Innovative Design and Experiments of a Semiconductor Cooling and Heating Box Driven By Solar Energy

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Abstract. Based on the research of semiconductor refrigeration, solar energy is introduced as the driving energy of semiconductor thermal effect, and the comprehensive utilization of semiconductor thermal and cold effects is deeply studied. Through theoretical design, experimental fabrication, testing and other research methods, a solar driven cold and warm box suitable for outdoor environment is designed and manufactured with semiconductor refrigeration chip as the core device. The results show that the cooling and heating effect of the new type of solar driven semiconductor cold and warm box is better. It not only has a wide range of applications in areas without electricity and lack of electricity, but also applies to areas with high level of development, such as car cold and warm box, tourism cold and warm box or field operation cold and warm box. At the same time, in poverty-stricken areas such as Africa, where the disease is rampant, this cold and warm box can also be used for the cryopreservation of drugs and vaccines, which shows the potential for export.

1. Introduction

With the exhaustion of conventional energy resources such as coal, oil and natural gas, the environmental pollution caused by the rapid economic and social development has become more and more serious. Many countries with higher scientific and technological level in the world have increased their investment in solar energy development and research. In recent years, the development shows that the proportion of household appliances with solar energy application is increasing in the composition of existing solar photovoltaic systems. Among them, solar energy application refrigeration and heating appliances and equipment are also gradually occupying more market. People are increasingly demanding to improve the quality of life. A compact, lightweight, pollution-free, noise-free, flexible and convenient semiconductor cooling and heating dual-purpose incubator has gradually become an indispensable item in modern people's leisure life.
2. Research Status
Semiconductor cold and warm box has always been a hot research object in the field of semiconductor industry and material industry [1].

2.1. Semiconductor Refrigeration Theory
In recent years, G. Min and D. M. Rowe [2] regard the interface of metal semiconductor as a simple Fermi gas-solid interface, and discuss the micro-essence of the Palpatite effect from the mechanism. Chen Zhenlin and Sun Zhongquan deduced the basic formula of semiconductor multistage refrigeration according to the theory of maximum working efficiency. J.G. Stockholm et al. [3] discussed the semiconductor refrigeration process from the point of view of thermodynamics and heat transfer, and studied the influence of current and thickness of thermoelectric materials on refrigeration performance. From the literature study, the theoretical research of semiconductor refrigeration technology is becoming more and more mature.

In recent years, increasing the optimal value coefficient of semiconductor refrigeration materials has become the main research direction of researchers. In 2001, Venkatasubramanian et al. produced the world's highest semiconductor material coefficient of 2.4 [4]. However, due to the high cost of its materials, it has not been widely used in the field of household appliances, but its theory and technology have pointed out a new direction for the study of new high-value semiconductors.

2.2. Structural Design and Heat Transfer Mode
M. Yamanashi [5] proposed a new method for optimizing the design of semiconductor refrigeration system. By optimizing the design of semiconductor refrigeration module, the difference between ideal performance coefficient and actual performance coefficient of semiconductor refrigeration module can be reduced, and the actual refrigeration performance of semiconductor refrigeration can be improved.

Scholars at home and abroad have proposed that the refrigeration efficiency can be effectively improved by using various enhanced heat dissipation modes [6, 7]. The results show that air natural convection heat dissipation, forced convection heat dissipation, water cooling heat dissipation, phase change boiling heat transfer and other ways can achieve good enhancement effect.

3. Design and principle of cold and heating box
Solar energy driven semiconductor cold and warm box, referred to as solar energy cold and warm box, mainly consists of solar panels, storage batteries, solar voltage regulator, semiconductor refrigeration module, temperature controller and box body, etc.

3.1. Basic Working Principle
When the solar heating and cooling box is in an environment with sufficient sunshine or high illumination intensity, the solar panel generates electricity, drives the semiconductor refrigeration module to refrigerate or heat directly through the solar regulator, and stores the surplus electric energy into the storage battery; when it is in an environment with low illumination intensity such as rainy days or nights. The battery directly sends the energy to the semiconductor refrigeration module through the solar energy regulator. In the process of refrigeration or heating, the temperature controller adjusts the internal temperature of the solar cooling and heating box.

The main function of the solar regulator is to combine solar panels, storage batteries, semiconductor refrigeration modules and temperature controllers, and extend the service life of solar panels and storage batteries through anti-backcharging circuit, battery overcharging, overdischarge protection circuit, etc. Its main functions include: (1) power supply and storage for semiconductor refrigeration module; (2) anti-refilling and protection circuit; (3) protection of storage battery; and (4) ensuring the safety of cold and warm box.
3.2. Design of lighting system
By investigating the relevant shape and characteristics of the existing cold and warm box, the lighting system outside the box is designed and the ring-wing lighting structure shown in Fig. 1 below is obtained.

As shown in the Fig. 1, the box body is rectangular in shape, with a semiconductor refrigeration unit and a temperature controller on one side, a solar panel on the other three sides and a top surface respectively. The two ends of the rotating support are fixed on the box body, the middle runs through one end of the solar panel, and the other end of the solar panel and one end of the hydraulic support rod. The other end of the hydraulic support rod is connected to the box body.

