



زانكۆی سه‌لاحه‌دین – هه‌ولێر

Salahaddin University-Erbil

Study of electromagnetic radiation and solar cell

Research project

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BSc. In physics

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ

الْعَلِيمُ الْحَكِيمُ ٣٢

صدق الله العظيم

SURAH AL-BAQARAH AYAT 32

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Supervisor Certificate:

This research project has been written under my supervision and has been submitted for the award of the degree of BSc. In (Physics)

Signature:

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Date:

I confirm that all requirements have been completed.

Signature:

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Head of department of physics

Date:

This project is dedicated

to :

Allah almighty , my

Creator and master,

My greate teacher and

Messenger , mohammed

*(may allah bless him and grant him) who taught us the purpose
of life,*

My homeland kurdistan , the warmest womb;

*My greate parents who never stop giving of themselves in
countless ways*

My beloved brother and sister

To all of my family the symbol of love and giving ,

My friends who encourage and support me,

And all the people in my life who touch my heart.

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SUMMARY

The study of electromagnetic radiation and solar cells is an important field of research that focuses on understanding the behavior of electromagnetic waves and how they interact with materials in solar cells. Electromagnetic radiation includes all forms of light, from radio waves to gamma rays, and can be used to generate electricity in solar cells.

Researchers in this field study the properties of electromagnetic waves, such as wavelength, frequency, amplitude, and polarization, to better understand how they can be harnessed to generate electricity. They also investigate the properties of different materials used in solar cells, including silicon, gallium arsenide, and cadmium telluride, to determine their efficiency in converting light into electrical energy.

Solar cells work by absorbing photons of light, which excite electrons in the material and generate an electrical current. Researchers study the efficiency of solar cells, the mechanisms that limit their performance, and ways to improve their design and performance.

The study of electromagnetic radiation and solar cells is an interdisciplinary field that combines physics, materials science, engineering, and chemistry. Its applications range from powering homes and businesses to powering spacecraft and satellites in space.

One of the key challenges in this field is developing new materials and techniques to improve the efficiency of solar cells. This includes exploring new materials that can absorb a broader range of light wavelengths, improving the design of solar cells to capture more light, and developing new manufacturing processes to reduce the cost of production.

In addition to improving the efficiency of solar cells, researchers in this field also study the impact of electromagnetic radiation on human health and the environment. This includes investigating the potential risks of exposure to electromagnetic radiation from sources such as cell phones, Wi-Fi networks, and power lines.

Overall, the study of electromagnetic radiation and solar cells is an important area of research with many practical applications. As the world continues to shift towards renewable energy sources, the development of more efficient and cost-effective solar cells will play an increasingly important role in meeting our energy needs while minimizing our impact on the environment.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

The study of electromagnetic radiation and solar cells is an interdisciplinary field that focuses on understanding the behavior of electromagnetic waves and how they interact with materials in solar cells. Electromagnetic radiation, including all forms of light, from radio waves to gamma rays, is used to generate electricity in solar cells by exciting electrons in materials that then generate an electrical current.

This field encompasses a range of research areas, including materials science, physics, engineering, and chemistry. Researchers in this field investigate the properties of different materials used in solar cells, the efficiency of solar cells, the mechanisms that limit their performance, and ways to improve their design and performance.

The development of more efficient and cost-effective solar cells is critical for meeting our energy needs while minimizing our impact on the environment. As the world shifts towards renewable energy sources, the study of electromagnetic radiation and solar cells will continue to play an increasingly important role in powering homes, businesses, and even spacecraft and satellites in space. Additionally, the impact of electromagnetic radiation on human health and the environment is also an important consideration for researchers in this field, as they explore the potential risks of exposure to electromagnetic radiation from various sources.

1.2 Human vision

As humans, our vision relies on the detection of electromagnetic radiation within a specific range of wavelengths, known as the visible spectrum. The study of electromagnetic radiation and solar cells is relevant to human vision because it involves understanding the behavior of light waves and how they interact with materials.

Solar cells, which convert light energy into electrical energy, rely on similar principles as our eyes. Both rely on the absorption of photons to generate electrical impulses, in the case of the eye, or current, in the case of solar cells.

Understanding the properties of electromagnetic radiation, such as wavelength and polarization, can help us better understand how light interacts with the eye and how we perceive colors and shapes. Additionally, the study of electromagnetic radiation and solar cells is also relevant to the development of new technologies that can be used to enhance our vision or even replace lost vision, such as retinal implants.

Overall, the study of electromagnetic radiation and solar cells has relevance to human vision because it involves understanding the fundamental principles of how light

interacts with materials, including those in our eyes, and how we can harness these interactions to generate electrical energy or improve our visual abilities.

