Research on improving the heat dissipation of monocrystalline silicon solar cells based on radiant cooling

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Introduction

In recent years, energy consumption has continued to increase, and the proportion of building energy consumption in the total energy consumption of society has been increasing year by year. In addition, the government is paying more and more attention to the development concept of "green" and "environmental protection". These factors have prompted us to seek a low-energy, pollution-free cooling method. As a new type of refrigeration method, radiant refrigeration is different from traditional refrigeration methods. Its biggest advantage is that it can reduce the temperature of objects without consuming energy, and has been widely developed in practical applications. The basic principle of radiant refrigeration is to radiate energy to outer space with a temperature close to 0K near the atmospheric window (8-13μm) so as to reduce the temperature of the object. In recent years, researchers have prepared materials that can be used for daytime radiant cooling. Zhu[1] and others put a radiant refrigeration film with a nano-lithography structure on top of a solar cell, which can achieve a maximum cooling of 18.3K, but the nano-lithography method requires strict nano-precision manufacturing, which is difficult to effectively apply on a large scale. Zhai[2] et al. embedded silica particles randomly into polymers to make a radiant cooling experiment. Under direct sunlight, the radiant cooling power is 93W/m^2, but the nanoparticles are randomly distributed, which will lead to the simulation and experiment process. There is a certain error in it.

This paper proposes a radiant refrigeration film, in which the upper layer is mixed with PDMS and SiO_2, and the lower layer is PVC. The radiant refrigeration film can be prepared by a spin coating method. The manufacturing process is simple and low in cost. Considering the influence of different substances on the radiant refrigeration film, the finite-difference time-domain method is used to optimize and analyze the film combination of different substance thicknesses to obtain a good cooling effect.

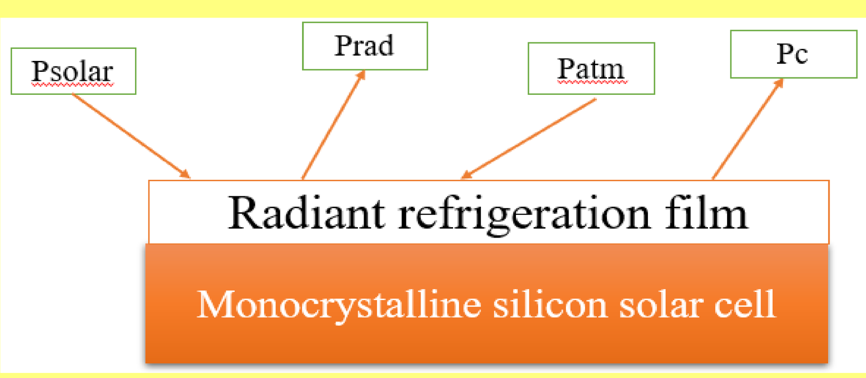

Fig.1Thermal model of solar radiation heat dissipation

Experimental setup

As shown in 2 from the spectral characteristics of the transmittance and absorption of the PVC100+6%(PDMS+ SiO_2) 60 combination, it can be seen that the average transmittance in the sunlight band is above 0.9, and the average emissivity in the atmospheric window is 0.93

