A New Design of Temperature-Controlled Chamber for OLED Panels

Hsin-Hung Chang, Jin-Lung Guan, and Ming-Ta Yang

Abstract—This paper presents an inexpensive and effective temperature-controlled chamber for temperature environment tests of Organic Light Emitting Diode (OLED) panels. The proposed chamber is a compact warmer and cooler with an exact temperature control system. In the temperature-controlled space of the chamber, thermoelectric modules (TEMs) are utilized to cool or to heat OLED panels, novel fixtures are designed to flexibly clamp the OLED panels of different size, and special connectors for wiring between the OLED panels and the test instrument are supplied. The proposed chamber has the following features. (1) The TEMs are solid semiconductive devices, so they operate without noise and without pollution. (2) The volume of the temperature-controlled space of the chamber about 160mm*160mm*120mm, so the chamber are compact and easy to move. (3) The range of the controlled temperatures is from -10 $^{\circ}$C to +80 $^{\circ}$C, and the precision is ±0.5 $^{\circ}$C. (4) The test instrument can conveniently and easily measure the OLED panels via the novel fixtures and special connectors. In addition to a constant temperature being maintained in the chamber, a temperature shock experiments can run for a long time. Therefore, the chamber will be convenient and useful for temperature environment tests of OLED panels.

Keywords—Thermoelectric module, Temperature environment test, OLED, chamber.

I. INTRODUCTION

THE OLED has unique characteristics, including self-emission, lightness, thinness, fast electronic response and a wide viewing angle [1, 2, 3]. Thus, the OLED panel could be the trend of next generation in information display. The OLED display will be more popular if the following problem can be resolved. They include lifetime evaluation, encapsulation, material receipts and power consumption [4]. So, OLED panels always require a temperature environment test to determine their characteristics under different operating temperature environments. Traditional temperature experiments are always conducted in a temperature chamber; however, a traditional chamber has many disadvantages. First, it has a huge volume and the precision of the temperature control is low. It is also very expensive. Second, there was no wiring and plug socket on the chamber for external connection and the measuring instrument cannot be put directly in the chamber, so long wires are needed. The length of the wiring greatly affects the test results. Last, since the chamber

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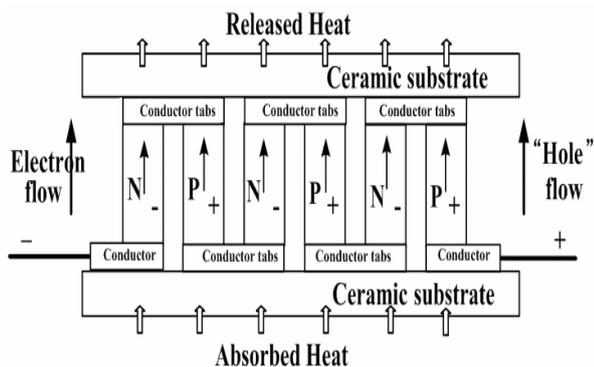M. T. Yang is with the St. John 's University, Taipei, Taiwan, R.O.C. (e-mail:mtyang@mail.sju.edu.tw).

includes such parts as compressor, refrigerant, and evaporator, it usually generates pollution and noise.

Only a few research has been presented, such as the chamber designed by KRYOTHERM CO. [5] and the temperature-controlled box (TCB) presented at the 2003 Thermoelectric Conference [6]. Both systems utilized thermoelectric modules (TEMs) for cooling and then used the water-cooling method to absorb the heat from the TEMs to achieve lower temperatures, but doing so required a much larger volume, and the structure was more complex than the air-cooling method. In the temperature-controlled space of these chambers, there are not the designed connectors and fixtures for the OLED panels. Functionally, these temperature-controlled chambers cannot meet the test requirements of the OLED panels, so we have designed a new thermoelectric temperature-controlled chamber. This proposed chamber also utilizes TEMs to cool or to heat the test OLED panels but it uses the air-cooling method to absorb the heat from the TEMs in the chamber. As a result, the chamber is small and has a low failure rate while producing no pollution and very little noise. In addition to these advantages, a good temperature-controlled precision is attained. Novel fixtures and special connectors are designed to make the experiments more convenient. In the following sections, the principles behind the thermoelectric module are first introduced, followed by the design and operation principles of each unit of this proposed chamber. Finally, several temperature experiments are used to demonstrate the effectiveness of the chamber

