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Chapter 17

Perovskite Photodetector for High Speed and Secure Li-Fi Wireless Data Transmission

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ABSTRACT

In the contemporary digital environment, the shortcomings of traditional radio-frequency wireless communication, like bandwidth congestion, energy inefficiency, and susceptibility to security breaches, have become increasingly evident. Light Fidelity (Li-Fi) is a viable option, utilising visible light to convey data at exceptionally high velocities while mitigating numerous urgent obstacles. This research centres on the creation of a high-speed and secure Li-Fi system, specifically highlighting the utilisation of a perovskite-based photodetector to improve performance.Perovskite materials have garnered interest in recent years due to their remarkable optoelectronic characteristics, including elevated absorption coefficients, adjustable bandgaps, and rapid photoresponse times. These attributes render them exemplary choices for photodetectors in optical communication systems. This study involves the fabrication of a perovskite photodetector, which is incorporated into a prototype Li-Fi system aimed at showcasing efficient, real-time data transmission utilising visible light sources, including LEDs or laser diodes. The proposed Li-Fi system utilises the underutilised visible light spectrum, which is around 10,000 times wider than the radio spectrum, facilitating ultra-fast data transfer rates and mitigating spectrum congestion. The incorporation of perovskite photodetectors improves the system's responsiveness and energy efficiency, rendering it appropriate for contemporary smart city infrastructure and advanced educational settings. Moreover, Li-Fi has inherent benefits regarding data security, as light is unable to permeate opaque materials such as walls, thereby limiting signal access to certain physical areas. This study showcases a small-scale demonstration of a perovskite-integrated Li-Fi communication system, emphasising its potential to transform wireless data transmission through enhanced speed, security, and sustainability. As Li-Fi technology advances and incorporates sophisticated photodetector materials such as perovskites, it heralds a new epoch of high-performance, environmentally sustainable wireless communication networks.

Key Words: Li-Fi (Light Fidelity), Perovskite Photodetector, High-Speed Wireless Communication, Energy-Efficiency, Data Security.

1. INTRODUCTION

Researching the creation of light sensors with semiconducting materials is an essential component of contemporary technology. Sensors are crucial in a wide range of industries, including consumer electronics and environmental monitoring. Comprehending the origins and procedures involved in developing these sensors is crucial for future progress in sensor technology.

Studying the characteristics and conduct of semiconducting materials in light detection can enhance sensor efficiency and sensitivity. This understanding can facilitate the creation of sophisticated and depen dable light sensors for various applications. Advancements in semiconducting materials have enabled the development of very sensitive photodetectors utilized in medical imaging and security systems. Furthermore, continued research in this field could result in the creation of smaller and more energy-efficient sensors for upcoming technological advancements.

The research of semiconducting materials in light detection has the potential to transform multiple sectors and improve everyday technology. Researchers can open new opportunities for boosting sensor performance and broadening their uses by further advancing scientific understanding in this field. Researchers can enhance the sensitivity and efficiency of PD by utilizing improvements in semiconducting materials, thus increasing their versatility and reliability for many applications. According to (L. Li et al., 2021), photodetectors, commonly known as light sensors, are essential components enabling devices to detect and respond to changes in light intensity. Semiconducting materials have emerged as promising candidates for light sensor fabrication due to their ability to convert light into electrical signals with high efficiency and sensitivity.

2. LITERATURE REVIEW

Photodetectors are essential in various industries such as telecommunications, security, and healthcare as they transform light impulses into electrical signals. Applications that require them include optical communication networks, surveillance systems, and medical imaging.
This article aims to explore the significance of photodetectors across different industries and emphasize their role in driving innovation and technological advancements. The paper will analyse several types of photodetectors and their unique uses in diverse industries.

Altered the method of light collection and utilization, leading to many technical improvements across multiple industries. Photodetectors are crucial in several applications such as identifying cancer cells in medical images and improving security in surveillance systems, contributing significantly to the advancement of our society. Enhanced sensitivity, quicker response rates, and increased reliability provided by photodetectors have made them essential in the aerospace, telecommunications, and environmental monitoring sectors.

