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Application of laser-spectroscopy on organic photovoltaic devices

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Abstract

Organic photovoltaics (OPV) with integrated ultra-barrier layer instead of afterward encapsulation are advantageous due to combination of functionalities: substrate for layered stack generation and protection against lifetime-limiting climatic exposure. Additionally, integration of the barrier into the functional layer stack saves one encapsulation step in the production. European H2020 project ALABO (Advanced Laser Ablation on Barrier films for Organic and large area electronic devices), addresses the challenges of lifetime enhancement and performance-cost-ratio . The consortium includes 3 multi-national industries, 3 research institutes and 1 university from 4 European countries.

To include an ultra-barrier layer onto the plastic substrate with functional opto-electrical layers on top and qualification of a roll-to-toll (R2R) suitable production process, implies development of adequate coating, laser structuring and characterization processes. Laser structuring of the front electrode (indium-tin-oxide ITO or dielectric-metal-dielectric DMD; P1 scribing), the electric energy generating organic layer (P2 scribing) and the back electrode layer (P3 scribing) are potentially harmful to the thin-film barrier underneath. Therefore, P1-P3 laser process development goes hand-in-hand with barrier performance characterization and performed by water vapour transmission rate (WVTR) measurements using tunable diode laser absorption spectroscopy (TDLAS), He-transmission-test, in-house developed optical Ca-test and Hyper-spectral Imaging (HSI).

A real time diagnostic setup for selective ablation during laser scribing using laser-induced breakdown spectroscopy (LIBS) technique was investigated to obtain the material identification at every laser pulse. The paper presents results of femtosecond and picoseconds LIBS, which generally enable discrimination of the separate laser-machined nm-scale layers by their corresponding emission lines.

Keywords: Organic solar cell; Laser scribing; Process control; Selective ablation; Laser spectroscopy

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Solar power is the ultimate source of renewable energy and it is important to focus on using the solar power efficiently for creating a green alternative for the advancement of the sustainable energy production. Organic Photovoltaic Devices (OPV) has been emerging as a prominent potential candidate in the last few years in this domain. The advantages of OPV over conventional solar cells are many and thus it is believed to be a true green future alternative if the quality to cost ratios are met.

Flexible solar cells used in this work consist of thin electrode layers and a photosensitive organic coating in between. The transparent flexible substrate is the base of the OPV. The salient feature of this solar cell is an integrated barrier layer on top of the substrate to keep off the environmental agents such as water vapor that degrades the lifetime of the solar cells. Fig. 1. shows the composition of the organic solar cells.

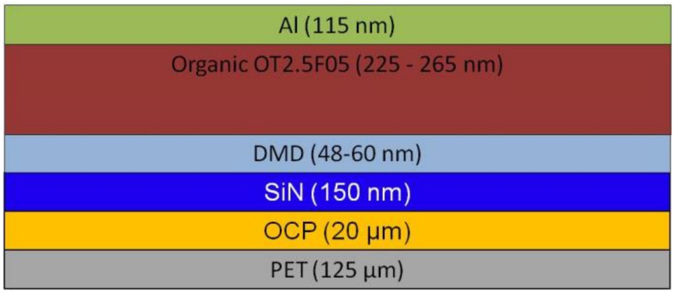

Fig. 1. Schematic of the solar cell

Silicon nitride as a ultra-barrier layer, transparent dielectric-metal-dielectric (DMD) layer as an electrode and aluminum as a back electrode have been used for as shown in Fig. 1. Electrical connections and power extractions from the solar cell need laser scribing on the different layers. The schematic of the laser scribing is shown in Fig. 2. The P1, P2 and P3 laser scribing are required to be done without damaging the barrier layer. Therefore, solar cell characterizations during the scribing is a vital procedure and we have explored the possibility to use Laser Induced Breakdown Spectroscopy (LIBS) to extract information on real time material detection. Laser Induced Breakdown Spectroscopy (LIBS) [1,2] is a non-contact quantitative analysis tool which identifies the elemental composition of a target material. Therefore, LIBS is an extremely powerful analytical technique for various applications in applied surface sciences.

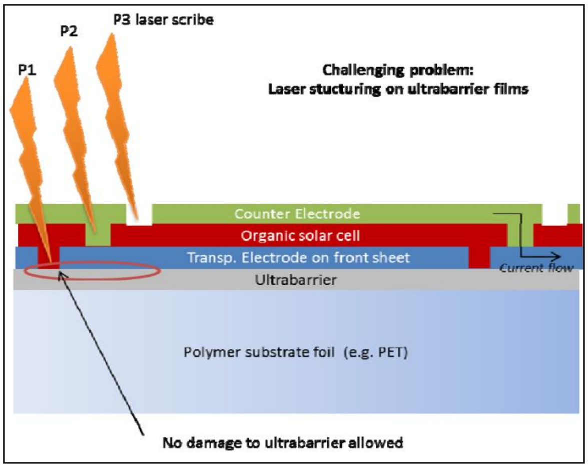

Fig. 2. Schematic of the laser scribing procedure on the solar cell

It has been demonstrated that material detection at different depths of a multi layered sample can be done using LIBS [3,4] by several researchers. In one of our recent work [5], femtosecond lasers along with suitable collection optics and spectrometer was used to distinguish emissions from thin layers of the organic solar cell. The present study is developing a process control during P1/P2/P3 scribing to obtain real time material identification and apply a feedback mechanism in an industrial setup to restrain barrier damage. Picosecond laser sources with IR/Green wavelengths were used for this experiment. Typical experimental setup is shown in Fig. 3.

