Photovoltaic properties of Dye-sensitized Solar Cells with natural sensitizers extracted from Salento local grapes

Sandro Lattante [1] , Marco Anni [1], Giuseppe De Benedetto [2] , Daniela Rizzo[2]

[1]Dipartimento di Matematica e Fisica "Ennio De Giorgi", Università del Salento, Italy

[2]Dipartimento di Beni Culturali, Università del Salento, Italy

Electrical power generation from solar light is, among the different renewable energy technologies, the one with the highest potential, due to the extremely high value of the total power received from the sun on the earth surface (about 90 PW), which is about 6000 times larger than the estimated total word power consumption (about 15 TW). Currently a very rich research activity on new technologies for solar cells exists, including many different active materials and device structures. Within the so called *third generation* solar cells a particularly interesting technology is the one of dye-sensitized solar cells (DSSCs), allowing to reach power conversion efficiency above 10%. The typical structure of a DSSC includes a transparent photoanode, an electrolyte solution containing a redox system and a counter-electrode. The photoanode typically consist of a TiO_2 nanoporous films on a transparent electrode, sensitized with a dye molecule, responsible for light absorption. The DSSC with the best efficiency are typically based on organic dyes, or on dyes containing transition metals like ruthenium, both characterized by high synthesis costs and high environmental impact, related to the disposal of the chemical byproducts.

For these reasons several research groups are currently working on the investigation of the possibility to replace the dyes obtained from chemical synthesis, with the ones used by the plants to absorb sunlight as the starting step for the photosynthesis. Mainly three families of dyes are used in nature, namely chlorophylls, betalains and anthocyanins. In particular the family of anthocyanins, responsible of the red color of many fruits and vegetables, is very wide, with about 500 different dyes already isolated for plants and an estimated global production from plant on the scale of 10^9tons/year. The combination of large quantities, natural origin of the compounds, and reasonable device performances, would open the way to cheap and environmental friendly dyes production. A large number of natural dyes have been tested to date, leading to a maximum DSSC efficiency of about 2 % [1]. In this work we investigated the photovoltaic properties of DSSC exploiting anthocyanins extracted from four different local Salento grapes, namely *Primitivo*, *Black Malvasia*, *Negramaro* and *White Malvasia* (see Fig. 1). Full details on the experiments can be found in Ref. [2].

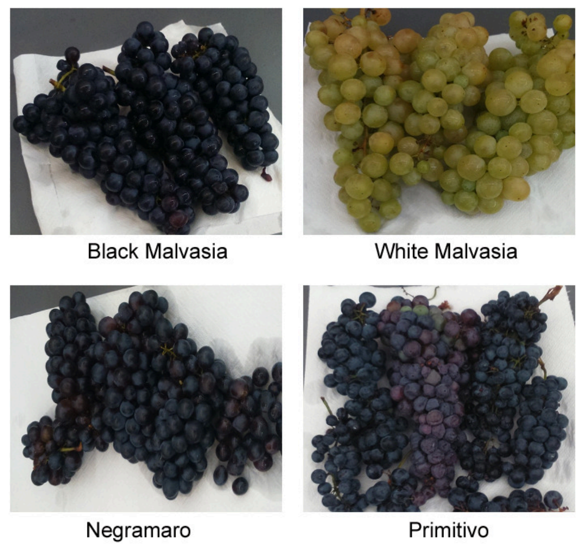

Figure 1. Photograph of four bunches of the four tested Salento grapes, namely Black Malvasia, White Malvasia, Negramaro and Primitivo.

The dyes have been extracted by immersion in methanol of the epicarps of the fresh fruits or of the whole grapes pulp/dense juice after two weeks of fermentation, followed by ultrasonic bath for several hours at room conditions and filtration. The liquids extracted from Black Malvasia, Negramaro and Primitivo were intensely dark red in color, while the White Malvasia extract was of a limpid yellow color, evidencing lower absorption in the red spectral region.