Photodetectors are expected to play a significant role in shaping the direction of several sectors as technology advances. The influence of photodetectors on technological advancements Photodetectors are essential in several industries such as telecommunications, security, and healthcare as they transform light impulses into electrical signals. This article discusses the importance of photodetectors in various sectors and how technological improvements have altered their functionalities. The transformation of light into electrical signals has led to improved precision and effectiveness in various applications, driving innovation and advancement in the industries they serve. Ongoing research and development in photodetector technology are leading to future advancements and improved capabilities. Advancements in communication systems, medical imaging, and environmental monitoring necessitate ongoing development of photodetectors. These devices are expected to have a crucial role in influencing the trajectory of various industries as they become more sophisticated.

3. METHODOLOGY

The ITO (Indium Tin Oxide) coated glass substrate is meticulously cleaned to eliminate surface contaminants at the outset of the fabrication process. This is an essential stage in order to guarantee optimal adhesion and film uniformity during the subsequent deposition process. Initially, the substrate is washed with water and a moderate detergent to remove dust, grease, and other impurities that have been acquired during the handling process. Subsequently, the ITO glass is immersed in a beaker containing acetone and subjected to ultrasonic cleansing for 15 minutes. The dislodging of microscopic particles and the dissolution of chemical residues are facilitated by the ultrasonic vibrations. Immediately following the acetone bath, the substrate is rinsed with isopropyl alcohol (IPA) to eradicate residual solvents and purge with argon gas to reduce surface oxidation and eliminate moisture.

The spin coating technique is employed to deposit thin films on the substrate after it has been cleansed and dried. A drop of the prepared perovskite solution is applied to the center of the cleansed ITO-coated glass, which is then placed on a spin coater. The substrate is initially spun at a modest speed of 1500–2000 rpm for 20 seconds to ensure that the solution is evenly distributed. The layer is subsequently thinned, and solvent evaporation is initiated by a high-speed spin at 3000–4000 rpm for 10 seconds, resulting in the formation of a uniform perovskite thin film. This stage is crucial for the achievement of optimal surface morphology and consistent film thickness, which are essential for the performance of the device.

To improve the electronic and structural properties of the perovskite layer, an annealing procedure is implemented. In order to enhance the quality of the film and encourage crystallization, the film is transferred to a hotplate and annealed at 100°C for 15 minutes. After the top contact (C electrode) is deposited, a subsequent annealing phase is implemented to guarantee the device's stability and optimal interfacial contact. The final thin films are characterized by using FTIR spectroscopy to identify functional groups and bonding structures, UV-Vis spectroscopy to determine optical bandgap, and an LCR meter to assess electrical resistance. The efficacy of the fabrication process and the suitability of the perovskite material for use in high-speed, secure Li-Fi photodetector applications are validated by these characterization techniques.

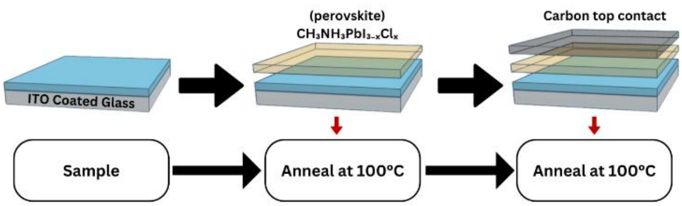

Figure 5 The PD devices fabrication protocol

4. RESULTS & DISCUSSION

The analysis of perovskite with an LCR meter provides a complete understanding of its electrical properties, which are critical for its use in light communication. The LCR meter was used to determine the resistance of the perovskite thin films, which is directly proportional to their conductivity. This test is critical in determining the material's potential as a photodetector in light communication systems, where low resistance and high conductivity are frequently needed for optimal performance.

