VOL. 18, NO. 13, JULY 2023 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

A REVIEW OF PEROVSKITE SOLAR CELL (PSC): ITS REVOLUTION AND MATHEMATICAL MODELLING

Lee Jin Yao[1], Rahifa Binti Ranom[1], Kyairul Azmi Baharin[1] and Norhafizah Md Sarif[2]
[1]Fakulti Kejuruteraan Elektrik (FKE), Universiti Teknikal Malaysia Melaka (UTeM), Hang Tuah Jaya, Durian Tunggal, Melaka, Malaysia
[2]Centre for Mathematical Sciences, Universiti Malaysia Pahang Al-Sultan Abdullah, 26300 Gambang, Pahang
E-Mail: m012120006@student.utem.edu.my

ABSTRACT

Perovskite solar cell (PSC) is one of the third-generation type of solar cells that has high efficiency and can be produced at a lower cost compared to silicon-based solar cells. However, one of its core problems is the uncertainty of its short- and long-term stability. To minimise this risk, proper modelling is required to assess its potential performance before fabrication. Modelling of PSC is also important to prevent wastage of time and optimise material use. This work provides a comprehensive review of current PSC circuitry and the electrochemical modelling techniques available. Circuitry modelling relates to the operation conditions where PSC is represented by an equivalent circuit model that contains a resistor, diode, photo-generated current source, and others. Meanwhile, electrochemical modelling refers to the operation mechanism of PSC and can be represented by mathematical equations that include parameters of charge density of the layers, drift, diffusion, generation, and recombination process of charge carriers. This paper also summarizes the numerical algorithms and modelling simulations used such as SCAPS, AFORS-HET, COMSOL Multiphysics, MATLAB to evaluate PSC model performance. Through this paper, a summary of the modelling results has been compiled covering various aspects of fabrication including the material's layer thickness, doping concentration, electron affinities as well as temperature distribution within the PSC during operation.

Keywords: perovskite solar cells, circuitry modelling, electrochemical modelling, steady-state, numerical simulation.

Manuscript Received 22 February 2023; Revised 24 August 2023; Published 13 September 2023

INTRODUCTION

Solar is a form of sustainable energy that can convert sunlight into electricity [1]. Table-1 depicts the process of developing power conversion tech that transforms solar power into electricity:

Table-1. The process of developing power conversion tech that transforms solar power into electricity.

Year	Process
1839	Alexandre Edmond Becquerel, a French physicist, discovered the photovoltaic effect by immersing a cell composed of metal anode and cathode in an electrolyte liquid and exposing it to light [2].
1877	William Grylls Adams and Richard Evans Day applied the photovoltaic principle that was discovered by Alexandre Edmond Becquerel in selenium [2].
1883	Charles Fritz invented the first selenium solar cell [2].
1940	Russell Shoemaker Ohl found that current flowed through silicon samples which had cracked in the middle when the sample was exposed to light [3].
1946	Russell Shoemaker Ohl patented the silicon solar cell with around 1% efficiency [4].
1954	Bell Labs scientists developed the very first practical solar cell using silicon with a 6% effectiveness [2].

THE REVOLUTION OF SOLAR CELL

The solar cell underwent a few revolutions over several decades from the first generation of silicon solar cells developed in 1954 until now. Table-2 compares the three generations of solar cells [5]. Among the third-generation solar cells, the efficiency of power conversion for perovskite solar cells (PSC) has growth with swiftly within a short time interval compared to other materials as it has tremendous potential in the future to upgrade solar cell performance to the next level in terms of increased power conversion efficiency and stability but with lower manufacturing costs. In this paper, the PSC will be explained in terms of their materials, structure architecture, and operation principles. The modelling of PSC conducted by researchers with different approaches will be reviewed in this paper to have a better understanding of the process of converting solar energy to electrical energy in PSC and extract the parameters that are involved in the related processes.

PEROVSKITE CRYSTAL STRUCTURE, MATERIALS, AND SOLAR CELL ARCHITECTURE

Perovskite is a natural mineral material found in the Ural Mountains in Russia. The founder of the perovskite is a mineralogist named L. A. Perovski who found the perovskite in 1839 composed of calcium, titanium, and oxygen with the chemical formula $CaTiO_3$ [6]. After that, an organic-inorganic lead or tin halide compound that has a similar material with the formula ABX_3 was considered a perovskite compound. In ABX_3