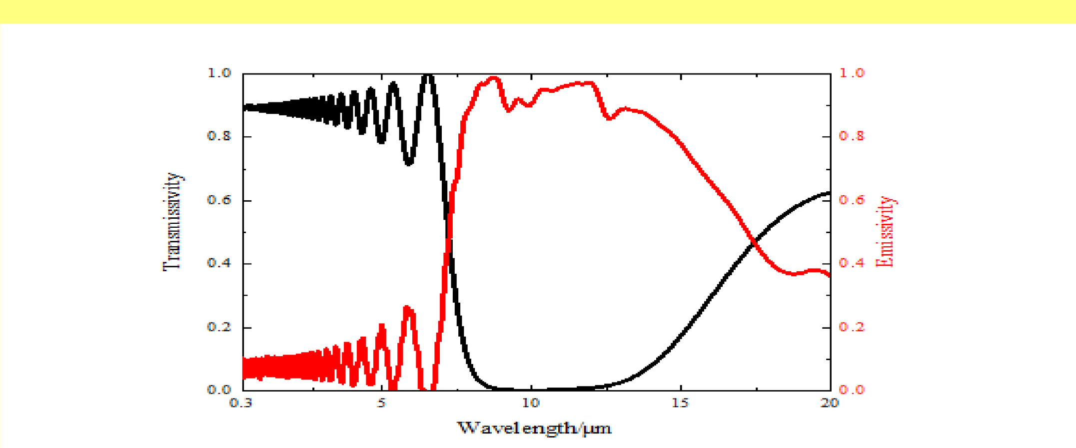

Fig.2 The transmittance and emissivity of the radiant refrigeration film

As shown in Fig3, T1-T6 are 6 temperature measurement points, T1 and T2 are the upper and lower temperatures of the PV-RC panel, T3 and T4 are respectively compared with the upper and lower parts of the PV panel temperature; T5 and T6 are the temperatures of the test environment. The resistance is uniformly adjusted to 30Ω. Solar radiometer is used for real-time monitoring of solar radiation (Jinzhou Sunshine Meteorological Technology Co., Ltd. TBQ-2). The test site is the roof of a building in Shanghai Electric Power University. The test will be conducted from 09:30 am to 3:00 pm on March 22, 2021.

Fig.3 The layout of the experimental bench

Experiment

Environmental conditions

The fig4 shows the weather conditions during the daytime experiment period, and the data of three meteorological parameters of ambient temperature, wind speed, and solar radiation intensity were tested. It can be seen from the figure that during this period of time, the ambient temperature has a tendency to increase and then decrease. The wind speed is roughly constant, basically varying between 1m/s-3m/s. The solar radiation intensity gradually increased from 700W/m^2 to 850-920W/m^2, and then gradually decreased after maintaining for a period of time, and finally decreased to 550W/m^2 at 15:00.

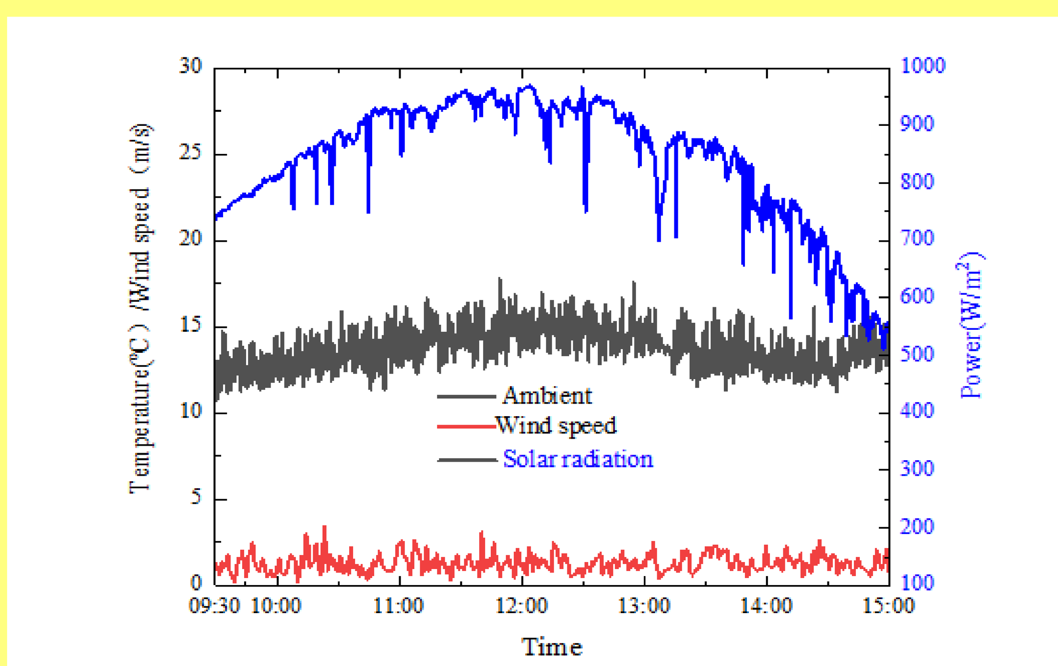

Fig.4 The weather data under daytime conditions

Results

The surface temperature of the solar cell

During the entire experimental period, the surface temperature of PVRC panels is always lower than that of ordinary PV solar cells, which has a significant gap. During the time eriod of 09:30-15:00, the maximum temperature of PVRC solar panels is 33.65℃, while the temperature of ordinary solar cells is 34.35℃. During the test, the difference in temperature between the two is 1.81℃.

