discussion

In Fig. 4 dark *I-V* characteristic measured with the constructed module from ITO|ZnPc|Al structure is presented. The curve exhibits a clear diode behavior, which is a typical case for organic solar cell. In Fig. 5 the dark *I-V* characteristic is plotted together with curves measured from the same sample under white light illumination. For the sake of clarification and estimation the electrical parameters of the samples, the data are presented in a semilogarithmic scale (the negative values of the current are multiplied by −1).

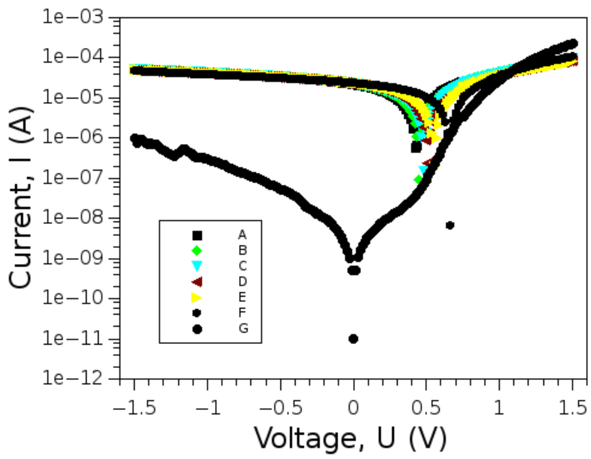

Figure 5. Current-voltage characteristic measured in dark and under light exposure

The dark-current diode curve (Fig. 5, Curve A) shows almost no contact barrier, which demonstrates a good interface contacts between the active OF and the electrodes. The dark curve measured in reverse direction has a tendency of diode saturation about -0.3 V. At higher voltages the measurement differs from the ideal diode which results in an increased curve slope. This effect could be related to the injection current as a result of the dominating bulk sample properties at higher voltages. Nevertheless the increased injection current in reversed direction which worsens the diode behavior a diode rectification ratio of more than two orders of magnitude was obtained. Under light exposure the open circuit voltage of 0.66 V was determined and the photocurrent in the clear diode part of the sample characteristic (0 to -0.3 V) increases almost 4 orders of magnitude comparing with the dark one.

The degradation of the sample reflected in a decrease of the open circuit voltage (Fig. 5, curves B÷F) under oxygen exposure was also investigated by the constructed. The dependence of the U_{OC} on the time of exposure on air is

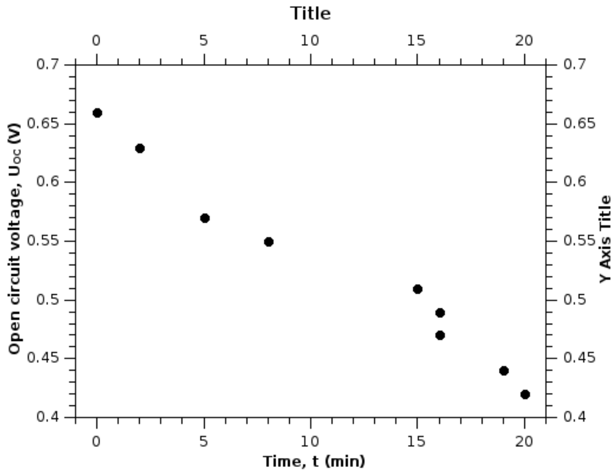

Fig. 6. Kinetics of the open circuit voltage

plotted in Fig. 6. Almost a linear U_{OC} decrease for a period of about 20 min air exposure could be seen.

IV. Conclusion

Computer controlled voltage source operating in the range of 0÷10 V with up to 16 bit resolution was constructed and tested

The device capabilities were tested by measurement of *I-V* characterisgics of organic solar celll.

The datk *I-V* curve taken from te tested solar cell shows clear diode behaviour. Under light exposure the photoconductivity, increases 4 orders of magnitude. The tests performed clearly show that the module constructed could be used for measurement of solar cells.

Acknowledgements

This work was supported by Czech Science Foundation via project No. 15-05095S, research infrastructures was supported by project MŠMT No. LO1211.

References

[1] A C. Grimsdale, K. L. Chan, R. E. Martin, P. G. Jokisz, and A. B. Holmes. *Synthesis of Light-Emitting Conjugated Polymers for Applications in Electroluminescent Devices*, Chem. Rev., 2009, Vol. 109, No. 3, pp. 897-1091• DOI: 10.1021/cr000013v •

[2] H. Hoppe and N. Sariciftci. *Organic solar cells: an overview*, J. Mat. Res., 2004, Vol. 19, No.7, pp. 1924–1945. doi:10.1557/JMR.2004.0252

[3] F. Garnier. *Organic-Based Electronics à la Carte, Acc.*, Chem. Res., 1999, Vol. 32, No 3, pp. 209–215.

[4] M. Lampert, P. Mark. *Current Injection in Solids*, Academic Press, New York, USA, 1970.

[5] I. Zhivkov, V. Strijkova, E. Spassova, G. Danev, S. Nespurek, and M. Iwamoto. *Space-charge effects in vacuum deposited polyimide layers,* J. of Optoel. and Adv. Materials, 2005, Vol. 7, No. 1 , pp. 245-248.

[6] P. Georgiev, I. Zhivkov, M. Vala, D. Todorov, R. Yordanov, and M. Weiter. *Wide range current amplifier with data acquisition system,* Annual Journal of Electronics, 2014, v. 8, p. 185, ISSN 1314-0078.