SCIENCE CHINA
Physics, Mechanics & Astronomy

•Editorial•
Special Topic: Recent Developments and Challenges in Solar Cells

January 2023 Vol. 66 No. 1: 217300
https://doi.org/10.1007/s11433-022-2027-9

Editorial

Modern society is becoming more dependent on clean and sustainable energy resources because of growing energy demand caused by population and economic expansion, as well as limited traditional fossil fuels, which can cause significant damage to our environment. Solar cell technology, which uses the photovoltaic effect to convert sunlight directly into electricity, has emerged as the most promising renewable energy source because of the infinite abundance of sunlight, low transportation costs, and low pollution. In most cases, the core structure of a solar cell consists of an absorption layer, which uses the photon energy of sunlight to produce electron-hole pairs in a semiconductor, and a p-n junction, which induces a built-in electric field to separate light-generated carriers and creates a flow of electricity when connected to an external circuit. In addition to matching window layer and electrode, an ideal solar cell absorber material should have the following attributes: (i) strong absorption of visible light with a direct energy band gap in the range of 1.0-1.5 eV; (ii) excellent defect properties for introducing charge carriers and reducing nonradiative carrier recombination; (iii) good transport and interface properties to rapidly move photo-generated carriers to the electrodes; and (iv) high stability with materials that are low cost and nontoxic.

After the first Si solar cell was introduced in 1954, other solar cell technologies were developed, such as single-junction thin-film solar cells based on direct band gap semiconductors, i.e., GaAs, CdTe, $Cu(In,Ga)Se_2$ (CIGS), and $Cu_2ZnSn(S,Se)_4$ (CZTS). The recent generation of solar cells also includes organic solar cells, dye-sensitized solar cells, quantum dot solar cells, and hybrid perovskite-based solar cells. Despite the tremendous technological advances of the past few decades, the power conversion efficiency (PCE) of a single-junction solar cell is still significantly lower than the Shockley-Queisser (SQ) limit, and the cost of solar cells relative to fossil fuel-based technologies has remained the major obstacle to its widespread applications. Most of the issues in these systems are connected to defect control [1]. For example, self-compensation is responsible for the low hole carrier density and short electron lifetime in CdTe, the significant nonradiative carrier recombination in CIGS, and the low open-circuit voltage in CZTS. In addition, easy defect formation and diffusion are the major factors of instability in hybrid perovskite solar cells. Progress in solar cell technology will require a breakthrough in understanding and controlling the defect properties of solar cell materials [1-10]. Developing multijunction tandem solar cells is considered the logical next step in the evolution of high-efficiency solar cells beyond the SQ limit of single-junction solar cells.

To further improve the efficiency, stability, and production cost of solar cells, it is critical to understand the various issues associated with the performance of solar cell technologies and the possible solutions to these issues. In this special topic, recent advancements, and unresolved issues of some of the solar cell technologies are reviewed, including traditional CIGS solar cells [2], CZTS solar cells [3], and emerging Pb chalcogenide-based quantum dot solar cells [4], perovskite/silicon tandem solar cells [5,6], and low-dimensional perovskite solar cells [7]. We would like to thank all the authors who have contributed to this special topic published by *SCIENCE CHINA Physics*, *Mechanics & Astronomy*. We hope that this study and other related studies [8-10] will provide a better understanding of the current status of solar cell technologies and the underlying physics and material sciences to guide the future development of solar cell technologies.

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