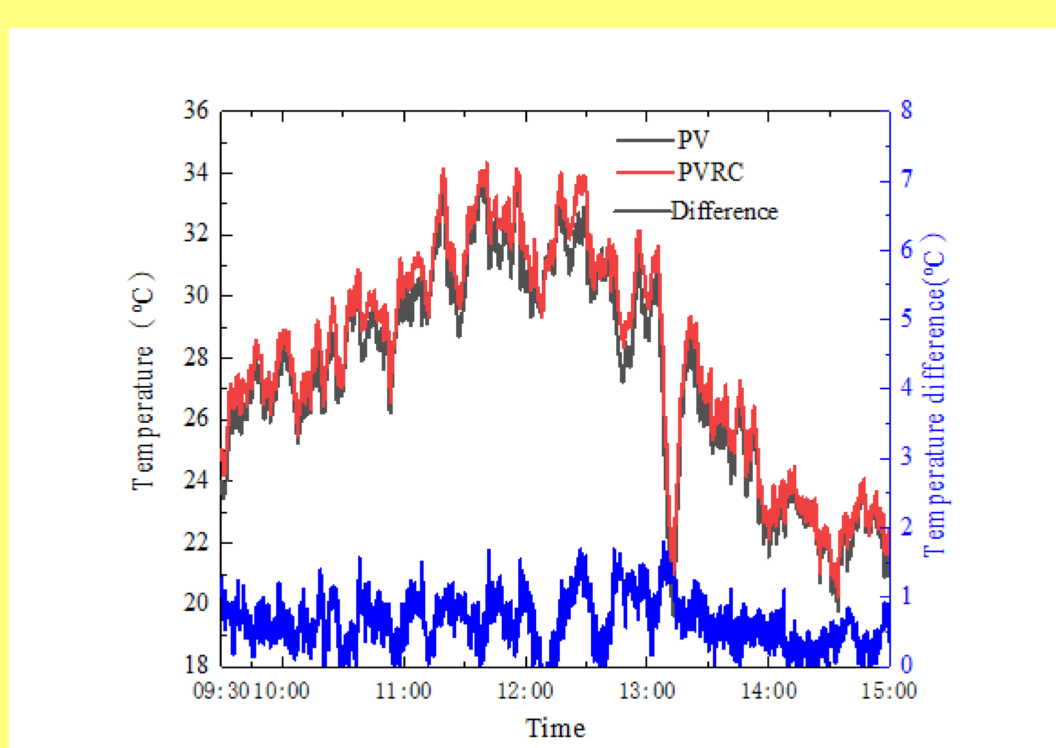

Fig.5 The surface temperature of the solar cell

It can be seen that the radiant refrigeration film can effectively improve the heat dissipation of the monocrystalline silicon solar cell, thereby improving the photoelectric conversion efficiency.

Electrical performance

It can be seen from the fig6 that with the increase of solar radiation intensity, the overall trend of photoelectric conversion efficiency is to first decrease and then increase. The efficiency of PVRC solar panels is higher than that of ordinary PV. During the experiment time, the maximum electrical efficiency of PVRC is close to 0.1694, while the maximum electrical efficiency of ordinary PV panels is 0.1607. In the period from 13:00 to 15:00, due to the decrease in solar radiation intensity, the temperature of the battery panel drops, and the photoelectric conversion efficiency slowly rises. The photoelectric conversion efficiency of ordinary PV panels decreases first and then increases because the temperature rise rate of PV panels is higher than that of PVRC panels in the initial stage, resulting in higher temperatures than PVRC panels, so the photoelectric conversion efficiency is correspondingly reduced. It can be seen that, compared with ordinary PV panels, the radiant refrigeration film of PVRC cells can increase the conversion efficiency of monocrystalline silicon solar energy by 0.0087-0.0131. The photoelectric conversion efficiency is improved, and the electrical performance of the solar cell is effectively improved.

