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Electrochromic Glass Design with Solar Energy

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Abstract **–** With the effect of the use of non-renewable energy sources, our world is facing the danger of global warming. The use of fossil fuels increases the rate of carbon dioxide emitted into the atmosphere, and thus, global warming, unfortunately, brings climate changes with it. Minimizing this danger can only be achieved by turning humanity towards renewable energy sources. Solar energy is a reliable, environmentally friendly and inexpensive source. The aim of this study is to perform the electrochromic glass by using solar energy without any electricity costs and thus to encourage people to more renewable energy technologies. In this study, it is desired to present a new technology design that is an alternative to the classical window glasses used in our country by using solar energy. The solar panel converts the sun's energy into electrical energy by using solar energy, and with this electrical energy, the opaque electrochromic glass changes color and becomes transparent. Thus, the glass makes the interior of the room show with this color change. This system, which works with a photovoltaic panel, operates the electrochromic glass with solar energy without the need for extra energy. For example, with this system, it also eliminates the need for curtains or roller blinds used in working and living areas and provide ease of use according to the desired conditions. This system can be used not only for this purpose, but also anywhere that is required for smart glass design and has solar energy potential. For this study, electrochromic smart glass obtained by placing polymer dispersed liquid crystal (PDLC) smart material and this material was sandwiched between indium tin oxide window films with the help of Polyvinyl butyral (PVB) layer. This electrochromic glass system is designed by connecting the connection cable and the on-off switch cable to the photovoltaic panel. In this study, electrochromic glass performance was tried to be analyzed depending on the exposure time of the photovoltaic panel in the sun.

Keywords –Photovoltaic Panel, Electrochromic Glass, Solar Energy, Energy Applications

I. INTRODUCTION

The increase in the world population, technological developments and industrialization intensify the demand for energy. Energy, which is used as a basis in production, is an important element for raising the living standards of societies, and it appears in many places in our daily lives [1-3]. Energy is often defined as the ability to do work. Because it exists in many forms such as magnetic, electrical, mechanical, heat, chemical and nuclear, and it never disappears. Energy can be transformed from one type to another with appropriate methods and can be grouped in different ways. Energy resources are mostly classified according to their recyclability and use. In the classification made according to their convertibility, primary and secondary energy sources are named. Based on their use, they are classified as renewable and non-renewable energy sources. The state of energy that has not been transformed or changed is called primary energy. Primary energy sources; coal, natural gas, petroleum, hydraulic, biomass, nuclear, wave-tide, wind and solar. The energy that emerges as a result of the conversion of primary energy is secondary energy. Diesel, gasoline, electricity, secondary coal, diesel oil, coke, pet coke, liquefied petroleum gas (LPG) and air gas constitutes such energy sources. There are two types of non-renewable energy sources, core-based and fossil-based. Oil, coal and natural gas are considered as fossil-based non-renewable energy sources. Thorium and uranium are classified as non-renewable energy sources of nuclear origin. Renewable energy sources include hydro, solar, wind, geothermal, biomass, wave-tide and hydrogen. Fossil fuels, which constitute the majority of energy sources, cause emissions of some substances harmful to human health and the environment. The dispersion of such substances in the environment. It causes not only environmental damage such as air and water pollution, but also climatic variations that have a global impact [4]

Solar energy is a very powerful energy formed as a result of the fusion reaction that converts hydrogen gas in the sun's core into helium. Technologies such as solar cells (photovoltaic batteries), solar power plants and solar collectors (collector) are being developed to benefit from this energy that reaches our world through the sun's rays. Photovoltaic phenomenon, which is one of the ways of obtaining electrical energy from the sun, has been widely used in recent years. Photovoltaic solar cells (PV, solar panels, solar cell, PV, solar panel) are electronic devices that consist of semiconductor materials and emit electricity when sunlight hits them. Solar energy in photon character is transferred to photovoltaic material. All photons transfer the necessary energy to photovoltaic particles for electron vibration. By connecting the part of the permeable lattice that is illuminated by the sun to the permeable at the back, free electrons provide the direct current to the outer permeable. All free electrons have a voltage of almost 0.6 V. Panels generally consist of 30-36 cells. They are connected in series to create an open circuit voltage from 18 to 22 V DC, that is, direct current voltage. The highest theoretical efficiency in this cycle, which converts light energy into electrical energy, is almost 28%.