II. PRINCIPLES OF THERMOELECTRIC MODULE (TEM)

Thermoelectric modules are based on the Peltier Effect, discovered in 1834 [7], by which DC current applied across two dissimilar material causes a temperature differential. A thermoelectric module (TEM) consists of several N & P pellets, which are connected electrically in series and thermally in parallel and are sandwiched between two ceramic substrates, as illustrated in Fig. 1. With the application of a DC current of the proper polarity, heat is pumped from the bottom substrate to the top substrate, where it is dissipated to the ambient. The result is that the bottom surface becomes cold.

By simply reversing the DC polarity, the bottom surface can also dissipate heat, thus making the top surface cold [7,8,9]. Because TEMs are so light and easy for use in cooling and heating, they are the key components in the system. Therefore, there are 2 TEMs in the proposed chamber.

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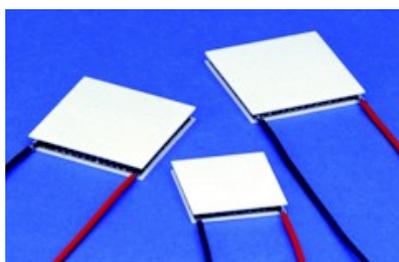Vol:1, No:4, 2007

Fig. 1 (a) Thermoelectric module

Fig. 1 (b) Thermoelectric module

III. DESIGN AND CALCULATION

A chamber consists of four separate subunits: (1) the temperature-controlled unit, (2) the power-controlled unit (3) the iron plate and the fixtures, and (4) the electric connectors.
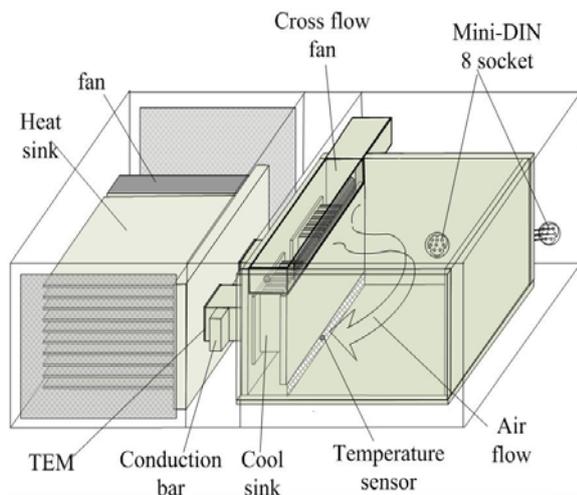

Fig. 2 Simplified structure of the temperature-controlled unit

The temperature-controlled unit can be used to heat and to cool, depending on the direction of the TEM current. Using a TEM in the heating mode is very efficient because all the internal heating (Joulian heat) and the load from the cold side are pumped to the hot side. This reduces the power needed to achieve the expected heating. Therefore, we only focus on the cooling mode design.

The initial design data:

(1) the temperature controlled space in chamber:
about 160mm*160mm*120mm

(2) an estimated heat load of $Wob(W) = 2W$

(3) a force convection type of released heat sink with a thermal resistance of $Rheat(^oC/W) = 0.2 \, ^oC/W$

(4) a forced convection type of absorbed heat sink with a thermal resistance of $Rcool(^oC/W) = 1.2 \, ^oC/W$

(5) an ambient temperature:
$Ta(^oC) = 25 \, ^oC$

(6) Insulation thermal resistance:
$Rins(^oC/W) = 4.00 \, ^oC/W$

In the temperature-controlled unit, we use 2 TEMs (FROST-74HT150 from Russia) as heat pumps. According to the computer software supplied by KRYOTHERM [5], we can get the following important results:

(1) The cold side temperature of the TEM:
$Tc(^oC) = 19.5 \, ^oC$

(2) The hot side temperature of the TEM:
$Th(^oC) = 47.3 \, ^oC$

(3) The temperature of the temperature-controlled space:
$Tob(^oC) = -12.5 \, ^oC$

