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Efficiency analysis of $RbGeBr_3$ perovskite solar cell with inorganic HTL and silver contact.

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Efficiency Analysis of $RbGeBr_3$ Perovskite Solar Cell with Inorganic HTL and Silver Contact

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Abstract— **This research investigated the use of $RbGeBr_3$ as an absorbing layer in two different types of perovskite solar cells. The study involved deliberate modifications to the thickness of the $RbGeBr_3$ absorber layer. Silver was chosen for the metal contact electrode. The $FTO/TiO_2/RbGeBr_3/Cu_2O/Ag$ configuration achieved a power conversion efficiency of 11.92%, with a short-circuit current of 14.476 mA/cm² and an open-circuit voltage of 1 V. These results are significant for advancing the development of more efficient perovskite solar cells utilizing mineral perovskite layers.**

Keywords—Finite Element Method, Perovskite Solar Cells, Mineral Perovskite, Absorber Layer, Hole and Electron Transport Layer.

I. INTRODUCTION

Mitigating global warming is one of the most pressing challenges of this century and a key focus of scientific discourse. One effective approach to addressing this issue, at least in part, is the scientific and responsible utilization of natural clean energy sources, such as solar energy. Solar cells, which have been in development since the 1920s, have experienced remarkable advancements in this field. Particularly, the fourth generation of perovskite solar cells, which primarily utilize organic-mineral perovskite materials, has shown a significant increase in efficiency, rising from 3.8% to 25.5% in just a decade [1,2]. In the realm of perovskite materials, inorganic perovskites offer superior durability against environmental factors such as temperature and humidity. However, they have received comparatively less research attention as light-absorbing layers [3-6]. As a result, research on all-inorganic perovskite materials as light-absorbing layers is still in its early stages and remains an area of extensive study [7,8]. The COMSOL Multiphysics Simulator is also employed for educational purposes to study the all-inorganic perovskite material $RbGeBr_3$ in a specific structure [9]. The impact of varying the thickness of the light-absorbing and electron-transporting layers on overall efficiency has also been investigated.

II. STRUCTURE DESIGN OF DESIRED PSCS

Perovskite materials are abundant in nature and offer various advantages [10,11]. The main objective of this study was to explore the light-absorbing properties of the mineral $RbGeBr_3$, which has a direct bandgap of 1.49 eV, within different PSC architectures [12,13]. In the studied structure, TiO_2 and Cu_2O are used as the semiconductor materials for the ETL and HTL, respectively, complemented by a silver (Ag) metal electrode [14]. Figure 1 illustrates the general working principle of PSCs and provides an overview of their electrostatic structure. Additionally, the light input power, denoted as P_{in}, is 100 mW/cm² for each PSC.

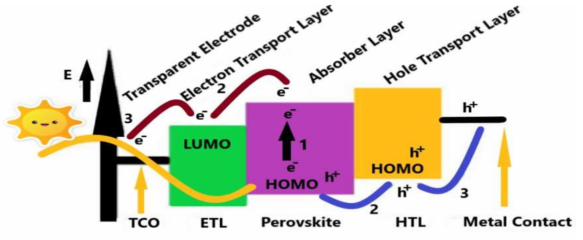

Fig 1, The electrostatic structure of a PSCs overall performance.

The configuration for this investigation is $FTO/TiO_2/RbGeBr_3/Cu_2O/Ag$. This multilayer sequence represents the structure under study.

III. SIMULATION DETAILS

In this study, the COMSOL simulator utilizes the semiconductor module in a two-dimensional context [15]. Optical properties are crucial to the simulation. The complex refractive index of the material is represented as:

$$N(\omega) = n(\omega) + ik(\omega) \tag{1}$$

Here, $n(\omega)$ represents the real part of the refractive index, which affects light reflection, while $k(\omega)$ is the imaginary part, important for simulating the material's absorption of the solar spectrum. The absorption coefficient, which is essential for understanding how the material interacts with incident light, is given by the equation $\alpha(\lambda) = \frac{4\pi k(\lambda)}{\lambda}$ [12]. This absorption coefficient is essential for determining how the material affects incident light, particularly in the solar spectrum at 1.5 AM. The generation rate of carriers [12]:

$$G(x,\lambda) = \frac{4\pi}{hc}\int_{\lambda_1}^{\lambda_2} k(\lambda)\Phi(\lambda)exp\big(-\alpha(\lambda)x\big)d\lambda \tag{2}$$

