Journal of Renewable Energies

Revue des Energies Renouvelables

journal home page : https://revue.cder.dz/index.php/rer

Using two-dimensional graphene lenses to increase the effectiveness of solar panels

Abid Boudiar [a,*], Habala Bendifallah [a,b], Faten Ziani [c]

[a] *Department of material sciences, Echahid Cheikh Larbi Tebessi University, Tebessa, Algeria*

[b] *Renewable Energy development Unit in Arid Zones, Echahid Hamma Lakhdar University, El Oued, Algeria*

[c] *Laboratory of Applied and Theoretical Physics, Echahid Cheikh Larbi Tebessi University-Tébessa, Algeria*

* *Corresponding author, E-mail address: boudiarabid11@gmail.com*
Tel.: + 213 555718853

Abstract

We aim to enhance the efficiency of solar panels by covering them with graphene lenses that collect and concentrate light rays onto the panels. The simulation was performed using the Monte Carlo method and provided precise results regarding the improvement of solar panel performance. The simulation showed a substantial increase in the intensity of electrical current at critical densities of the graphene lenses used, suggesting the need for further research to enhance the utilization of renewable energy sources, even in regions with limited sun exposure and varying weather conditions.

Keywords: Graphene, Lenses, Solar panels, Non-desert areas.

1. Introduction

Solar energy is poised to be a major source of power in the future, due to its well-known benefits, as evidenced by the large body of research that has been conducted in this field. However, there are still several technological challenges that need to be addressed, such as the storage and transmission of electrical energy generated by solar panels, as well as their usage in non-desert or cloudy areas [1]. This research aims to improve the performance of solar panels in low-light conditions, such as in urban areas or regions with changing weather [2]. To achieve this, the study utilized 2D materials, specifically graphene, which possesses a range of desirable properties, including transparency, high conductivity (a million times that of copper.), flexibility, and strength. With the capability to produce large quantities of ultra-thin graphene lenses in a compact space, it is now possible to use these lenses to increase the amount of sunlight reaching solar panels [3]. The Monte Carlo method was used to model and run the simulation, taking advantage of the randomness in the intersection ratio and the number of graphene chips stacked on top of each other. The ratio of current intensity produced by the solar panels before and after they were covered with graphene lenses was calculated using statistical physics, allowing for the identification of critical values to enhance performance. The positive results of this study offer a wide range of potential applications, especially with the advancements in the mass production of graphene chips. The mass production of ultra-thin and densely packed graphene lenses will increase the intensity of light beams reaching solar panels, thereby boosting their efficiency [4].

2. Improving solar cells using graphene lenses

Research has become increasingly focused on ultrathin lenses due to advancements in technology across a variety of industries, such as medical diagnostics, communication, and sensing. This is largely driven by the emergence of two-dimensional materials, specifically graphene, which has gained significant attention from researchers [5]. Graphene is a single layer of carbon atoms arranged in a hexagonal pattern, possessing exceptional optical properties and the ability to interact with different wave frequencies, which can be adjusted through chemical doping or electrostatics [6]. The strength and flexibility of ultrathin lenses made from graphene oxide allow for effective focusing even under stressful conditions, leading to the production of high-density lenses on graphene surfaces that provide precise manipulation of light [7]. Additionally, these ultra-thin graphene lenses exhibit resistance to thermal, chemical, and environmental damage, even when exposed to UV light [8]. There is also potential for practical applications, such as improving solar cell efficiency by creating a protective layer and collecting more light. Large-scale production of ultrathin graphene lenses has the potential to bring environmental and economic benefits by covering solar cells with a vast number of lenses [9].

3. Monte Carlo simulations

The effectiveness of graphene lenses has been well proven by extensive research and experiments. However, there are still some technological challenges that need to be overcome before they can be used to cover solar panels. The main challenges are:

1- Current technology does not allow the creation of large enough graphene lenses to cover the surface area of solar panels.

2- There is a possibility to form two or three layers of graphene lenses, which may lead to localized inhomogeneities on the surfaces of the solar panels.

The Monte Carlo method is used to study the impact of these issues on solar power generation efficiency, as it is prone to unpredictability. Three factors are taken into account, namely the number of layers, their direction and the intensity of the light. The simulation starts with the Monte Carlo method and a first random number (RN-LN) specifies the number of intersecting layers, with a range of 2 to 10. The second random number (RN-LIR) represents the ratio of the intercept with the range 0 to 1. The third random number (RN-LMV) represents the maximum radiation intensity received by the graphene lenses, which correlates with random weather conditions.

