Editorial
Advances in Photovoltaic Materials and Devices
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Over the last few years, we have witnessed a formidable increase in the public sensitivity toward more sustainable lifestyle choices, with more and more people realizing the importance of preserving the Earth’s natural resources. This wind of change is inducing governments across the globe to take important actions to combat environmental and climatic changes. Two important examples include the European Strategic Research and Innovation Agenda and the United Nations’ 2030 Agenda for Sustainable Development, which include decarbonization strategies and promise to invest in a circular economy. This “green revolution” must be coordinated with investments in renewable energy sources to make up for the constantly increasing energy demand.

Among the various renewable energy sources available for exploitation, solar energy is undoubtedly the most abundant source of energy at our disposal and has the potential to be harvested with minimal environmental impact. However, at present humans are harvesting only a minimal part of the solar radiation (“More energy from the sun falls on the earth in one hour than is used by everyone in the world in one year”—The National Renewable Energy Laboratory), and much work is yet to be done in terms of both research and public dissemination.

In this context, photovoltaic energy generation is the vital technology with the capacity to drive the energy transition. In fact, since the invention of the first silicon-based solar cells at the Bell Labs in 1954, there has been an exponential boost in the number of publications on the field of solar energy. This field has developed many different technologies that exploit various materials and architectures beyond commercial mono- and poly-crystalline silicon panels.

Despite all these achievements, to reach the goal of net zero greenhouse gases emission in a circular economy framework, there remain open challenges that need to be tackled: the development of low-cost, large area and eco-sustainable technologies; the quest for non-critical raw materials; and the integration of photovoltaic devices for IoT applications.

This Special Issue of Crystals, entitled “Advances in Photovoltaic Materials and Devices”, compiles original research articles investigating the properties and stability of photoactive materials, and offers a review report addressing the latest advancements in thin-films deposition for large-area perovskite solar cells.

At present, heterojunction solar cells based on crystalline silicon exemplify the leading technology for the production of high-efficiency and high-quality solar panels. However, the high production cost of crystalline silicon wafers motivates the quest for other materials, among which multi-crystalline silicon represents one of the most valid candidates. Multi-crystalline silicon cells with rear interdigitated electrodes were fabricated by Abdouli et al. [1]. The authors investigated the effects of surface recombination and silicon base thickness on the cell efficiency, providing a comprehensive theoretical analysis that amply elucidates the experimental evidence accrued. The best results were achieved for cells with 200 µm thick bases, whereas the effect of surface recombination was mitigated by a porous-silicon passivation that also helped to improve cell reliability.

Perovskite materials provide another alternative to silicon, combining high-power conversion efficiency with low-cost fabrication processes. As happens for silicon cells, surface recombination, as well as grain-to-grain recombination, negatively affects device
performance. Xiao et al. [2] examined charge recombination on single-crystal mixed-halide perovskites (namely, MAPb(Br$_{1-y}$I$_y$)$_3$) by performing time-resolved photoluminescence and microwave photoconductivity analyses. Their study suggests the presence of three different recombination processes: two dominated by trapping of electrons with a lifetime below 60 ns; and one dominated by the trapping of holes with a lifetime up to 10 µs. The authors also found that such recombination processes are strongly related to the stoichiometric ratio between the two anions (Br$^-$ and I$^-$), and that their results will be helpful in the proper design of p-i-n architectures for perovskite-based solar cells.

Despite the large power conversion efficiency achieved by perovskite solar cells, this technology still suffers from limited stability and reliability. These issues were addressed by Lago et al. [3], who investigated the intrinsic instability of triple-cation mixed-halide perovskite solar cells. The authors monitored cell behavior during shelf-life conditions, focusing their attention on the role of the hole-blocking layer. They tested two commonly adopted hole-blocking layers, namely bathocuproine (BPC) and tin oxide (SnO$_2$), showing that they are the cause of short-circuit current and open-circuit voltage instabilities, respectively. They also confirmed their analysis by introducing a predictive model that will be useful to understanding future reliability studies on perovskite solar cells.

Finally, Ma et al. [4] reviewed the strategies for perovskite thin-film deposition by the use of ultrasonic spray-coating technique. They discussed the advantages of spray-coating with respect to the spin-coating methodology, emphasizing the scale-up capabilities of the former technique. Indeed, the pressing need of new alternatives to silicon demands the fine control of thin-film parameters like thickness, roughness, and crystal size, in order to achieve a uniform perovskite layer over a large area. The authors also reviewed the principal characterization techniques for use in monitoring the quality of the deposited thin-film, which is fundamental for industrialization. This critical analysis encourages the implementation of ultrasonic spray-coating within a roll-to-roll process for the fabrication of perovskite solar cells, moving forward from small-area laboratory-scale to large-area industrial-scale production.

This Special Issue, entitled “Advances in Photovoltaic Materials and Devices”, provides a compact view of the research interests in the field of next-generation photovoltaic materials, discussing topics ranging from multi-crystalline silicon to perovskites.

Conflicts of Interest: The author declares no conflict of interest.

References
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