Electrochromism is the situation in which a voltage is applied to an electrochromic material, resulting in differences in its physical and chemical structure. With electrochromism, the color of the electrochromic material can be changed. In addition, optical qualities such as light transmittance, light reflection and light absorption undergo differentiation. Electrochromic devices generally consist of two electrodes (anode and cathode), at least electroactive layer with an electrolyte. For coloration to occur, coloration occurs in at least one or both of these electrodes or in the electrolyte. In order for the color change to occur in electrochromic devices, some reactions (reduction and oxidation) are required. A voltage is applied to the system for the operation of electrochromic devices [5-10]. Thanks to this voltage, mobile ions (which can be H^+, Li^+ or Na^+) are transported between the electrochromic active layer and the ion storage layer. When electrochromic material is electrified, the material stores or loses electricity. As the given electricity increases, the color of the material changes and becomes transparent and its light transmittance increases. When it decreases, the color becomes darker and the light transmittance decreases [11-15].

Smart glass technologies are used extensively in the residential sector. It is very important to evaluate energy in the most efficient way by looking at today's rising energy need and issues in energy resources. At the same time, the welfare of the working and living spaces is given importance for the people [16-20]. Therefore, the areas where smart glass technologies (electrochromic glass coatings in general) are used a lot are building applications [21-22]. Although their use is limited, another area of use for smart glasses is the aerospace industry [23]. The level of sunlight to which airplanes are exposed also changes as they fly at various altitudes [24]. In order for travelers to be comfortable during their flights, the use of smart glass technologies on their planes has increased by world-renowned companies. Another use of smart glass technologies is in the automotive segment [25]. Some companies supply manufacturers with materials with smart glass technology for mirrors in cars. The reflection of the light at different angles in the mirrors used in the vehicles in general can disturb the people around them and the driver. Therefore, smart glass technologies are important in terms of security in the automotive industry. We also encounter smart glasses in screen science today. With the advancement of technology, there are many smart glass coating technologies in tablets, computers and mobile phones. Likewise, OLED and active host liquid crystal science is utilized in high-scale digital indications [26-28].

Among the renewable energy sources, solar energy is the type of energy with the largest capacity. All energy sources in our world have come from the sun. However, fossil fuels are coming to the point of depletion. At the same time, fossil resources are not preferred because of the damage they cause to the environment. Solar energy is reliable, environmentally friendly and cost-effective. At the same time, this energy can be renewed again. Solar energy reduces carbon dioxide emissions, reduces energy costs and provides prosperity to our environment with clean energy. In this study, it is to ensure that the energy required for color change is obtained from solar energy by integrating electrochromic glass device that can be used in smart glass technology by using the clean and free solar energy with the help of photovoltaic panel.

II. Materials and Method

In this designed project, photovoltaic panel (A 22 W Polycrystal (42x36 cm) Lexron LXR-022), PDLC film ((15x30 cm) Mectech.), ITO glass, key switch and cable were used as materials. H05VV-F 2 x 0.75 mm^2 300/500 V cable is used for the connection. The maximum short circuit temperature of the cable is 160 ^oC, the maximum operating temperature is 70 ^oC and the rated voltage is 300/500, 450/750 V. It can be used in closed and dry places and tools where mechanical stresses are low.

As a result of the sunlight coming to the photovoltaic panels, the photovoltaic cells present in the panels convert the sun rays into electric current. Therefore, light energy is converted into electrical energy. The layers in the structure of the photovoltaic panel are as follows: Aluminum frame, air glass, EVA (encapsulant), solar cells, EVA (encapsulant), back cover and electrical junction box.

By being absorbed into the photovoltaic panel, the sunlight coming to the photovoltaic cells detaches electrons from the p-type semiconductor material at the bottom of the cells and the ejected electrons move towards the n-type semiconductor material at the top. Therefore, the unilateral and continuous electron flow from the p-type semiconductor material to the n-type semiconductor material is converted to direct current (DC).

PDLC class window films are smart materials that are transparent when electric current is applied and opaque (frosted glass) when electric current is not applied. The liquid crystal droplets in its structure allow the optical properties of the PDLC film to be controlled by electric current. PDLC films are in a sandwich structure. This structure consists of a highly optically permeable polymer layer with liquid crystal droplets placed between two transparent conductive layers (ITO-PET film). When electric current is applied to ITO-PET films, the liquid crystals are polarized in one direction and allow the incoming light to pass. When the electric current is interrupted, the liquid crystals are randomly oriented and scatter the passing light.

Smart film is an LCD product based on PDCL technique and two-layer soft ITO film as electrode. Its transparency can be adjusted by AC power. It draws 5 W of power.

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III. Results and Discussion

The electrochromic glass design project, which works with a solar cell, converts solar energy into electrical energy with the help of a solar panel on it.

