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Design of intelligent dimming glass system

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Abstract: An intelligent dimming glass system is designed using PDLC. The system includes luminance sensors and temperature sensors to monitor the environment in real time. The heating film is adopted to overcome the disadvantage of PDLC's narrow working temperature range. Whole fit technology is used to bond the heating film and the glass. The whole system can be controlled in three methods: automatic, manual and remote control. Perception experiment is carried out to obtain the threshold of luminance. Finally, intelligent dimming can be realized.

Keywords: PDLC, dimming glass, intelligent control, heating film.

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1. INTRODUCTION

With the development of electronic information technology, dimmer glass has been paid more and more attention, especially in the field of intelligent building, automobile and other applications. Dimming glass has the advantages of safety glass. It also can achieve the following effects, like privacy protection, projection, heat insulation, ultraviolet insulation and sound insulation. Two states, transparent and frosted, can be achieved (Fig.1).

Fig.1 Two working state of dimming glass

At present, the common technologies which can be used in dimming glass mainly includes thermochromic glass [1], liquid crystal glass, and so on. These dimming glasses are all reversible devices and can realize the transparent- frosted effect switching. Thermochromic

dimming glass is made up of transparent heating layer and electrochromic layer. The structure is like sandwich structure, which consists of two glasses sandwiched with polymer gel. When it reaches a certain temperature threshold, the effect of the glass changes from transparent to frosted [1]. But this kind of dimming glass is mainly controlled by temperature, which is inconvenient. In comparison, the liquid crystal dimming glass realizes the switching of glass state by adding power, which enables more convenient control. The liquid crystal dimming glass usually uses polymer stabilized liquid crystal (PSLC) and polymer dispersed liquid crystal (PDLC) [2]. At present, PDLC technology is more mature, and has fast response and high contrast [3]. It has been widely used in dimming glass market. However, PDLC also has some disadvantages, such as high driving voltage, selective transmission and etc. The PSLC material can solve these problems [4]. The material has the advantages of both liquid crystals and polymers and has attracted more and more attention [5]. However, such materials are not used widely in the market of dimming glass. If we want to have integrated applications, it will be inconvenient.

For dimming glasses, the main evaluation factors are transmittance, response time, temperature characteristics and contrast. Among them, the transmittance is mainly related to voltage, preparation method and other factors [6]. As the voltage increases, the transmittance increases significantly for most PDLC. Under the condition of no voltage, the transmittance is very low, and it is frosted. So transparent state can be achieved by adding power resource. Different preparation methods also have different transmittance. When the concentration of liquid crystal changes, the shape of the curve will be different. The response time is the time that luminance increases from 10% to 90% after adding power source. It usually takes milliseconds to finish the process. The lower the temperature is, the slower the response time will be. Contrast refers to the ratio of transmittance of two states of dimming glass, or the ratio of brightness to two states. Different preparation methods can lead to different contrast. In practical applications, the contrast is also affected by temperature. The working temperature range must be at -10^{o} C ~ 50^{o} C. When the temperature is too lower, the contrast will be terrible and the state cannot be changed perfectly.

Generally speaking, dimming glass has been widely used in many occasions. PDLC dimming glass is the most common used product. Most researches focus on how to prepare this material and evaluate the characteristics. The work on how to use it intelligently is limited. So, an intelligent dimming glass system is designed in this paper. The system can be controlled by ambient illumination and wireless signal. What's more, an automatic system is added considering the disadvantage of PDLC.

2. HARDWARE STRUCTURE DESIGN

2.1 Overall design

In this system, three working modes are designed to improve customer experience, including automatic working mode, remote control mode and manual working mode. The diagrammatic sketch is provided in Fig.2. In this picture, 7 parts are included. 1 is a client, which can be cell

phone or computer. 2 is sensor, including temperature sensor and luminance sensor. 3 is MCU with WIFI module. 4 is PDLC drive module to convert the control signal from MCU to the drive signal of PDLC. 5 is heating film to keep the PDLC working regularly under -10°C. 6 is PDLC dimming glass. 7 is button, which is used to control the PDLC manually.