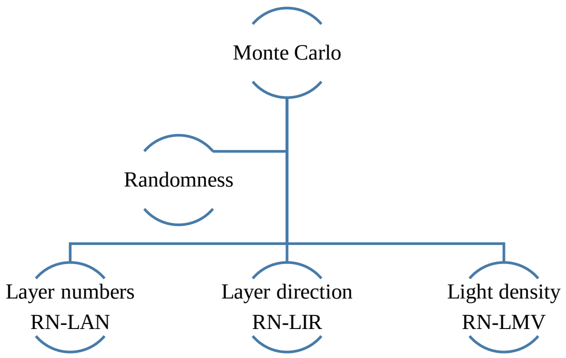

Fig 1. A graphical representation depicting the three elements of randomness.

4. Results and discussions

The simulation results of a single graphene lens' focused energy density reveal that, similar to traditional light-focusing lenses, the highest density is concentrated at the center, as depicted in Fig. 2.

Fig. 3 shows that when the energy crosses over, it scatters to two nearby locations but with a smaller size. We utilized a modeling approach to determine the effect of coating a solar panel with a layer of graphene on its ability to generate electric current, which confirmed that there is a specific range of critical concentrations, between 0.8 and 1, where the electric current can be increased by approximately 2 times.

The data presented in Fig. 3 indicates that the electric current of solar panels coated with 2D graphene lenses increases in the range of 0.8 to 1 in intensity. The reason for this is the restriction of the ratio of connections between the lenses, producing the maximum power generation. However, as the surface concentration of graphene lenses increases, the increase in electric current slows down as a result of more connections between the lenses reducing efficiency. Nevertheless, the current density ratio stays above 1, demonstrating the success of this approach.

The statement also reveals that the maximum increase in electric current is attained with the highest lens concentration per graphene wafer "delta", displayed in red in Fig. 3. This means that the negative intersections between the lenses can be controlled by increasing the area of the graphene flakes utilized for solar panel coating. This was made feasible due to advancements in industrial-level graphene production methods [10].

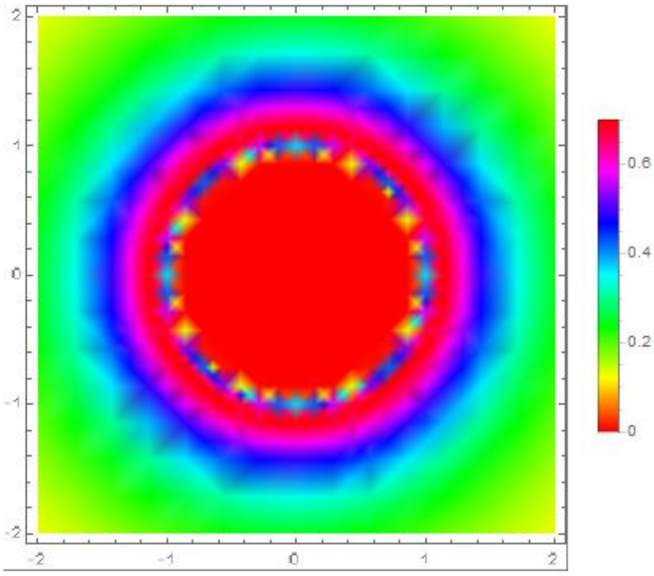

Fig 2. Energy density focused by one graphene lens.

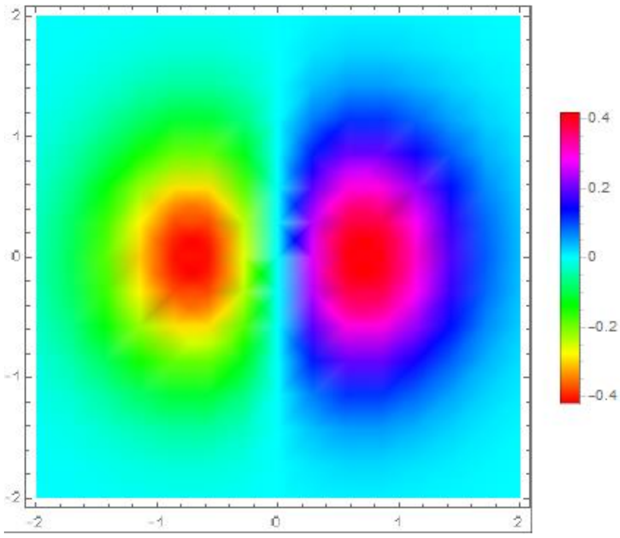

Fig 3. Energy density focused by two intersecting graphene lenses.