The DSSC devices have been realized using the components of a DSSC preparation kit from So-

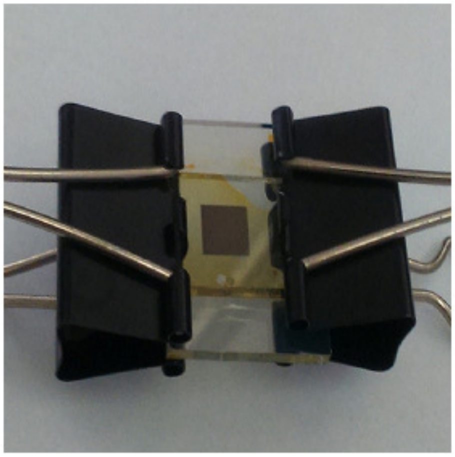

Figure 2. Photograph of a solar cell based on pigments extracted from Negramaro. The black central square is the TiO_2 layer infiltrated with the pigments, the brown region is the electrolite solution, sandwitched between two transparent electrodes deposited on the external glass layers.

laronix, consisting in a pre-patterned TiO_2 substrate on FTO glass (0.7 x 0.7 cm^2 active area) and a platinum-coated counter electrode, using a I^-/I_3^- solution as electrolyte.

All the realized devices showed a clear solar cell behavior under simulated solar light illumination (AM 1.5) (see Fig. 3), with a maximum short circuit current density (J_{sc}) for *Negramaro*, comparable IV curves for *Black Malvasia* and *Primitivo*, and the lowest J_{sc} for *White Malvasia*. A very high open circuit voltage V_{oc} of about 0.52 V is observed in all the cells based on dark grapes, while again the lowest value is observed for the *White Malvasia* cell (about 0.50 V). Concerning the photogenerated power density, all the devices show a clear maximum for a voltage of about 0.40 V, with a power conversion efficiency of 0.23% for *Negramaro*, 0.19% for *Black Malvasia* and *Primitivo*, and 0.09% for *White Malvasia*. The differences in the performances of the red grape based DSSC can be related to the different nature of the component anthocyanins in the respective extracts [2], while the poor performances of the *White Malvasia* are related to the absence of dyes absorbing in the red part of the spectrum, as clearly evidenced by the yellow color of the extract. Overall the realized cells show extremely high values of V_{oc} and Fill Factor (for anthocyanins based DSSC), with global performances limited by the low values of the J_{sc} (about one order of magnitude lower than the best anthocyanins DSSC). There is room for further improvement, starting from the optimization of the current density by properly doping the used electrolyte, by modifying the TiO2 substrate, or by optimizing the solvent for the dyes extraction.

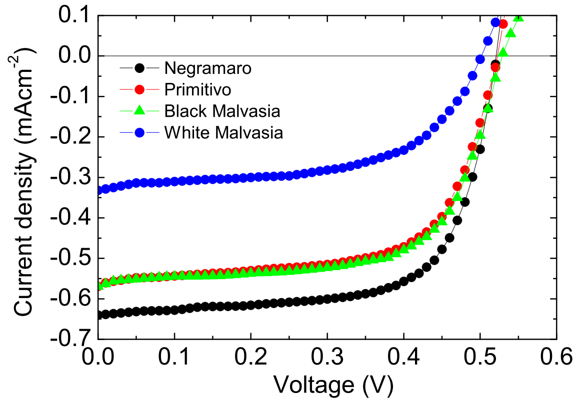

Figure 3. Current voltage characteristic curves of the best device with each grape kind under simulated solar cell light.

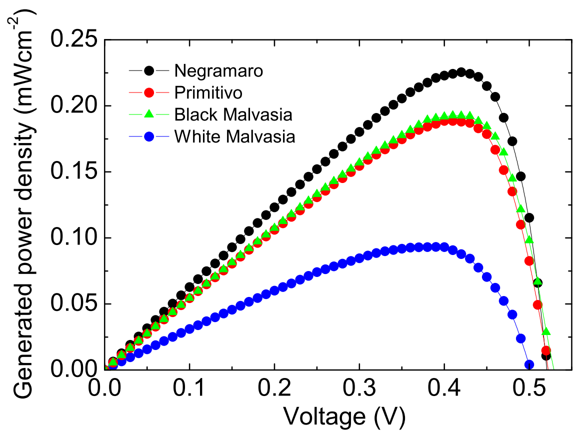

Figure 4. Voltage dependence of the photogenerated power density of the four devices.

REFERENCES

1. G. Calogero, Jun-Ho Yum, A. Sinopoli, G. Di Marco, M. Grätzel, and M. K. Nazeeruddin Solar Energy **86**, 15631575 (2012).
2. S. Lattante, G. De Benedetto, D. Rizzo and Marco Anni, Current Physical Chemistry in press.