African Union Journal of Academic and Research Studies
مجلة الاتحاد الأفريقي للدراسات الأكاديمية والبحثية
Volume 1, Issue 3, 2026, Pages: 01-06
Journal homepage :https://aujars-journal.com/index.php/aujars/ar/index

Calculating the Efficiency of a Magnesium Oxide-Coated Solar Cell Based on Voltage and Current Variables

Mohammedain Adam Allhgabo Belal *[1], Magzoub Mohammed Alhassan Mustafa [2], Ali Salih Ali Salih [3], Mohammed Abbas Alhag [4], Safa Hussein Hassan Braima [5], Tasabeeh Farh Althir Hassan [6]

[1,2] Department of Physics, Faculty of Science, University of Kordofan, Elobeid, Sudan
[3] Department of Physics, Faculty of Education, University of Kordofan, Elobeid, Sudan
[4] Faculty of Engineering and Technical Studies, Kordofan University, Sudan
[5,6] Department of Diagnostic Radiology, Military Hospital, Elobeid, Sudan

حساب كفاءة الخلية الشمسية المطلية بأكسيد المغنيسيوم اعتماداً على متغيرات الجهد والتيار

محمدين آدم الله جابو بلال [1]*، مجذوب محمد الحسن مصطفى [2]، علي صالح علي صالح [3]، محمد عباس الحاج [4]، صفاء حسين حسن بريمة [5]، تسابيح فرح الطاهر حسن [6]

[1،2] قسم الفيزياء، كلية العلوم، جامعة كردفان ، الأبيض، السودان
[3] قسم الفيزياء، كلية التربية، جامعة كردفان، الأبيض، السودان
[4] قسم الهندسة الكهربائية، كلية الهندسة والدراسات التقنية، جامعة كردفان، السودان
[5،6] قسم الأشعة التشخيصية، مستشفى السلاح الطبي، الأبيض، السودان

*Corresponding author: allsaffre@gmail.com

Received: September 09, 2026	Accepted: November 13, 2026	Published: November 22, 2026

Abstract:
This study aimed to analyze the effect of magnesium oxide (MgO) layer thickness on the electrical properties of thin solar cells. Samples with thicknesses of 16, 24, and 36 nm were prepared, and measurements were taken for short-circuit current (Isc), short-circuit current density (Jsc), open-circuit voltage (Voc), and fill factor (FF). The results showed that increasing MgO thickness leads to higher short-circuit current and current density, thus improving the maximum power and efficiency, while the open-circuit voltage showed a non-linear variation. These results highlight the importance of controlling MgO thickness to optimize the performance of thin solar cells.

Keywords: magnesium oxide, thin solar cells, thicknesses, short-circuit current, short-circuit current density, open-circuit voltage, fill factor, efficiency.

الملخص:
هدفت هذه الدراسة إلى تحليل تأثير سُمك طبقة أكسيد المغنيسيوم *(MgO)* في الخصائص الكهربائية للخلايا الشمسية الرقيقة. أُعدّت عينات بسماكات 16 و24 و36 نانومترًا، وأُجريت قياسات تيار القصر *(Isc)*، وكثافة تيار القصر *(Jsc)*، وجهد الدائرة المفتوحة*(Voc)* ، ومعامل الامتلاء *(FF)*. أظهرت النتائج أن زيادة سُمك طبقة أكسيد المغنيسيوم تؤدي إلى ارتفاع تيار القصر وكثافة تياره، مما يحسّن القدرة القصوى والكفاءة، في حين أظهر جهد الدائرة المفتوحة تغيرًا غير خطي. وتبرز هذه النتائج أهمية التحكم في سُمك طبقة أكسيد المغنيسيوم لتحسين أداء الخلايا الشمسية الرقيقة.

الكلمات المفتاحية: أكسيد المغنيسيوم، الخلايا الشمسية الرقيقة، السُمك، تيار القصر، كثافة تيار القصر، جهد الدائرة المفتوحة، معامل الامتلاء، الكفاءة.

1. Introduction:

1.1. Magnesium oxide:

Magnesium oxide (MgO) is an important inorganic material that has attracted significant attention due to its excellent optical, electrical, and thermal properties. It has a wide band gap (~7.8 eV), high transparency in the visible region, and good chemical stability, making it suitable for applications in optoelectronic devices and thin-

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

film technologies [9]. In recent years, MgO has been widely used as a coating layer in solar cells to improve light absorption, reduce recombination losses, and enhance overall device performance [10].
The thickness of MgO thin films plays a crucial role in determining the efficiency and electrical characteristics of solar cells, as it directly affects current density and voltage behavior [11].