1.3 Literature review

The field of electromagnetic radiation and solar cells has received significant attention in recent years due to the increasing demand for renewable energy sources. This field encompasses a range of research areas, including materials science, physics, engineering, and chemistry. In this literature review, we provide an overview of some of the key developments and findings in this field.

One of the primary areas of research in this field is the development of new materials and techniques to improve the efficiency of solar cells. Researchers have investigated a range of materials, including silicon, gallium arsenide, and cadmium telluride, to determine their efficiency in converting light into electrical energy. Additionally, there has been significant interest in the development of new materials that can absorb a broader range of light wavelengths, such as perovskite materials.

Another important area of research in this field is the study of the mechanisms that limit the performance of solar cells. One of the primary limitations is the loss of energy due to recombination of charge carriers. Researchers have developed various approaches to reduce recombination, including passivation techniques and the use of heterojunctions.

Researchers have also explored new manufacturing processes to reduce the cost of producing solar cells. This includes the use of thin-film technologies, such as amorphous silicon and copper indium gallium selenide (CIGS), which can be deposited on flexible substrates.

In addition to improving the efficiency of solar cells, researchers in this field also study the impact of electromagnetic radiation on human health and the environment. This includes investigating the potential risks of exposure to electromagnetic radiation from sources such as cell phones, Wi-Fi networks, and power lines. While there is still much to be learned in this area, recent studies have suggested that the risks associated with electromagnetic radiation may be lower than previously thought.

Overall, the study of electromagnetic radiation and solar cells is an important area of research with many practical applications. As the world continues to shift towards renewable energy sources, the development of more efficient and cost-effective solar cells will play an increasingly important role in meeting our energy needs while minimizing our impact on the environment.

1.4 Present work

1- Developing perovskite solar cells: Perovskite materials have shown great potential for use in solar cells due to their high efficiency and low cost. Researchers are currently exploring new ways to improve the stability and reliability of perovskite solar cells, as well as developing new manufacturing techniques to scale up production.

2- Investigating tandem solar cells: Tandem solar cells, which consist of multiple layers of materials that can absorb different wavelengths of light, have the potential to significantly improve the efficiency of solar cells. Researchers are currently exploring different materials and manufacturing processes to develop tandem solar cells that are both efficient and cost-effective.

3- Exploring new materials for solar cells: In addition to perovskite materials, researchers are also investigating new materials that can be used in solar cells, including metal-halide perovskites, organic-inorganic hybrid perovskites, and quantum dots. These materials have unique properties that may lead to more efficient and cost-effective solar cells.

4- Developing new manufacturing techniques: Researchers are exploring new manufacturing techniques to reduce the cost of producing solar cells, including roll-to-roll printing, spray-coating, and inkjet printing. These techniques could enable the production of large-area solar cells at a lower cost than traditional methods.

5- Studying the impact of electromagnetic radiation: Researchers continue to investigate the potential health and environmental risks associated with exposure to electromagnetic radiation from various sources. Studies are ongoing to better understand the biological effects of electromagnetic radiation and to develop guidelines for safe exposure levels.

Overall, the field of electromagnetic radiation and solar cells is a rapidly evolving area of research with many ongoing projects. These projects are focused on developing new materials, improving the efficiency of solar cells, reducing manufacturing costs, and understanding the potential risks

associated with exposure to electromagnetic radiation. The results of this research will have important implications for the future of renewable energy and our overall understanding of the behavior of electromagnetic waves.

CHAPTER TWO

MATERIALS , METHODS AND MATH

2.1 Materials

Materials are a critical component in the field of electromagnetic radiation and solar cells, as they determine the efficiency, stability, and cost-effectiveness of solar cell devices. Here are some of the key materials that are being used and studied in this field:

1- Silicon: Silicon is the most widely used material in solar cell manufacturing due to its abundance and well-understood properties. It is used in the majority of commercial solar cells today, and researchers continue to explore ways to improve its efficiency and reduce manufacturing costs.

2- Perovskites: Perovskite materials have emerged as a promising alternative to silicon due to their high efficiency and low cost. These materials can be solution-processed, which makes them relatively easy to manufacture, and can absorb a broad range of light wavelengths. However, the long-term stability and reliability of perovskite solar cells remain a

challenge, and researchers are working to improve the materials and device designs to address these issues.

3- Cadmium telluride (CdTe): CdTe is a thin-film material that is used in some commercial solar cells. It is less expensive than silicon and can be deposited on a variety of substrates, making it an attractive option for large-scale manufacturing. However, CdTe solar cells are generally less efficient than silicon cells, and there are concerns about the toxicity of cadmium.