![Figure 1. Structure model of ring-wing lighting system](image)

1. Box, 2. Solar panel, 3. Rotary shaft of solar panel, 4. Rotary support shaft, 5. Semiconductor chiller fan unit, 6. Temperature controller

This lighting system can make full use of solar energy, reduce the dependence on vehicle-mounted batteries, facilitate field use, and has a wide range of applications. Solar panels can be retracted to the side of the main body of the cold and warm box when not in use, which reduces the occupied space of the whole set of devices and facilitates transportation and storage.

3.3. Design of Circuit
In the process of design and manufacture, based on the design of ring-wing solar cooling and heating box, the corresponding design parameters are selected and the circuit design is carried out, as shown in Fig. 2. Among them, the upper part is the principle of temperature controller, which is replaced by XH-W1308 temperature controller in practice; the lower left corner is rectifier filter circuit, which is replaced by 12V solar panel photocontrol controller in actual production; and the fan of semiconductor refrigeration unit is indicated by small bulb in Multisim simulation.

4. Physical fabrication and performance testing
In order to test the cooling and heating effect of solar energy driven cooling and heating box, ring-wing lighting system was selected to make the box in kind. Through experiments, the working conditions of solar energy driven cold and warm boxes are explored.

4.1. Two Semiconductor Refrigerators Refrigerate at the Same Time

4.1.1. Experimental Environment. The ambient temperature of laboratory space is 20.2 C. The working voltage and current of the semiconductor refrigerating sheet are 11.5V and 4.0A respectively, and that of the other is 11.5V and 4.0A respectively.
4.1.2. Experimental Contents. (1) Two semiconductor chillers are refrigerated simultaneously at 11.5V voltage and 4.0A current. (2) The internal fan operates at a voltage of 12V and a current of 0.225A. (3) The working voltage of the external fan is adjusted to 12V, 10V, 8V, 6V and 4V respectively, and the corresponding current value is measured. (4) Measure the temperature inside the solar radiator in different time periods within 30 minutes and record the data. (5) Processing data, analysing the relationship between temperature change and time, fitting curve and function by origin software, and getting some experimental rules.

4.1.3. Experimental Data Curve. The fitting curve of experimental data is shown in Fig. 3.

Through the analysis of the fitting curve, it can be seen that the refrigeration efficiency of the two semiconductor chillers is higher in the first ten minutes, which has a great influence on the temperature change in the chamber. Within ten to thirty minutes, the refrigeration efficiency decreases gradually, and the influence on the temperature in the chamber decreases gradually. After thirty minutes, the temperature in the solar chiller tends to a certain level. A stable value. The working
power of the external fan has a great influence on the refrigeration efficiency of the semiconductor refrigerating sheet. The higher the working power, the higher the refrigeration efficiency of the semiconductor refrigerating sheet, and the greater the influence on the temperature in the box.

4.2. Simultaneous Heating of Two Semiconductor Refrigerators

4.2.1. Experimental Environment. The ambient temperature of laboratory space is 20.5°C. The working voltage of the semiconductor refrigeration chip is 12V and the working current is 2.7A. The other one is 12V and the working current is 2.7A.

4.2.2. Experimental Contents. (1) Two semiconductor chillers are heated simultaneously at a voltage of 12V and a current of 2.70A. (2) The internal fan operates at a voltage of 12V and a current of 0.225A. (3) The operating voltage of the external fan is adjusted to 12V, 10V, 8V, 6V and 4V respectively, and the corresponding current value is measured. (4) Measure the temperature in the solar radiator in different time periods within 30 minutes and record the data. (5) Processing data, analyzing the relationship between temperature change and time, fitting curve and function by origin software, and getting some experimental rules.

4.2.3. Experimental Data Curve. The data fitting curve is shown in Fig. 4 below.

![Data fitting curve](image)

Figure 4. Data fitting curve

Through the analysis of the fitting curve, it can be seen that the heating efficiency of the two semiconductor chillers is higher in the first ten minutes, which has a great influence on the temperature change in the box. In the ten to thirty minutes, the heating efficiency decreases gradually, and the influence on the temperature in the box decreases gradually. After thirty minutes, the temperature in the solar chiller tends to a certain level. A stable value. The working power of the external fan has a great influence on the heating efficiency of the semiconductor refrigerating sheet. The higher the working power, the lower the heating efficiency of the semiconductor refrigerating sheet, and the less the influence on the temperature in the box.

5. Conclusion

The results of data processing and analysis show that the refrigeration efficiency of semiconductor chillers is related to the heat dissipation efficiency at the hot end. The higher the working power of the fan at the hot end, the higher the heat dissipation efficiency and the refrigeration efficiency. The heating efficiency of semiconductor chiller is related to the heat absorption efficiency of its cold end. The higher the power of the fan, the lower the heat absorption efficiency and the lower the heating efficiency.
It can also be concluded from the experiment that the refrigeration efficiency of the semiconductor refrigeration sheet is not very high, and the refrigeration and heating efficiency of the semiconductor refrigeration sheet is higher than that of the refrigeration sheet under the same conditions. Therefore, if the refrigeration and heating functions of semiconductor refrigeration chips can be applied at the same time, the working efficiency of semiconductor refrigeration chips will be greatly improved, but this is only suitable for certain special occasions, perhaps using its high heating efficiency, but special attention should be paid to its temperature control within a certain range, otherwise semiconductor refrigeration. The sheet is extremely vulnerable to damage.

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