2. Theoretical background:

2.1. Photovoltaic Effect

Solar cells operate based on the photovoltaic effect, where incident light photons are absorbed by a semiconductor material, generating electron–hole pairs. These charge carriers are separated by an internal electric field, producing an electric current when the cell is connected to an external circuit [1][2].

2.2. Current–Voltage Relationship

The performance of a solar cell is mainly described by the relationship between current and voltage. The short-circuit current represents the maximum current produced when the external resistance is negligible and depends on light absorption and photon flux [2][3].
The open-circuit voltage represents the maximum voltage when no current flows. It is influenced by material properties such as band gap, recombination mechanisms, and internal resistances. While current is strongly dependent on light intensity, voltage is more sensitive to internal losses [3][4].

2.3. Solar Cell Efficiency

The efficiency of a solar cell indicates its ability to convert incident light into electrical energy. It depends on the combined effect of current, voltage, and device quality. Achieving high efficiency requires optimizing both current generation and voltage output simultaneously [2][5].

2.4. Fill Factor (FF)

The fill factor is a key parameter that reflects the quality of a solar cell. It describes how close the actual power output is to the ideal value. A higher fill factor indicates lower internal losses and better electrical performance [4][5].

2.5. Role of MgO Thin Films

Magnesium oxide (MgO) is widely used as a coating material due to its wide band gap, high transparency, and chemical stability. It improves light transmission and reduces surface recombination, enhancing solar cell performance [6][7].

2.6. Effect of Thickness on Performance

The thickness of the MgO layer plays a critical role in determining solar cell performance. Increasing thickness can enhance light absorption and current generation, but excessive thickness may introduce recombination losses and internal resistance, reducing voltage and efficiency [6][8].

2.7. Charge Carrier Generation and Recombination

When photons are absorbed, electron–hole pairs are generated, but some recombine before contributing to the current. Recombination reduces carrier lifetime and decreases efficiency. Minimizing recombination is essential for improving solar cell performance [1][3][5].

2.8. Internal Resistances in Solar Cells

Solar cells are affected by series and shunt resistances. High series resistance reduces current flow, while low shunt resistance causes leakage currents. Both factors negatively impact voltage, fill factor, and overall efficiency [4][5].

2.9. Optical Properties and Light Absorption

Efficient light absorption is crucial for high-performance solar cells. Materials with suitable optical properties enhance photon absorption. MgO layers can improve light management and reduce reflection losses, contributing to better performance [6][7].

2.10. Thin-Film Solar Cell Technology

Thin-film solar cells use very thin layers of materials, reducing cost and material consumption. However, optimizing layer thickness is necessary to maintain efficient light absorption and electrical performance [2][8].

3. Research problem:

Thin solar cells face challenges in improving light absorption and electrical efficiency due to the limited thickness of active layers. Understanding the relationship between MgO layer thickness and the electrical properties of the cell is essential for designing more efficient solar cells.

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

4. Objective:
1-To study the effect of MgO layer thickness on short-circuit current (Isc) and current density (Jsc).
2-To measure the open-circuit voltage (Voc) and fill factor (FF) of the solar cells.
3-To evaluate the impact of MgO thickness on maximum power output and overall electrical efficiency.

5. Importance of the Research:
1-Improve the design of thin solar cells by selecting the optimal MgO thickness.
2-Increase light absorption and electrical efficiency of the solar cells.
3-Provide a scientific basis for economically and technically efficient thin solar cell fabrication.

6. Materials, Instruments, and Tools:
6.1. Instruments:
Devices for measuring voltage and current.

6.2. Materials:
1-MgO films with thicknesses of 16, 24, and 36 nm.
2-Substrate for thin film deposition.
3-Electrical wires for connections.

6.3. Tools:
1-Voltage and current measurement devices.
2-Sample preparation and thin-film deposition equipment.

7. Methodology:
1-Prepare three MgO samples with thicknesses of 16, 24, and 36 nm on suitable substrates.
2-Connect the samples to the electrical circuit and measure:
a-Short-circuit current (Isc)
b-Short-circuit current density (Jsc)
c-Open-circuit voltage (Voc)
3-Calculate the fill factor (FF) and maximum power (Pmax) for each sample.
4- Determine the electrical efficiency of each sample and compare results based on MgO thickness.

8. Results and Discussion:
Introduction:
Thin solar cells are among the most important renewable energy technologies, as they rely on absorbing light and converting it into electrical energy. The properties of thin layers, such as the thickness of the magnesium oxide (MgO) layer, play a significant role in the performance of solar cells in terms of current, voltage, and efficiency. Studying the effect of MgO thickness helps improve light absorption and increase the electrical output of the cells, contributing to the development of more efficient and energy-saving solar cells.

