Advanced multi-junction polymer solar cells

Solar energy represents an alternative source of electricity which could fulfil the energy needs of our society. The energy of light can be converted into electricity via the use of solar cells which, upon exposure to light, generate voltage and an electric current. Nowadays, silicon solar cells are the most traditional and commercially available solar cells on the market. Yet, their range of applications is often limited by their encumbrance. Polymer solar cells might overcome this limitation, yet they generally display lower efficiencies than traditional silicon cells. The PhD research of Dario Di Carlo Rasi focused on the fabrication of advanced multi-junction polymer solar cells, or, in other words, polymer solar cells combining multiple light absorber materials. These solar cells can be manufactured using printing techniques and they are capable of remarkable efficiencies of up to 17.3%.

The world population is steadily increasing, so does the demand for energy. Harnessing solar energy via solar cells offers the opportunity to solve this problem in a sustainable way. Traditional solar cells based on silicon are currently leading the global market of solar cells. However, the need for higher material purity and the bulky nature of these solar cells are some of the main limitations which fostered the development of alternative type of solar cells. Among them, Polymer Solar Cells (PSCs) emerged as an intriguing alternative because of their good performances and low manufacturing costs.

PSCs are made of special organic molecules, which can be deposited as thin layers with thicknesses of about 100 nm (nearly 600 times thinner than a human hair). Contrary to the vast majority of solar cells, PSCs are suitable for flexible or free-form structures, coloured solar cells or for semi-transparent designs. PSCs have been reported to have a solar-to-electrical power conversion efficiencies of more than 14%. To boost the efficiency further, multiple layers of complementarily-coloured absorber molecules might be stacked on each other to form the so-called “multi-junction architecture”. Fabricating such complex device stacks from solutions represents a real challenge in terms of the processing schemes since each layer must preserve its functionality through the complete processing in order to guarantee optimal performance. Also, to date, the fabrication of multi-junction PSCs required the development of ad-hoc, intricate, and diverse processing conditions and materials for the interconnection layers (ICL) between the adjacent absorbers.

In his PhD project, Di Carlo Rasi focused on the development of better fabrication methods and the possibility to increase the complexity of solar cells by combining more absorbers. By researching solvent additives and processing atmospheres, Di Carlo Rasi developed numerous PSCs with tandem and triple-junction configuration (two and three absorbers, respectively). Using detailed characterization of solar cells and by comparing optical and electrical modelling, Di Carlo Rasi demonstrated that the stacking of cells came with hardly any additional losses. A particular highlight of his research was the demonstration of the first quadruple-junction PSC deposited entirely from solution, with four complementary absorbers. In particular, a stack of eleven films (comprising the absorbers) was created from these solutions. To extract charges from the absorber layers, nanoparticle metal oxide films were used. Di Carlo Rasi showed that tin oxide particles are superior to commonly used zinc oxide particles, because they have comparable electrical and optical properties but improved chemical stability. Efficiencies in excess up to 10.4% were obtained.
The results described in the thesis represent novel contributions to the advancement of multi-junction polymer solar cells. A continued effort in the synthesis of new high-performing absorber materials, together with studies oriented to improve their stability with time and their fabrication over a large surface, will lead to the final commercialization of this technology.

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