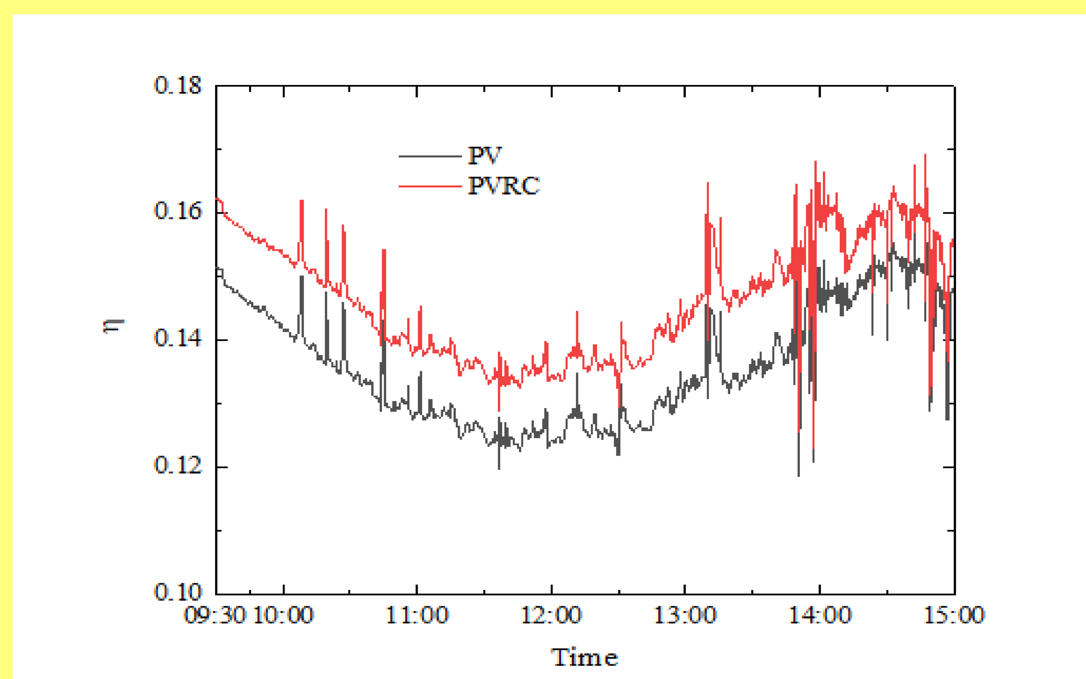

Fig.6 The photoelectric conversion efficiency

Conclusions

In this study, the finite-difference time-domain (FDTD) method was used to study and analyze the spectral characteristics of radiant refrigeration film materials, and the following conclusions were drawn:

（1）Using PVC100+60 (PDMS+SiO_2) 6% radiant refrigeration film, the light transmittance is above 0.90, and the emissivity is above 0.93.

（2）During the experiment, the maximum temperature of PVRC solar panels was 33.65°C, while the temperature of ordinary solar cells was 34.35°C. During the test, the difference in temperature between the two was 1.81°C. It can be seen that the developed thin film can effectively reduce the temperature of monocrystalline silicon solar cells, thereby improving the photoelectric conversion efficiency.

（3）As the intensity of solar radiation increases, the surface temperature of photovoltaic panels also increases. The photoelectric conversion efficiency of PVRC has always been higher than that of ordinary PV panels. After comparison, the conversion efficiency of monocrystalline silicon solar energy can be increased by 0.87%-1.31%.

References

[1] Linxiao, Zhu, Aaswath, et al. Radiative cooling of solar cells[J]. Optica, 2014, 1(1):32-38.

[2] Zhai Y , Ma Y , David S N , et al. Scalable-manufactured randomized glass-polymer hybrid metamaterial for daytime radiative cooling[J]. ence, 2017:1062.