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Editorial

Novel Materials and Processes for Photovoltaic Technology

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1. Introduction

Photovoltaic (PV) technology is the symbol of a sustainable future in many countries around the globe [1]. As a result, numerous investments have been made in research, development, demonstrations, and production lines. No other renewable technology has received such strong appreciation from the public, or in politics and industry. New technologies have paved the way for new materials, products, and additional market segments [2,3]. Engineering, nanoscience, nanotechnology, and surface science have contributed to introducing new materials and customized processes for solar technology. In recent decades, many research institutes, companies, and consortia have demonstrated that the new concept of solar cell technology can achieve high performance, large application areas, and industrialization. Different types of solar devices exist among the third-generation PVs that have recently emerged [3,4], and their benefits and issues have been exhibited in various studies: dye-sensitized solar cells (DSSC) [5,6], hybrid and organic solar cells [7], quantum dot solar cells [8], and perovskite (PVSK) solar cells (PSC) [9,10].

Here, the successful invited submissions to the Special Issue of *Energies* on "Novel Materials and Processes for Photovoltaic Technology" are presented. The third-generation PV technologies chosen by the authors are DSSC and PSC.

2. Special Issue Articles

In this Special Issue, DSSC (the first developed) and PSC were the two mainly investigated third-generation PV technologies.

The following features make DSSC technology suitable for building-integrated PVs (BIPVs) [11], consumer electronics, and indoor applications [12]: different device colors [13], transparency in the visible range [14], low correlation with the light angle [15,16], better operation in diffuse light compared to traditional PV technologies [17], bifacial concept [18], low-cost fabrication processes [11], possibility to use rigid and flexible substrates [19], and environmental sustainability.

The comparable fabrication procedures with organic electronics and DSSC have boosted the success of PSC technology [20,21]. Moreover, the organometal halide perovskites possess unique physical–chemical properties [22–24] (high absorption coefficient, ambipolar charge transport, large charge carriers lifetime and diffusion length, flexible bandgap tuning, low exciton binding energy) that are permitted to develop a solution process PV technology with power conversion efficiencies (25.7% for the single junction) higher than any thin-film PV and closely resembling that of silicon [25].

In this Special Issue, semi-transparent dye-sensitized solar modules (DSSMs) and panels (DSSPs) were fabricated to filter the sunlight from the roof of an aquaponic greenhouse [26], according to recent progress [27]. The agrovoltaic hot topic is related to the optimization of land by combining solar PV and food crops [28]. Greenhouses are equipped with many control devices for temperature, lighting, fans, and monitoring. DSSC can both satisfy the energy needs and selectively control the entry of light [29,30]. In the published paper, the aperture area (312.9 cm^2) module efficiency and AVT (average visible transmittance) are equal to 3.88% and 35%, respectively [26]. The devices exhibited thermal

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and light stability during accelerated tests and were laminated to realize 10 panels (2 m^2). The produced power was about 3 W in compliance with energy needs in a greenhouse. Moreover, the plant growth was not affected by DSSPs light filtering.

In a PSC, the electron transporting layer (ETL) and the hole transporting layer (HTL) drain from the photoactive layer electrons and holes to the respective electrodes, in order to limit recombination [31]. The hole-transporting material (HTM) is responsible for the stability, efficiency, and cost of a PSC. Since the HTM doping agents are mainly hygroscopic, the research focuses on finding a dopant-free HTM, such as small molecules or polymers.

The first review article in this Special Issue collects all the relevant organic dopant-free small-molecule HTMs adopted to fabricate PSCs with an efficiency above 15% [32]. The HTMs are classified according to their topology (1D linear, 2D star-shaped, 3D spiro-like) and related features. HTMs based on benzodithienosilole, benzodipyrrole, dithienopyrrole, bithiophencarboximide, truxenes, spirobifluorene and spiro[fluorene-9,9′-xanthene] cores guaranteed PSCs with an efficiency of more than 20%. Regarding the compaction of the molecules, the authors reported how the hole mobility can be improved by reducing the contact distance between packed molecules, particularly if the lowest distances include the chemical centers (simply oxidized and reduced). Moreover, the molecular planarity can help to improve the cell efficiency thanks to the stacking and high contact of the molecules. The review also presented high-stability compounds for potential commercialization.

This Special Issue also contains an article that tested an alternative efficient and stable low-cost fluorene-xanthene-based HTM [33]. The reference Spiro-OMeTAD HTM has high efficiency, but it is expensive and has low stability in the presence of humidity. For the first time on a large-area cell, the authors reported the low-cost X55 HTM with a deeper HOMO level and higher hole mobility and conductivity with respect to the Spiro-OMeTAD HTM [34]. The PSCs based on the homogeneous X55 film show higher V_{OC} and maximum power point-stabilized efficiency with respect to the reference HTM because of poor defects and pin holes. The efficiency loss was about 15% lower with respect to Spiro-OMeTAD in a 1000 h ISOS-D-1 test (room temperature at 50% humidity).

The last review article focuses on n-i-p PSC efficiency and stability improvement by interfacial engineering through passivation treatment, in order to reduce non-radiative recombination [35]. Passivation acts as a shielding layer to protect the PVSK surface by reducing the trap states at the grains and grain boundaries. The paper introduces the surface reconstruction concept, i.e., the formation of a 3D [36], low-D interlayer [37], and the surface reconstruction with mixed salt through a synergistic effect [38]. The first two approaches reconstruct the PVSK surface through the formation of an optimized layer of 3D or low-D PVSK. Moreover, the low-D PVSK can enhance surface hydrophobicity. The mixed salts approach combines different improvements. In recent years, some passivation approaches have been upscaled to the module level [39,40]. The authors discovered a lack of studies concerning the material selection criteria and understanding of the passivation mechanisms.

3. Conclusions

The Special Issue "Novel Materials and Processes for Photovoltaic Technology" is composed of four papers: two research and two review articles. These cover some hot topics related to DSSC and PSC, such as large-area alternative application, efficiency, stability, cost, and sustainability. This editorial contains a brief summary by the guest editor of the main findings and considerations from the published invited submissions. The guest editor would like to thank the outstanding contributors, reviewers, MDPI *Energies* publisher, and editorial staff.

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