Table (1) Current and voltage of MgO sample, thickness 16 nm, Solar cell**.**

Voltage (V)	Current (mA)
0	13
0.47	13
0.20	12.8
0.47	13
0.38	12.78
0.46	12.66
0.52	9.40
0.53	5.05
0.535	0

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

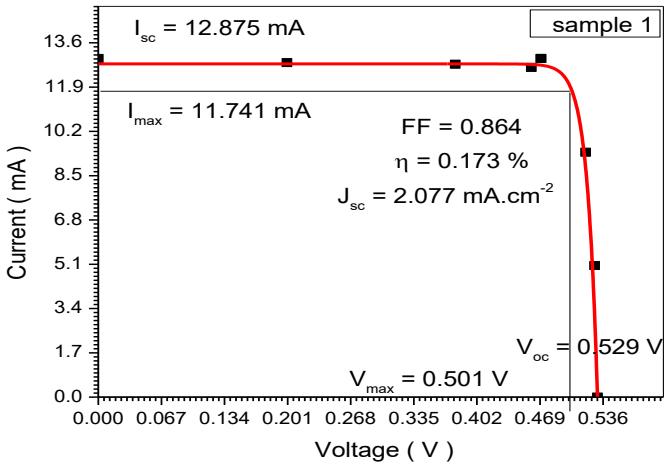


Figure 1: Several factors for the characterization of the MgO sample thickness of 16 nm Solar cell.

Fig (1) Several factors for characterization of MgO sample thickness 16 nm solar cell Short-circuit current (I_{sc}) and short-circuit current density (J_{sc})If the external circuit is simply a wire and has no appreciable resistance, the current that flows is the short-circuit current (I_{sc}) and is directly related to the number of photons of light being absorbed by the cell. Short-circuit current density (J_{sc}) is short-circuit current per active are I_{SC} = 12.875 m A $J_{sc} = I_{sc} \div active\ aera = 2.077 m$Acm^{-2} Open–circuit voltage (V_{oc}) V_{oc}= 0.529 V Fill factor (FF). The fill factor (FF) is obtained by dividing the product of current and voltage measured at the power point (maximum output power P_{max}) by the product of short-circuit current and the open-circuit voltage**.**

Table (2) Current and voltage of MgO sample, thickness 24 nm Solar cell.

Voltage (V)	Current (mA)
0	22.6
0.00865	22.08944
0.01692	21.82551
0.10087	21.91349
0.18481	21.64223
0.22269	21.91349
0.2499	21.45894
0.27942	21.45894
0.32558	21.37097
0.34212	17.93988
0.34567	10.72581
0.35	0

\

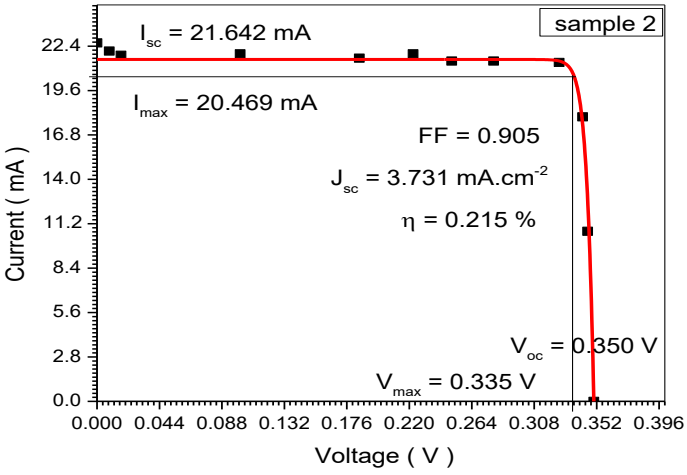


Figure 2 Several factors for the characterization of the MgO sample thickness of 24 nm Solar cell.

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Fig (2) Several factors for characterization of MgO sample thickness 24 nm solar cell. Short-circuit current (I_{sc}) and short-circuit current density (J_{sc})If the external circuit is simply a wire and has no appreciable resistance, the current that flows is the short-circuit current (I_{sc}) and is directly related to the number of photons of light being absorbed by the cell. Short-circuit current density (J_{sc}) is short-circuit current per active are I_{SC} = 21.642 mA $J_{sc} = I_{sc} \div active\ aera = 3.731\ m\text{Acm}^{-2}$ Open–circuit voltage (V_{oc}) V_{oc}= 0.350 V. Fill factor (FF). The fill factor (FF) is obtained by dividing the product of current and voltage measured at the power point (maximum output power P_{max}) by the product of short-circuit current and the open-circuit voltage.