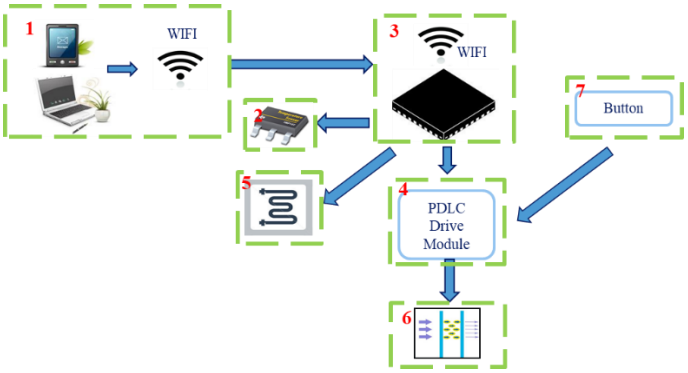


Fig.2 System diagrammatic sketch

In these three different modes, the actuators, PDLC drive module and PDLC dimming glass, are used in all situations. Besides the glass and its' drive module. MCU and heating film are used in different working mode, since heating function is always needed when the temperature is lower than the threshold. Other modules are different in different modes according to the function.

Manual working mode is the simplest mode. Like most life scenes, the glass is controlled by mechanical switches through giving a control signal to the drive module.

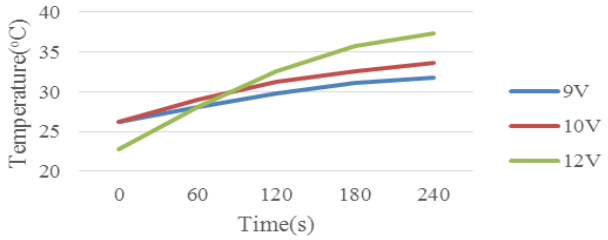
When the system works in remote mode, client, WIFI module and MCU are used. The client can send control signal to cloud platform through WIFI. When the MCU receives the control signal, it will control the PDLC drive module to work.

The manual working mode is the most intelligent mode. The state of the glass is determined by luminance and temperature. The optimized value is determined by perception experiment.

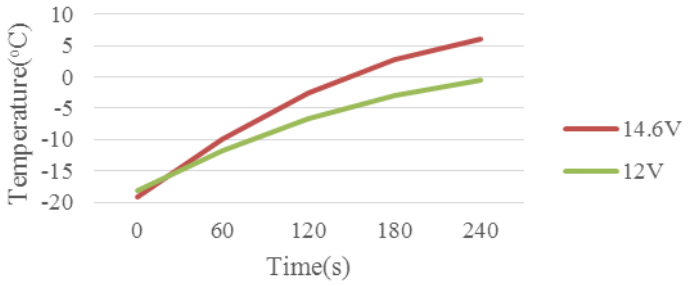
2.2 Heating film selection and whole fit technology

Among all the components, heating film is difficult to select, since power consumption, heating time, and transmittance must be taken into account at the same time. A transparent thin film from Shine Optoelectronics Co., Ltd is used. The film has high transmittance higher than 80% and the square resistance is about 9 ohms.

The curve of temperature is recorded when different voltage is applied to the film in different working temperature. The results are shown in Fig.3.



(a) Room temperature



(b) Below 0oC

Fig.3 The results of temperature after heating

From Fig.3, the higher the voltage is, the faster the temperature rises and the curve is steeper. When the temperature is at room temperature, the temperature will increase 14.5°C in 4 minutes when the 12V voltage is used. The value is up to 17.8°C when the temperature is below 0°C. The heating film can achieve a better effect when the temperature is lower, which is suitable for our application. Although higher voltage can decrease the heating time, the power consumption will be higher. In practical applications, heating time and power consumption cannot be considered simultaneously. If time is the first consideration, the temperature can be increased by 10 degrees in 1 minutes when 14.6V voltage is used. In our design, both of the two factors are considered. So, 12V voltage is selected.

How to bond the film and the dimming glass is another technology difficult. In this study, the whole fit technology is used. The film and the glass are glue together in a seamless way with optical grade glue material. Compared with traditional bonding technology, the whole fit technology can achieve better optical display effect and ultra-thin appearance design. The air between the film and the glass can be eliminated. The reflection between them can also be reduced to realize better transmittance.

