New devices for energy harvesting and storage: integrated third generation photovoltaic solar cells and electrochemical double layer capacitors

ABSTRACT

A worldwide conversion towards renewable energy sources has to be implemented in order to hopefully avoid the irreversible consequences of the global temperature increment caused by the greenhouse gases production.

In addition, the current need to benefit from electricity in every moment of daily life, mainly in case of limited access to the electric grid, is forcing the scientific community to an intensive effort towards the production of integrated energy harvesting and storage devices.

The topic of this PhD thesis is to investigate and propose innovative solutions for the integration of third generation photovoltaic (PV) cells and electrochemical double layer capacitors (EDLCs), the so-called photo-capacitors.

Different photo-capacitor structures have been studied and experimentally fabricated. At first, flexibility was explored, as it is a mandatory requirement to cover non-planar or bendable surfaces, which are more and more common in nowadays portable electronics. Easily scalable fabrication processes have been used for both the harvester and the storage units, employing photopolymer membranes as electrolytes and metallic grids as current collectors and electrodes substrates. For this configuration, the best overall conversion and storage efficiency ever reported for a flexible Dye sensitized solar cell (DSSC)-based photo-capacitor was demonstrated.

Subsequently, observing in the literature an evident lack in the exploitation of high voltage photo-capacitors, EDLC electrolytes with broad voltage windows have been examined. These electrolytes allowed to fabricate stable and reliable devices integrating the EDLC with a PV module and not only with a single solar cell, as normally is done. High voltage values, up to 2.5 V, have been obtained employing an ionic liquid electrolyte (Pyr14TFSI) or –alternatively- a solid state electrolyte (PEO-Pyr14TFSI) for storage section fabrication.

Moreover, novel electrolyte mixtures of organic solvents and ionic liquids with good physical and electrochemical properties have been employed with the aim to increase energy density and voltage with respect to commercial EDLCs.

Finally, a novel polymer-based platform has been suggested for the fabrication of an innovative “two-electrodes” self-powered device. The multifunctional polymeric layer, made of two poly(ethylene glycol)-based sections separated by a perfluorinated barrier, was obtained by oxygen-inhibited UV-light crosslinking procedure. For the energy harvesting section, one side of the polymeric layer was adapted to enable iodide/triiodide diffusion in a DSSC, while the other side empowered sodium/chloride ions diffusion and was used for on-board charge storage. The resulting photo-capacitor results in a planar architecture appreciably simplified with respect to other recently proposed solutions and is definitely more easily exploitable in low power electronics.