Table (3) Current and voltage of MgO sample, thickness 36 nm, Solar cell.

Voltage (V)	Current (mA)
0	24.5
0.0519	24.20161
0.11095	23.50806
0.14487	24.20161
0.18134	23.50806
0.25663	23.70968
0.32202	23.60484
0.37106	17.45161
0.37729	8.91935
0.38	0

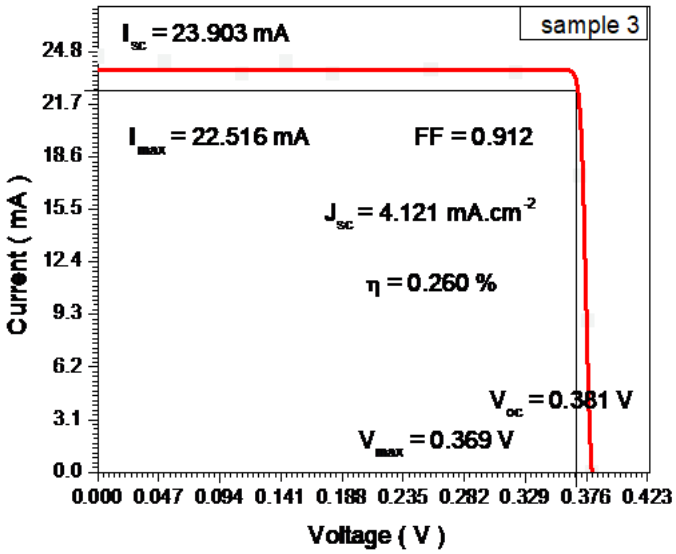


Figure 3 shows several factors for the characterization of the MgO sample thickness of 36 nm Solar cell.

Fig (3) Several factors for characterization of MgO sample thickness 36 nm solar cell. Short-circuit current (I_{sc}) and short-circuit current density (J_{sc})If the external circuit is simply a wire and has no appreciable resistance, the current that flows is the short-circuit current (I_{sc}) and is directly related to the number of photons of light being absorbed by the cell. Short-circuit current density (J_{sc}) is short-circuit current per active are I_{SC} = 23.903 m A $J_{sc} = I_{sc} \div active\ aera = 4.121\ m\text{Acm}^{-2}$ Open–circuit voltage (V_{oc}) Voc= 0.381 V Fill factor (FF). The fill factor (FF) is obtained by dividing the product of current and voltage measured at the power point (maximum output power P_{max}) by the product of short-circuit current and the open-circuit voltage.

9. Recommendations:

1-Use MgO thickness between 24–36 nm to achieve the highest current density and efficiency.
2-Study the effect of thermal treatment and different deposition methods on cell properties.
3-Integrate MgO with other materials, such as TiO_2 or ZnO, to enhance light absorption and efficiency.

10. Conclusion:

The study showed that increasing the MgO layer thickness leads to higher short-circuit current, current density, and maximum power, improving the solar cell's electrical performance. However, the open-circuit voltage

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

changes non-linearly with thickness, highlighting the importance of selecting an optimal thickness to balance light absorption and electrical efficiency. These results provide a scientific basis for designing more efficient thin solar cells.

Reference:

[1] Sze, S. M., & Ng, K. K. (2007). *Physics of semiconductor devices* (3rd ed.). Wiley.
[2] Green, M. A. (1982). *Solar cells: Operating principles, technology, and system applications*. Prentice-Hall.
[3] Nelson, J. (2003). *The physics of solar cells*. Imperial College Press.
[4] Luque, A., & Hegedus, S. (2011). *Handbook of photovoltaic science and engineering*. Wiley.
[5] Würfel, P. (2009). *Physics of solar cells: From basic principles to advanced concepts*. Wiley-VCH.
[6] Kittel, C. (2005). *Introduction to solid state physics* (8th ed.). Wiley.
[7] Yacobi, B. G. (2003). *Semiconductor materials: An introduction to basic principles*. Springer.
[8] Chopra, K. L., Paulson, P. D., & Dutta, V. (2004). Thin-film solar cells: An overview. *Progress in Photovoltaics*, *12*, 69–92.
[9] Sze, S. M., & Ng, K. K. (2007). *Physics of semiconductor devices* (3rd ed.). Wiley.
[10] Green, M. A. (1982). *Solar cells: Operating principles, technology, and system applications*. Prentice-Hall.
[11] Callister, W. D. (2007). *Materials science and engineering: An introduction*. Wiley.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of **AUJARS** and/or the editor(s). **AUJARS** and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

 Copyright: © 2026 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).