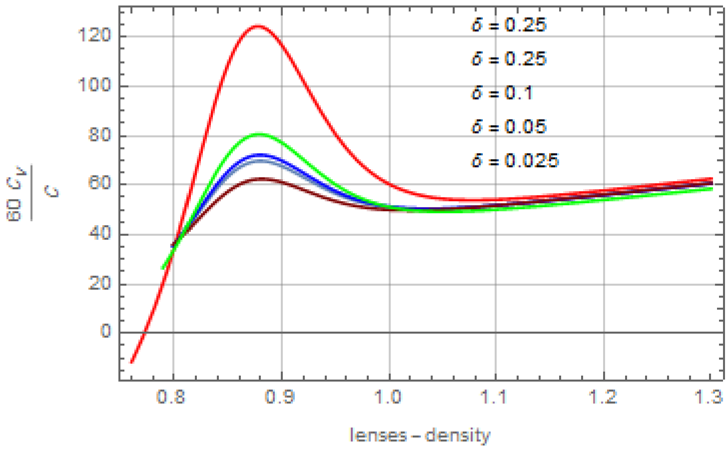

Fig 4. Current ratio of coated solar panel vs lenses intensity.

5. Conclusion

There are several independent variables, which causes the simulation process to take a lengthy time. It can be shortened, though, when figuring out the values of some of those random variables, such the RN-LMV coefficient in a certain meteorological scenario. The process of manufacturing a single thin film lens for surface coating of solar panels is technically very challenging, at least for the time being. Therefore, the emergence of intersections between the layers of graphene lenses is inevitable. However, we found via the use of the Monte Carlo simulation approach that the impact of these edges is minimal because we saw a high energy density at these intersections.

Although there are many new researches concerned with improving the performance of solar panels with different technologies, weather factors are the hard test for all of these technologies. And our research tries to give one solution to these two issues.

As the distinguished properties of graphene, known for its strength, flexibility and transparency, will protect the solar panels from volatile weather factors. The use of ultra-thin lenses that are formed in large quantities on the surface of the graphene will increase the intensity of the incident light and thus increase the amount of energy produce.Therefore, this research shows the extent of the impact of this phenomenon on the proposed model, and we expect the proposed model to perform well when put into practice.

6. Acknowledgements

The authors are grateful to the Research Center for the Development of Renewable Energies in Arid Zones at El-Oued University for their support of this study.

7. References

[1] Zheng X, Jia B, Lin H, Qiu L, Li D, Gu M. Highly efficient and ultra-broadband graphene oxide ultrathin lenses with three-dimensional subwavelength focusing. Nature communications. 2015;6(1):8433. doi.org/10.1038/ncomms9433.

[2] Yettou F, Malek A, Haddadi M, Gama A. Etude comparative de deux modèles de calcul du rayonnement solaire par ciel clair en Algérie. Journal of Renewable Energies. 2009:12(2):331-46.

[3] Cao G, Lin H, Fraser S, Zheng X, Del Rosal B, Gan Z, Wei S, Gan X, Jia B. Resilient graphene ultrathin flat lens in aerospace, chemical, and biological harsh environments. ACS applied materials & interfaces. 2019;11(22):20298-303. doi.org/10.1021/acsami.9b05109.

[4] Wu J, Lin H, Moss DJ, Loh KP, Jia B. Graphene oxide for photonics, electronics and optoelectronics. Nature Reviews Chemistry. 2023:1-22. doi.org/10.1038/s41570-022-00458-7

[5] Yin R, Xu Z, Mei M, Chen Z, Wang K, Liu Y, Tang T, Priydarshi MK, Meng X, Zhao S, Deng B. Soft transparent graphene contact lens electrodes for conformal full-cornea recording of electroretinogram. Nature communications. 2018 ;9(1):2334. doi.org/10.1038/s41467-018-04781-w.

[6] Liu W, Hu B, Huang Z, Guan H, Li H, Wang X, Zhang Y, Yin H, Xiong X, Liu J, Wang Y. Graphene-enabled electrically controlled terahertz meta-lens. Photonics Research. 2018 :6(7):703-8. doi.org/10.1364/PRJ.6.000703.

[7] Lee S, Jo I, Kang S, Jang B, Moon J, Park JB, Lee S, Rho S, Kim Y, Hong BH. Smart contact lenses with graphene coating for electromagnetic interference shielding and dehydration protection. ACS nano. 2017;11(6):5318-24. doi.org/10.1021/acsnano.7b00370.

[8] Deng S, Yetisen AK, Jiang K, Butt H. Computational modelling of a graphene Fresnel lens on different substrates. RSC advances. 2014;4(57):30050-8. doi: 10.1039/C4RA03991B.

[9] Ferrari I, Motta A, Zanoni R, Scaramuzzo FA, Amato F, Dalchiele EA, Marrani AG. Understanding the nature of graphene oxide functional groups by modulation of the electrochemical reduction: A combined experimental and theoretical approach. Carbon. 2023 :203:29-38. doi.org/10.1016/j.carbon.2022.11.052.

[10] You X, Zhang Q, Yang J, Dong S. Review on 3D-printed graphene-reinforced composites for structural applications. Composites Part A: Applied Science and Manufacturing. 2023:107420. doi.org/10.1016/j.compositesa.2022.107420.