Highlights

main title

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- Proposed deep learning-based method to predict iron contamination in Si-SC by using IV curve.
- The simulated IV characteristics are used to create training and test datasets.
- The DNN's configurations are proposed.
- The mean squared relative error of prediction is up to 0.005.

main title

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ABSTRACT

Defect-assisted recombination processes frequently limit the photovoltaic device performance. The low-cost and express methods of impurity contamination control are in demand at solar cell manufacturing. In this paper, we applied deep learning-based approach to extract the iron concentration in silicon solar cell from an ideality factor values.

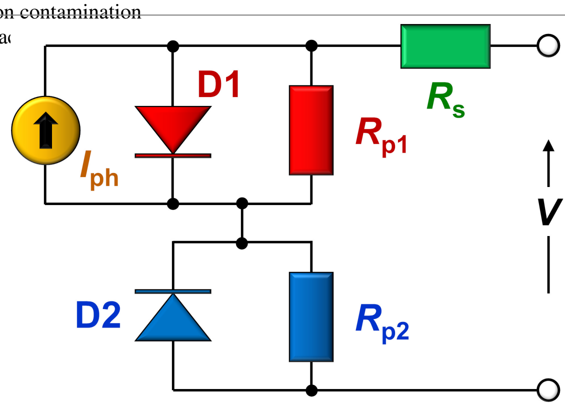

Figure 1: The opposed two–diode equivalent–circuit model of a solar cell.

1. Introduction

2. Models and Methods

2.1. Solar cell model

Fig. 1 vividly reveals the structure of the used model [1]. It can be seen from the figure that model contains a current source accompanied by a diode D1, a shunt resistor R_{p1} to show the leakage current, and a series resistor R_s to consider the losses associated with the load current. Besides, the second diode D2 with a second parallel resistance R_{p2} is placed opposite to the first one and is essential to simulate the non-ideal effects of the active layer/cathode interface. In this model, D1 is responsible for the exponential behavior of the I–V curve, the main contribution of D2 is to simulate the S–shape. The analytical solution $V(I)$ of the opposed two–diode equivalent circuit model was obtained [2] using Lambert W-function [3]:

$$\begin{aligned}
V \;=\; & (I+I_{ph}+I_{01})R_{p1} \\
& -\frac{n_1kT}{q}W\left\{\frac{qI_{01}R_{p1}}{n_1kT}\exp\left[\frac{qR_{p1}(I+I_{ph}+I_{01})}{n_1kT}\right]\right\} \\
& +\frac{n_2kT}{q}W\left\{\frac{qI_{02}R_{p2}}{n_2kT}\exp\left[-\frac{qR_{p2}(I-I_{02})}{n_2kT}\right]\right\} \\
& +(I-I_{02})R_{p2}+IR_s\,, \qquad (1)
\end{aligned}$$

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Table 1

where I_{01} and I_{02} are the saturation currents and n_1 and n_2 are the ideality factors for D1 and D2 respectively, and I_{ph} is the ideal photocurrent. Thus, the model employs eight lumped parameters (I_{01}, n_1, R_{p1}, I_{02}, n_2, R_{p2}, R_s, and I_{ph}) that need to be determined from the I-V curve.

The expression (1) has a drawback in that it tends to stray from the range of numbers that can be accommodated by the standard 64-bit floating-point format owing to the presence of exponential functions for larger numbers. To overcome this drawback, the use of the g–function $g(x) = \ln(W(\exp(x)))$ was suggested [4]. The analytical solution $V(I)$ using the g–function is as follows [4]

$$\begin{aligned}
V(I) =& IR_s+\frac{n_1kT}{q}g(x_1)-\frac{n_2kT}{q}g(x_2) \\
& -\frac{n_1kT}{q}\ln\left[\frac{qI_{01}R_{p1}}{n_1kT}\right]+\frac{n_2kT}{q}\ln\left[\frac{qI_{02}R_{p2}}{n_2kT}\right]\,,
\end{aligned} \qquad (2)$$

with

$$x_1=\ln\left(\frac{qI_{01}R_{p1}}{n_1kT}\right)+\frac{q(I+I_{ph}+I_{01})R_{p1}}{n_1kT}\,, \qquad (3)$$

and

$$x_2=\ln\left(\frac{qI_{02}R_{p2}}{n_2kT}\right)-\frac{q(I-I_{02})R_{p2}}{n_2kT}\,. \qquad (4)$$

We used Eqs. (2)–(4) both for simulation I–V curves and during the approximation procedure. The g–function was evaluated by using iterative procedure [4].

References

[1] F. A. de Castro, J. Heier, F. A. Nüesch, R. Hany, Origin of the kink in current-density versus voltage curves and efficiency enhancement of polymer–C_{60} heterojunction solar cells, IEEE J. Sel. Top. Quantum Electron. 16 (2010) 1690–1699.

[2] B. Romero, G. del Pozo, B. Arredondo, Exact analytical solution of a two diode circuit model for organic solar cells showing S–shape using Lambert W–functions, Sol. Energy 86 (2012) 3026–3029.
[3] L. Lóczi, Guaranteed- and high-precision evaluation of the Lambert W function, Appl. Math. Comput. 433 (2022) 127406.
[4] K. Roberts, S. R. Valluri, On calculating the current-voltage characteristic of multi-diode models for organic solar cells, 2015.