4- Copper indium gallium selenide (CIGS): CIGS is another thin-film material that has shown promise for use in solar cells. It is highly efficient and can be deposited on flexible substrates, which makes it suitable for a wide range of applications. However, the manufacturing process for CIGS cells can be complex, and there are still challenges to overcome to make these cells cost-competitive with silicon.

5- Organic materials: Organic materials, such as polymers and small molecules, have also been investigated for use in solar cells. These materials are generally low-cost and can be deposited on flexible substrates, which makes them attractive for some applications. However, their efficiency is currently

lower than silicon and other inorganic materials, and there are still challenges to overcome to make them viable for large-scale manufacturing.

6- Quantum dots: Quantum dots are tiny particles that can absorb and emit light at specific wavelengths, making them potentially useful for solar cell applications. They can be tuned to absorb a specific range of wavelengths, which could increase the efficiency of solar cells. However, the stability and toxicity of quantum dots remain a concern, and further research is needed to address these issues.

Overall, the choice of materials is a critical factor in determining the efficiency, stability, and cost-effectiveness of solar cells. Researchers are exploring a wide range of materials, from traditional silicon to emerging perovskites and quantum dots, to develop more efficient and cost-effective solar cells that can meet the world's growing demand for renewable energy. (Markvart, & Castaner. (2005))

2.2 Methods

In the field of electromagnetic radiation and solar cells, a variety of methods are used to study and improve the efficiency, stability, and cost-effectiveness of solar cell devices. Here are some of the key methods used in this field:

- 1- Photovoltaic characterization: This method involves measuring the electrical properties of solar cells under illumination to determine their efficiency and performance. Parameters such as open-circuit voltage, short-circuit current, and fill factor can be measured to evaluate the effectiveness of different materials and device designs.
- 2- Spectroscopy: Spectroscopic techniques, such as photoluminescence spectroscopy and transient absorption spectroscopy, can be used to study the optical and electronic properties of materials used in solar cells. These techniques can provide insight into the mechanisms of charge generation and recombination in solar cells, as well as identify potential defects and degradation mechanisms.
- 3- Modeling and simulation: Mathematical models and simulations can be used to predict the performance of solar cell devices and optimize their design. These models can incorporate a variety of parameters, such as material properties, device architecture, and operating conditions, to predict the efficiency and stability of solar cells under different conditions.
- 4- Materials synthesis and processing: Researchers use a variety of techniques to synthesize and process materials used in solar cells, such as chemical vapor deposition, solution processing, and physical vapor deposition. These techniques can be used to control the structure and composition of materials and optimize their properties for use in solar cells.

5- Device fabrication and testing: Once materials have been synthesized and processed, they must be integrated into solar cell devices. This involves a variety of fabrication techniques, such as spin-coating, sputtering, and inkjet printing, to deposit the materials onto a substrate and create the necessary structures for charge collection. Once the devices have been fabricated, they must be tested to evaluate their performance and stability over time.

6- Environmental testing: Solar cells must be able to withstand a variety of environmental conditions, such as temperature and humidity fluctuations, UV exposure, and mechanical stress. Environmental testing can be used to evaluate the stability and durability of solar cells under these conditions and identify potential failure modes.

Overall, a variety of methods are used in the field of electromagnetic radiation and solar cells to study and improve the performance of solar cell devices. These methods span a wide range of disciplines, from materials science and chemistry to electrical engineering and physics, and require a multidisciplinary approach to successfully optimize solar cell

performance and meet the world's growing demand for renewable energy. (Inamuddin, Boddula, Rezakazemi, & Imran Ahamed, (2021)).

MATH

there are many mathematical equations that are related to the study of electromagnetic radiation and solar cells. Some of the most commonly used equations in this field include:

1- The Planck-Einstein relation: $E = hf$, where E is the energy of a photon, h is Planck's constant, and f is the frequency of the electromagnetic radiation. This equation is used to determine the energy of photons absorbed by solar cells.

2- The Lambert-Beer law: $I = I_0 e^{-\alpha L}$, where I is the intensity of light transmitted through a material, I_0 is the initial intensity of light, α is the absorption coefficient of the material, and L is the thickness of the material. This equation is used to determine the absorption of light in solar cells.

3- The Shockley-Queisser limit: This equation provides a theoretical upper limit on the efficiency of a solar cell, and is given by:

$$\eta_{\max} = (E_g/q) / (E_g/q + kT/q)$$

where η_{\max} is the maximum theoretical efficiency, E_g is the bandgap energy of the material, q is the elementary charge, k is the Boltzmann constant, and T is the temperature in Kelvin.

4- The current-voltage (I-V) curve: This equation is used to determine the electrical behavior of a solar cell, and relates the current output of the cell to the voltage across it. The I-V curve is affected by several factors, such as the material properties of the cell, the incident light intensity and spectrum, and the temperature.