2.3 PDLC driving module

PDLC is one type of liquid crystal. The driving signal is simply. The direction of liquid crystal molecules will be fixed when the voltage is higher than the threshold. The threshold is determined by many factors, like preparation method, temperature and etc. Different like Liquid Crystal Display, each pixel has different control signal and the driving signal is complicated. All the LC molecules works in the same way to realize the consistent display effect. Same voltage is added in this system. 220V alternating current is converted to 12V DC by the voltage conversion circuit. A relay is also used to receive the control signal from MCU and give a command to drive the PDLC.

3. SOFTWARE DESIGN

3.1 Perception experiment

Before design of the software, threshold of luminance should be confirmed especially in automatic working mode. In the perception experiment, a room with two windows is chosen. Two frosted glasses are used to simulate the state that dimming glass works on frosted state.

Ten subjects participated in the experiments. They were asked to give a score of their feelings according to the following scale.

Table 1 Five-grade impairment scale for perception experiment

Grade	Comfort
5	Very comfortable
4	Comfortable
3	Slightly uncomfortable
2	Uncomfortable
1	Very uncomfortable

Four different situations are used. The weather is sunny or cloudy. People sit beside the window or in the middle of the room.

1. Sunny and beside the window

In this situation, both of the luminance indoor and outdoor are higher than 2000lx. 90% of the subjects prefer frosted window since the sunshine is too bright. The left people said it depends on what are you doing.

2. Sunny and in the middle of the room

The luminance of indoor is about 200lx. In this situation, 100% of the subjects like the transparent working mode.

3. Cloudy and beside the window

The luminance of indoor is about 170lx and the luminance outdoor is about 200lx. In this situation, 100% of the subjects like the transparent working mode.

4. Cloudy and in the middle of the room

The luminance of indoor is less than 100lx. In this situation, 100% of the subjects like the transparent working mode.

From the results, frosted situation only be preferred when the weather is sunny and people sit beside the window. In other situations, the luminance is always lower than 300lx. All of the people choose the transparent working mode. So, the threshold is set to be 2000. When the luminance is higher than 2000lx, MCU controls the glass to be frosted working state.

3.2 wireless base station software flow design

The specific working process of the system software is shown in Fig.4.

After starting and initialization, the MCU judges whether the WIFI module has received the instruction. If there is a command, read it and send a signal to I/O port 1 to control the glass when the received command is “Open”. And then repeat the process after 5 minutes. If there is no command. MCU read both of the time information and the information from temperature sensor and luminance sensor. If the time is between 19:00pm and 7:00am, no signal is write to I/O ports. If the temperature is lower than -10^{o}C, MCU write I/O port 2 to control the heating film. If the temperature is higher than -10^{o}C, heating film stops working. If the luminance is lower than 2000lx, MCU write a high-level voltage to I/O port 1 to switch the glass to transparent state.

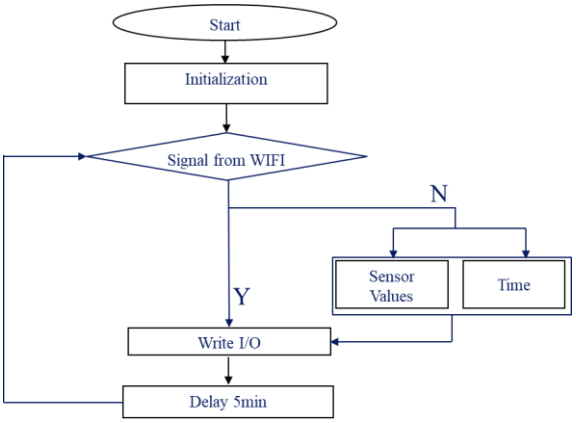


Fig.4 Software flow chart of the system

4. CONCLUSION

Based on PDLC, an intelligent dimming glass system is designed. In this system, three working modes, including automatic working mode, remote control mode and manual working mode, can be selected. When working in remote control mode, the state of the glass can be controlled through MCU and WIFI module. When automatic mode is selected, the state of glass is determined by ambient illumination and the time. Heating film works automatically when the temperature is lower than -10^{o}C to keep the PDLC working regularly. The film is bonded with the glass using whole fit technology. This system can overcome the defect of PDLC. It is significant for further promotion of dimming glass.

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