(4) The heat leaking in from the outer world:
$Qleak(W) = 9.4W$

(5) The power for the TEMs:
$Qs(W) = V * I = 12 * 8.29 = 99.4W$

(6) The total released heat from chamber:
$Qh(W) = Qs + Qleak + Wob = 110.8W$

(7) The coefficient of performance:
$COP = 0.114$

According to the above results, when we supply about 110W for the chamber, the minimum temperature of the temperature controlled space is -12.5 ^oC. The result shows that maintaining a temperature of -10 ^oC and a cooling power of 2W could be achieved in the chamber. In addition to the cooling mode, TEMs can also operate in the heating mode. Although heating the TEM over 80 ^oC is easy and fast, the high temperature air flow is a big challenge for a convection fan. Hence, we use a cross flow fan instead of an axial flow fan because the aluminum blades of the former can withstand high temperatures, as shown in Fig. 2.

To increase the precision of the temperature control, we select the DS1621 digital thermometer as the temperature sensor, as it provides a digital interface for the power-controlled unit to show the temperature in the temperature-controlled unit. The precision is ±0.5 ^oC in a range of -10 ^oC to +80 ^oC. The temperature sensor is located at the air intake of the cold sink to measure the temperature of the airflow. This measured temperature is used as the feedback signal to control the temperature in the temperature-controlled unit.

The power-controlled unit which is based on a microprocessor controls the operating temperature of the temperature-controlled unit. Alternatively, the user can control the temperature-controlled unit directly from the panel of the power-controlled unit. As shown in Fig. 3, the power-controlled unit includes a microprocessor circuit and a drive unit. The drive unit includes a 12V/12A DC power supply for

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supplying 2 TEMs and the fan in the temperature-controlled unit, an "H" bridge circuit, and a digital control circuit.
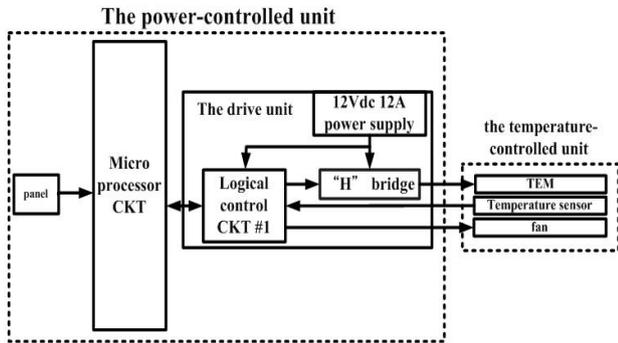

Fig. 3 Block diagram of the power-controlled unit

The "H" bridge circuit provides bi-directional (heating and cooling) power control for the TEMs in the temperature-controlled unit, as shown in Fig. 4. The "H" bridge is designed to provide a seamless transition between heating and cooling. That is, there is no discontinuity in the control function during the transition between heating and cooling. These MOSFET HRF3205 components of the "H" bridge circuit are of the N-channel type, so they have a low resistance of 0.008 ohm. Since N channel MOSFETs typically have a lower Rdson resistance as compared to P channel types, we designed the circuit with N channel MOSFETs to reduce the power dissipation. Apparently, the component must have a smaller turn-on resistance when the TEMs operating current become larger.
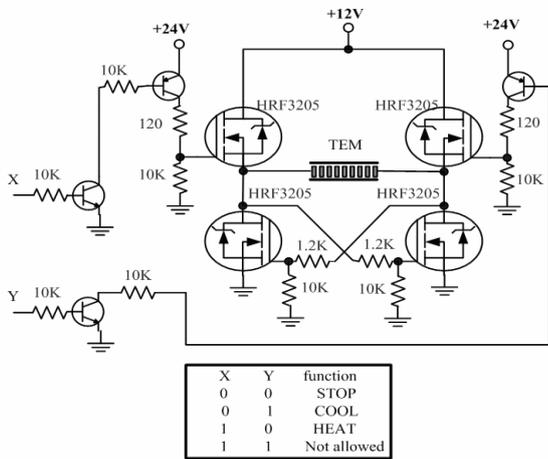

Fig. 4 "H" bridge CKT

The digital control circuit provides drive signals X and Y for the "H" bridge circuit, a +24V power for the MOSTFET Gate control, and a digital interface for the temperature sensor. The +24V Gate control voltage is generated by a voltage doubler (ICL7662) in the digital control circuit.