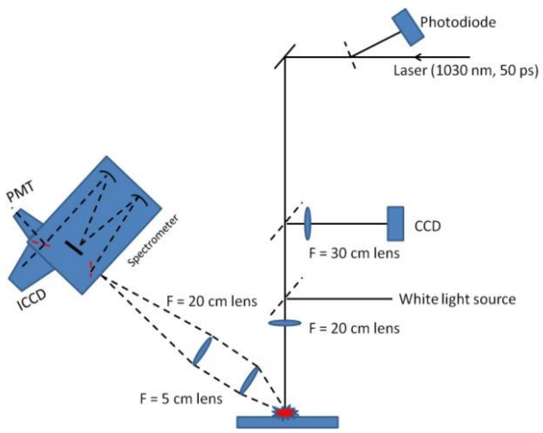

Fig. 3. Schematic of the experimental setup

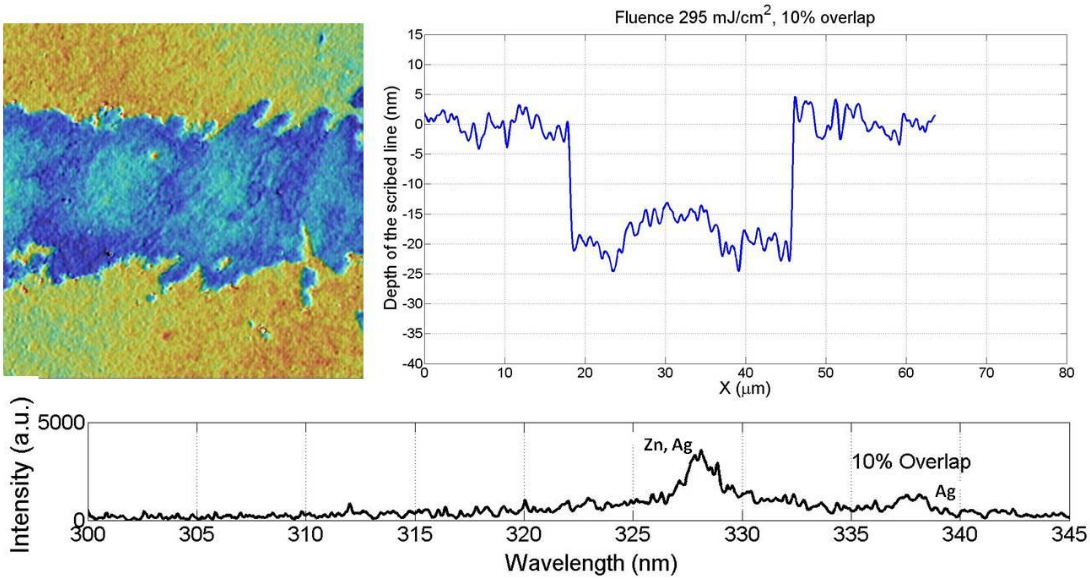

Fig. 4. LIBS spectra and corresponding scribe profile at 295 mJ/cm^2 with 10% overlap

Fig. 4. shows the scribed line on a DMD surface (P1 scribing) using 295 mJ/cm^2 energy fluence at 10% overlap and the corresponding LIBS spectra as well as the depth of the scribed line. Confocal microscope has been used to measure the depth of the line. It has been observed that the depth of the crater was approximately 30 nm which was well under the thickness of the DMD layer. Therefore, the SiN barrier layer was not damaged and silicon peak was not visible as well. Similar experimental campaign had been carried out successfully for the P2 and P3 scribing where the goal was not to damage the barrier but make an electrical connection between the electrodes. Therefore, LIBS has been proven to be a potential candidate to monitor real time material identification during scribing for all the scribing conditions.

Acknowledgements

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References

[1] J. P. Singh, S. N. Thakur (Eds.), "Laser-Induced Breakdown Spectroscopy", 1st Edition, Elsevier Science, 2007.

[2] R. Noll (Ed.), "Laser Induced Breakdown Spectroscopy-Fundamentals and Applications", Springer, 2012.

[3] V. Margetic, M. Bolshov, A. Stockhaus, K. Niemax, R. Hergenroder, 2001, "Depth profiling of multi-layer samples using femtosecond laser ablation", J. Anal. At. Spectrom. 16, p. 616-621.

[4] S. P. Banerjee, Z. Chen, I. Utkin, R. Fedosejevs, 2013, "Detection of buried layers in silicon devices using LIBS during hole drilling with femtosecond laser pulses", Appl. Phys. A 111, p. 791-798.

[5] S. P. Banerjee, Thierry Sarnet, Panayiotis Siozos, Michalis Loulakis, Demetrios Anglos and Marc Sentis, 2016, "Characterization of Organic Photovoltaic Devices Using Femtosecond Laser Induced Breakdown Spectroscopy", Applied Surface Science (http://dx.doi.org/10.1016/j.apsusc.2016.11.136).