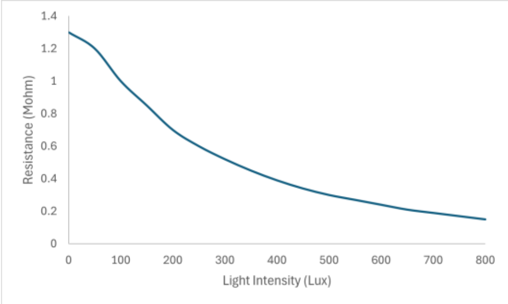

Figure 6 Resistance over light intensity

Figure 2 displays the graph from collected results that tested using LCR meter to get resistance while changing the distance of intensity of light. The light intensity is defining using light sensor on how much the lux when the distance of light has been changed. The data shows that the resistance keeps increasing when the light source getting far from the PD shows that the graph was having a direct relationship.

The resistance of the perovskite films was measured at 1 kHz frequency, where the material's response is stable and provides reliable data. The LCR meter's readings helped in identifying the resistive behaviour of the films, which is important for determining the electrical characteristics of the fabricated semiconductor. Another test has been done to see the performance of the device as shown in Figure 2.

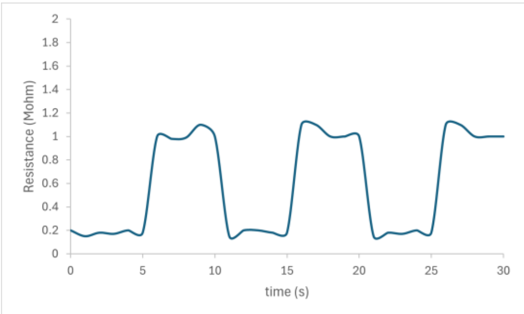

Figure 7 Resistance over time

Figure 3 shows the result of the PD that connects with LCR Meter, undergoes a specific condition for 10 seconds. The device will be having light switched on for 5 seconds and the light will be switched off for another 5 seconds repeatedly for 30 seconds with a total of 3 cycles to switch on-off the light source. This experiment is to test the performance of the

PD that has been fabricated will react to the light source to understand the electrical properties.

By performing the measurements at various conditions, we were able to study the dependence of the material's electrical properties. This is particularly important for understanding how the perovskite material behaves under different operating conditions, which can vary in practical applications like light communication. The results from the LCR meters also help to assess the uniformity of the thin films, as variations in resistance across the sample could indicate inconsistencies in the fabrication process or the presence of defects that could impact performance.

5. CONCLUSION & RECOMMENDATION

This project successfully exhibits the capabilities of perovskite-based photodetector for sophisticated light communication applications. This project created a PD with excellent responsivity by carefully selecting materials, optimizing production procedures, and conducting extensive characterization. The perovskite material, Methyl Ammonium Iodide Lead Chloride ($CH_3NH_3PbI_{3-x}Cl_x$) have exceptional optoelectronic properties, making them appropriate for these applications. The spin-coating approach, followed by thermal annealing, was successful in producing high-quality perovskite films. Optical characterization with UV-Vis confirmed the perovskite films' excellent light absorption.

This research emphasizes the scalability of the fabrication method, opening the door for possible commercial applications. The findings of this study contribute to a better understanding of perovskite photodetector technology, revealing that these materials can outperform standard semiconductors in many ways.

Additionally, integrating perovskite-based photodetectors into Li-Fi systems offers a chance to overcome some of the drawbacks of conventional wireless communication systems. Higher data transfer speeds and better signal-to-noise ratios may be made possible by perovskite materials' capacity to function across a broad range of light wavelengths. To improve system performance, future research can look into hybrid systems that combine perovskite photodetectors with cutting-edge modulation techniques. Additionally, investigating the production of photodetectors on flexible or transparent substrates may create new avenues for incorporating Li-Fi technology into wearable electronics, smart windows, and other cutting-edge uses.

In order to guarantee reliable performance in real-world applications, research can also focus on comprehending how perovskite-based photodetectors interact with environmental elements like humidity and temperature. The creation of economical and ecologically friendly production techniques that complement sustainable practices is another direction for future research. By improving these features, the use of perovskite-based photodetectors in Li-Fi systems has the potential to transform wireless communication and open the door for next-generation consumer electronics, smart cities, and effective industrial automation.

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