The OLED panel is fixed to the iron plate by unique fixtures, as shown in Fig. 5. The bottom of the fixture is a flat magnet that can attract the iron plate. We can move these fixtures to fit the shape of the OLED panel. After the iron plate is loaded with the OLED panel and the fixtures, the whole plate can be placed into the temperature-controlled unit for testing.

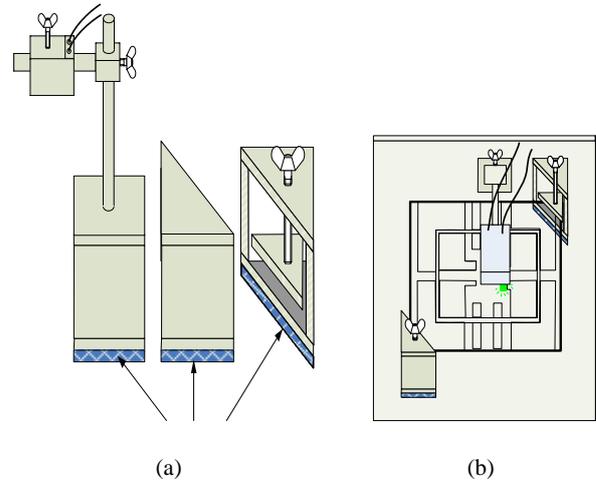
(a)   (b)

Fig. 5 (a) the fixtures (b) fixtures holding the iron plate

For easy wiring in the airtight temperature-controlled space, we place some wiring clips and 2 Mini-DIN 8 sockets inside and outside of the temperature-controlled unit. Other instruments can be used to measure the characteristics of the OLED panel through the sockets and clips, as shown in Fig. 6.
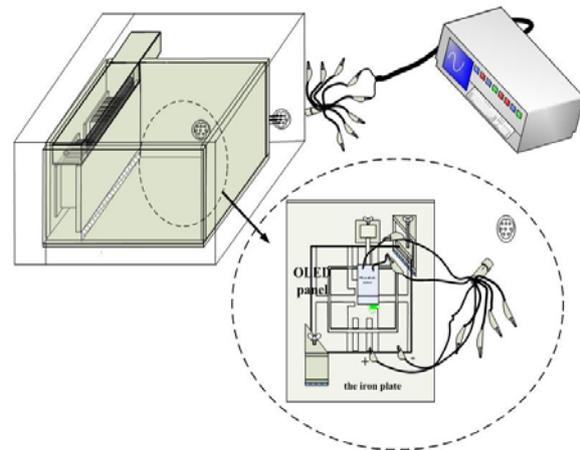

Fig. 6 Wiring between the outside instrument and the inside OLED panel

This proposed chamber adopts the PI digital control method to control the temperature. Since the temperature changes very slowly, the sampling rate of the temperature sensor is once per second. Based on the difference between the sampled temperature and the desired temperature, the PI digital control method generates new control data for the TEM power control. As a result, proper control data from the PI method offers rapid and accurate temperature control of the chamber.

Changing the TEM supply voltage is one method for changing the TEM supply power, as well as a method for changing the cooling or heating power of the TEMs. Based on the control data from the PI method, the proposed system utilizes Pulse Width Modulation (PWM) to control the TEM

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supply voltage. This PWM-based frequency is 100Hz, and every cycle is divided into 256 control partitions. As a result, the TEM voltage control has a 0.4% control voltage resolution.

The PI digital control data and the PWM control signal are generated by the firmware on the microprocessor in the power-controlled unit.