5- The Shockley diode equation: This equation is used to model the behavior of a p-n junction in a solar cell, and is given by:

$$I = I_0(e^{(qV/kT)} - 1) - I_{ph}$$

where I is the current output of the cell, I_0 is the reverse saturation current, V is the voltage across the cell, k is the Boltzmann constant, T is the temperature in Kelvin, and I_{ph} is the photocurrent generated by the incident light.

These equations, and many others, are fundamental to the understanding and design of solar cells, and are used extensively in research and development in this field.

(Anspaugh, B. E. (2014))

CHAPTER THREE

CONCLUSION AND FUTURE WORK

3.1 Conclusion

In conclusion, the study of electromagnetic radiation and solar cells is an important area of research that has the potential to significantly impact the future of energy production. With the increasing demand for renewable energy sources, the development of efficient and cost-effective solar cell technology is crucial for meeting global energy needs while minimizing the impact on the environment. The research in this field involves a multidisciplinary approach, with researchers from various fields such as materials science, chemistry, physics, and engineering collaborating to optimize solar cell performance. Through the use of a variety of methods, including photovoltaic characterization, spectroscopy, modeling and simulation, materials synthesis and processing, device fabrication and testing, and environmental testing, researchers are able to better understand the behavior of materials used in solar cells, optimize device design, and improve the efficiency and stability of solar cells. With continued advancements in this field, solar cells have the potential to become a primary source of energy production, revolutionizing the way we generate and consume energy in the future.

However Solar cells (which are a type of renewable energy technology that converts sunlight into electricity) offer several advantages and disadvantages, as outlined below:

Pros:

- 1- Renewable: Solar energy is a renewable resource, meaning it will never run out. As long as the sun continues to shine, solar cells can generate electricity.
- 2- Cost-effective: The cost of solar cells has decreased significantly in recent years, making them more affordable for consumers and businesses.
- 3- Low maintenance: Solar cells require little to no maintenance, reducing operational costs and minimizing downtime.
- 4- Environmentally friendly: Solar cells produce no greenhouse gases, air pollution, or other harmful emissions, making them a cleaner source of energy compared to fossil fuels.
- 5- Versatile: Solar cells can be used in a variety of settings, from small portable devices to large-scale power plants.

Cons:

- 1- Weather-dependent: Solar cells require sunlight to generate electricity, meaning their output can be affected by weather conditions such as cloud cover or shading.

- 2- Initial investment: While the cost of solar cells has decreased, the initial investment for installation can still be relatively high.
- 3- Land use: Large-scale solar power plants require significant amounts of land, which can be a concern in areas where land is scarce or valuable.
- 4- Energy storage: Solar cells generate electricity only when the sun is shining, so energy storage solutions are needed to provide power during periods of low sunlight or at night.
- 5- Environmental impact: While solar cells produce no emissions during operation, their production and disposal can have environmental impacts, such as the use of toxic chemicals or the accumulation of waste materials.

Overall, solar cells offer several advantages as a renewable energy source, but also have limitations that must be considered. As technology continues to advance, solar cells have the potential to become an even more cost-effective and environmentally friendly source of energy.

3.2 Future work

The study of electromagnetic radiation and solar cells is a rapidly evolving field, and there are many areas of future research that hold promise for advancing our understanding of these technologies. Some potential areas of future work include:

1- Improving solar cell efficiency: One of the main goals of research in this field is to increase the efficiency of solar cells, allowing them to generate more electricity from the same amount of sunlight. This could involve developing new materials with optimized bandgap energies, exploring novel device architectures, or improving light management strategies within the cell.

2- Developing new materials: The search for new materials with properties that are well-suited for use in solar cells is an ongoing area of research. This could include materials that are highly efficient at absorbing specific wavelengths of light, or materials that are highly stable and can withstand long-term exposure to sunlight.

3- Integration with energy storage: While solar cells are a promising source of renewable energy, their output is highly dependent on weather conditions and time of day. Integrating solar cells with energy storage technologies, such as batteries or capacitors, could help to overcome this limitation and make solar energy a more reliable source of power.

4- Exploring new applications: Solar cells are not just limited to powering homes and businesses. There are many other potential applications for these technologies, such as powering wearable devices, sensors, or even vehicles. Future research could focus on developing solar cells that are optimized for these types of applications.

5- Understanding the environmental impact: While solar cells are a cleaner source of energy compared to fossil fuels, their production and disposal can still have environmental impacts. Future research could focus on developing more sustainable methods for manufacturing solar cells, or exploring new recycling technologies to minimize waste.

Overall, the study of electromagnetic radiation and solar cells is a dynamic and exciting field, with many potential avenues for future research. Advances in this field have the potential to play a key role in the transition towards a more sustainable and carbon-neutral energy system.

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