修士学位論文要約（令和４年３月）

高強度近赤外光照射下における Si PV セルの発電特性に関する研究

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Power Generation Performance of Si PV Cell under High-intensity Near Infrared Light Irradiation

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Wireless power transfer technology has attached much attention and urgently needs to be realized. Comparing to other wireless power transfer methods, optical wireless power transfer (OWPT) has its unique feature, that very high optical power can be transmitted for a long distance by using lasers. In this case, for supplying enough rated power to maintain the appliances' operation, the PV cell as an optical-to-electric power converter will be irradiated by high-intensity light beam. Therefore, it is important to investigate the power generation performance of PV cell under such circumstance. In this paper, we first use high power LED light sources with 730 nm, 850 nm and 940 nm wavelengths and a condensing optics to realize 10-sun level high optical power irradiation for the measurements. More than 0.22 W electric power is generated from a 1cm^2 conventional Si heterojunction PV cell and the estimated power conversion efficiencies exceed 22.5%. Then, we transmit 32-sun level optical power for 30 meters indoor through 980 nm LD, around 0.53 W electric power is generated from the same PV cell.

1. Introduction

Nowadays, the conception of wireless charging has been rapid spread. By far, most of mobile or long-distance-placed electrical appliances are typically powered by batteries that have limited operation time and inconvenient. Hence, wireless power transfer (WPT) or wireless charging technology has been attached much attention and urgently needs to be realized. To offer sufficient power over long distance for safely wireless charging and mobile electrical appliances, which usually need Watt-level power over meter- level distances, optical wireless power transfer (OWPT) is proposed. OWPT [1,2] has many unique advantages such as, 1) Transmitting high optical power for a long distance by using lasers as light sources; 2) Small light beam divergency angle; 3) And if it is combined with tracking system, the light propagation path can be controlled to feeding some moving objects. Thus, we chose the field of OWPT to carry out our research.

In this research, we choose economic and technic mature Si PV cell as the power converter, and near-infrared light as the light source, which is expected to a higher efficiency and less generated heat. In order to verify the feasibility of feeding high-power electrical appliances which is placed at a relatively long distance through OWPT, this research designed and implemented the experiment of conventional Si PV cell irradiated by extremely high-intensity near-infrared light and transferring the optical power for a 30 meters distance. According to the experimental results, the laser power indoor transfer efficiency has been investigated. Moreover, various parameters (maximum generated power, power conversion efficiency, et.) and their temperature dependence have been analyzed for investigating the power generation performance of the Si PV cell.

2. Determination of incident light intensity range

The explanation for determine light irradiance power range is shown as follows. Considering that the drones require moderate supplied power in many high-power OWPT applications, we take it as a reference to estimate the electricity needs. By far, most of drones' endurance are limited less than 30 minutes due to the battery's capacity. For flying continuously and saving battery energy, feeding or charging the in-flight drones through lasers is proposed. Figure 1 shows an imagination usage scenario illustration of that idea. In this case, PV panels as the medium power charger are installed on wings or carried under fuselage. The OWPT could eliminate the need for landing and taking off, or at least reduces the distance the drone travels when it needs to be recharged. Typically, the consumer drones need around 15 ~ 150 W/kg to fly, and its weight is less than 1.3 kilograms. As the result, for the most of consumer drones, 20 ~ 195 W rated electric power is theoretically enough for feeding the drone while in its flight status. And that is the goal of generated power from the PV cell in our experiment. And by converting them into multiples of 1-sun level power are respectively equal to 10-sun and 30-suns.

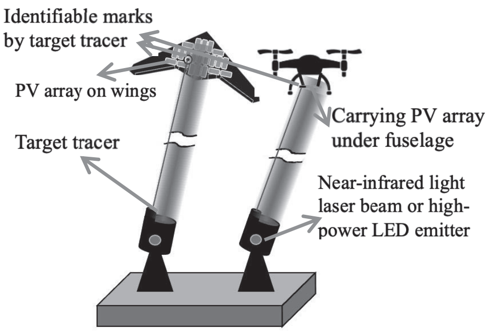

Figure 1 Feeding or charging in-flight drone through OWPT

3. Fundamental experiment by using LEDs

For investigating how's the cell's power generation performance when irradiated by high optical power. We designed the experiment configuration as shown in Fig. 2 and use the high-power near-infrared LEDs with three different wavelengths of 730 nm, 850 nm, 940 nm as light sources.

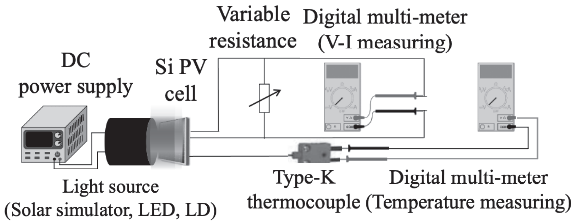

Figure 2 Experiment configuration

The experiment measurements were performed within 3 to 5 seconds light irradiation for avoiding the heat effects as much as possible. The estimated value of maximum generated power can be obtained from V-I and V-P curves. With the illuminance up to 10-sun, the maximum generated power (P_{max}) could reach to 0.22 W. And by using monochromatic near-infrared light as light sources, all the power conversion efficiencies (*Eff*) are over 22%. For the practical use of OWPT, since the strong light will continuously irradiate to the PV cells, the heat effect is inevitable. So, we also investigated the cell's operating temperature and *Eff*s during 10 minutes 10-sun irradiation. Thanks to the heatsink attached behind the cell, its temperature increased only about 14-20 degrees. In the case of 10-sun power level, although the *Eff* gradually decreased due to the temperature rise over time, they still maintained high values over 21.5%.

4. 30 meters indoor OWPT experiment by using LD

In the case of 30 meters OWPT indoor experiment by using 980 nm LD, the laser power attenuation is about 3%. The power generation performance when the illuminance up to 32-sun are summarized by the measurement data through V-I and V-P curves. About 0.53 W power was generated from 1 cm^2 PV cell. However, under this circumstance, the high Eff cannot be remained, which decrease to less than 17%, which may relate to the fractional power loss due to resistances.

5. Conclusion

Through this research, we can draw three conclusions. First, by taking advantage of the sensitivity of the Si PV cell to near-infrared light, the optical-to-electrical power conversion efficiency is increased by at least 0.4% comparing to the sunlight irradiation, and the rising temperature of the cell during its operation is also reduced. Second, the Si PV cells have great potential to generate large electric power even under extremely high intensity near-infrared light irradiation. Under 10-sun and 32-sun level power irradiation, more than 0.22 W and 0.52 W electric power are respectively generated by a 1 cm^2 heterojunction Si PV cell. Third, the effects of rising temperature on a heterojunction Si PV cell are small, however the effects of extremely high-intensity optical power irradiation are significant. Therefore, for practical use of OWPT, it has a bright future for some high-power electrical appliances, which need to be feed or charged by optical power less than 10-sun.

Reference

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2) J. Zhou, X. He, T. Kato, K. Yoshikawa, H. Yamada, IEICE Electronics Express, 2022, Volume 19, Issue 3, Pages 20210476 (10 February 2022).