Condensation is a problem when a temperature-controlled system cools the target below the ambient temperature. The proposed system uses convection cooling method to cool the targets with the lower temperature of the airflow in the temperature-controlled space, thus preventing water from condensing on the surface of the targets. In addition, the temperature-controlled space is small and airtight, so little water exists at the cool side sink and it will not affect the accuracy of the temperature

IV. EXPERIMENTAL RESULT

This proposed chamber has been tested in several experiments and the results are shown in Figs. 7 and 8.

The first experiment tests the responsiveness of the proposed system to a step temperature command and the control accuracy of maintaining the desired temperature. Fig. 6 shows the time curves of the temperature response of the 3 different processes when there is a 2W load in the airtight temperature controlled space in the temperature-controlled unit. As can be seen, in about 15 minutes, this system can decrease the difference between the original temperature and the desired temperature by 90%. In about 30 minutes, the system has finished the process and stably maintains a temperature- controlled precision of $\pm 0.5\,^{\circ}$C.
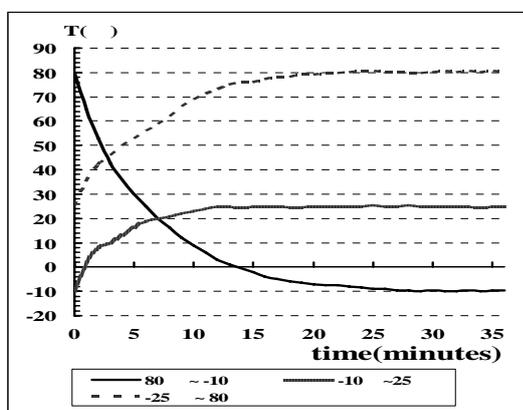

Fig. 7 Time response curves of 3 temperature- controlled processes

Fig. 8 shows an example setup in which the proposed system operated with an OLED lifetime instrument [4] in an OLED lifetime measurement experiment. The OLED lifetime system can measure the brightness and the voltage drops of an OLED panel for a long time to estimate the lifetime of the OLED panel at room temperature. With the proposed system, the OLED lifetime instrument can measure both the lifetime of the OLED panels at different temperatures simultaneously and the deviation in the characteristics of the OLED panels in

temperature shock experiments. This proposed system can thus greatly improve the function of the original instrument.
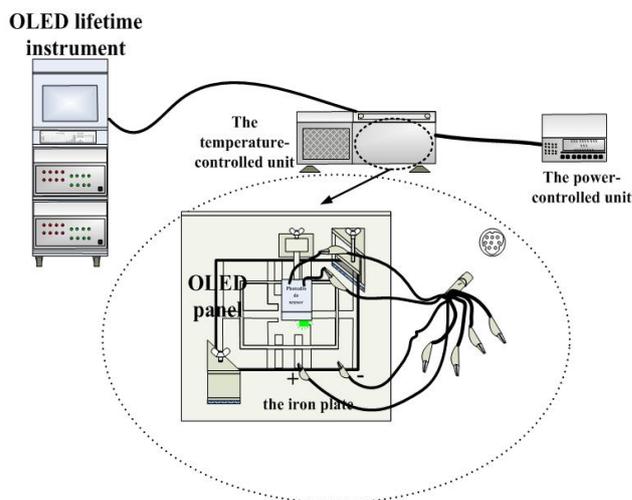

Fig. 8 Proposed chamber with an OLED lifetime instrument

V. CONCLUSION

This paper presents a new chamber that provides temperature-controlled environments for measuring temperature characteristics of OLED panels. The chamber attains a controlled temperature ranging from -10 $^{\circ}$C to +80 $^{\circ}$C and temperature-controlled precision of $\pm 0.5^{\circ}$C. With specially designed fixtures and iron plates, the OLED panel can be placed in the airtight temperature-controlled space easily. With special wiring clips and connectors, the probes of the measuring instrument can easily be connected to the test OLED panel during it operates.

The experimental results show that the proposed chamber is an inexpensive and feasible system for temperature experiments of OLED panels. Future, we will expand the proposed chamber up to 8 sets and the whole system will be controlled by the Windows program of the PC. In addition, control commands are provided to other test instruments through RS232, allowing the system to be controlled directly by those test instruments.

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