Here $\Phi(\lambda)$ illustrates the solar spectrum. The incident wavelength range is specified with λ_1 at 300 nm and λ_2 at 800 nm. Furthermore, the equations depicted below can be utilized to determine the cell's [15]:

The net current I is presented in equation 3:

$$I = I_{ph} - I_D = I_{ph} - I_0[\exp\left[\frac{eV}{K_B T_c}\right] - 1] \tag{3}$$

The open-circuit voltage Voc is written in equation 4:

$$V_{oc} = \left(\frac{K_B T}{q}\right) \ln\left(\frac{J_{sc}}{J_0}\right) \qquad (4)$$

The final efficiency is shown in equation 5[15]:

$$\eta = \frac{P_{max}}{P_{in}} = \frac{I_{max}V_{max}}{P_{in}} \qquad (5)$$

IV. RESULTS AND DISCUSSION

In this study, we developed a two-dimensional optoelectronic model to illustrate the effects of the absorber layer in a solar cell. The thickness of the absorber layer varied from 200 nm to 500 nm, while the hole transport layer and the electron transport layer were maintained at constant values of 300 nm and 80 nm, respectively.

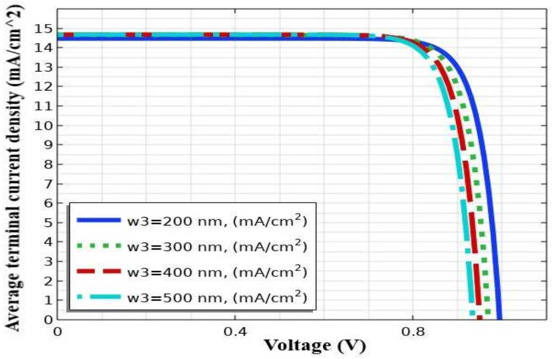

Fig 2. Impact of absorber layer on short circuit current density(J_V)

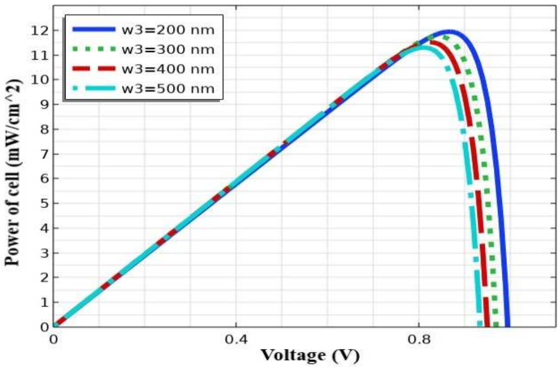

Fig 3. Impact of absorber layer on the power output of the solar cell (P_V)

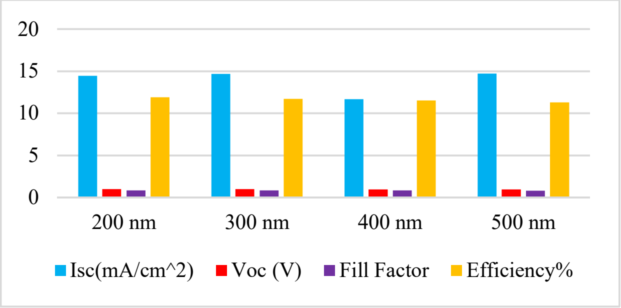

Fig 4, output power variations in these architectures

The simulated results demonstrated that the highest efficiency achieved was 11.92% at a temperature of 300 K for the given configuration. These values can be used or validated through experimental processes. Figure 2 shows the highest average terminal current density of 14.476 mA/cm². Figure 3 illustrates the impact of the absorber layer on the power output of the solar cell. Figure 4 shows how increasing the thickness of the light-absorbing layer affects the output results.

V. V. CONCLUSION

To summarize, the study investigated the performance of $RbGeBr_3$ as a light-absorbing layer in the configuration $FTO/TiO_2/RbGeBr_3/Cu_2O/Ag$. The research demonstrated that varying the thickness of the absorber layer influenced the final (J-V) characteristics, power output (P_V), and overall efficiency. The highest efficiency achieved was 11.92%, with a short-circuit current of 14.476 mA/cm² and an open-circuit voltage of 1 V. The optimal thickness of the layers and the choice of semiconductor materials are crucial factors affecting the solar cell's efficiency. This research provides valuable insights for future studies to improve power conversion efficiency (PCE) in more advanced cell designs.

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