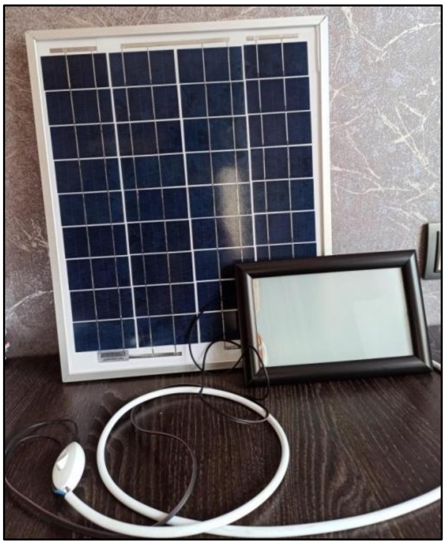

Fig. 1 The prototype of this study

The converted electrical energy is transmitted to the PDLC smart window film by means of a connector and a cable, allowing the film to change from opaque to transparent. Since the project is aimed to serve as a curtain, it was designed accordingly. Therefore, it is necessary to let light into the house during daylight hours. Therefore, electrochromic glass should be transparent during the daytime and opaque at night. In order for the electrochromic glass to be transparent, the solar panel should be placed in a sunny place. The solar panel converts the solar energy into electrical energy and transmits this electricity to the electrochromic glass when the adapter is in the on position.

Experiment data conducted in partly cloudy weather at 18 ^oC between 12:00 and 13:00 hours are available in Table 1. The solar panel was kept in the sun for certain minutes, then it was put into the shade and it was tried how many times the electrochromic glass could be switched On/Off. When this process is repeated, it is observed how long the electrochromic glass works. This test was carried out again under the same weather conditions, at 21 oC, between 17:00 and 18:00, and the test results are shown in Table 2. As a result of the observation results, it has been observed that the longer the solar panel stays in the sun, the longer the switching and operating time of the electrochromic glass. At the same time, the increase in air temperature also showed an increase in the effect of electrochromic glass on the switching and operating time.

Table 1. Experimental data recorded during partly cloudy weather at 18 ^oC between 12:00 and 13:00 hours

exposure time for solar panel (min)	**the number of switches**	**the working time (s)** *(when the electrochromic glass is switched once)*
1	6	90
5	32	314
10	86	503
20	46	1060

Table 2. Experimental data recorded during partly cloudy weather at 21 ^oC between 17:00 and 18:00 hours

exposure time for solar panel (min)	**the number of switches**	**the working time (s)** *(when the electrochromic glass is switched once)*
1	20	128
5	49	507
10	203	1013
20	384	1500

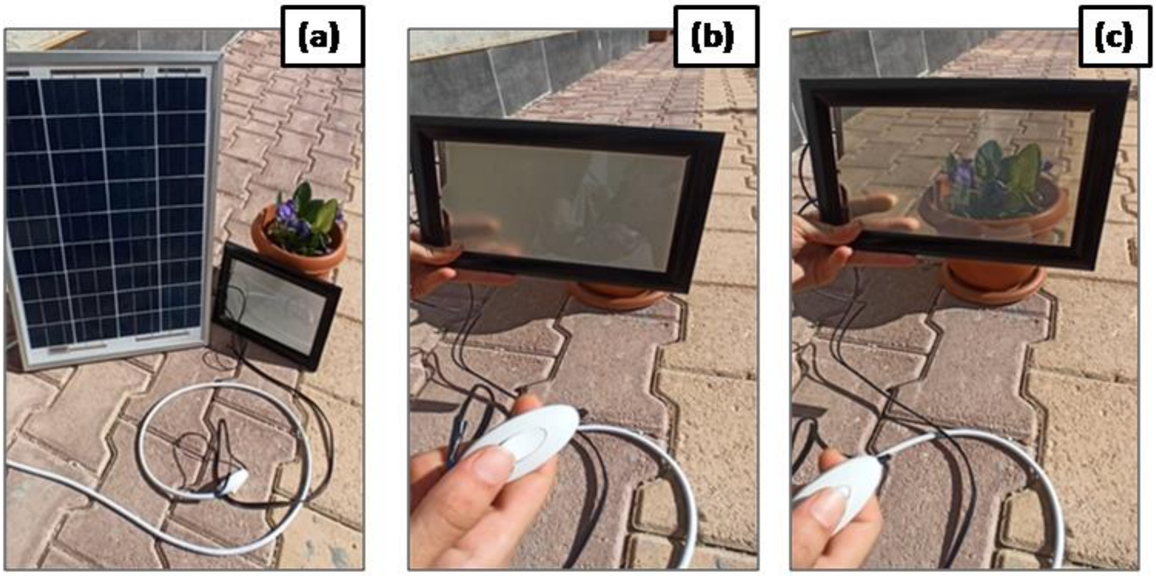

Fig. 2 (a) Display of the system in daylight (b) image of electrochromic glass when the switch is OFF (c) image of the electrochromic glass when the switch is ON

In order to show the working logic of the system, after designing the system in a sunny weather, a switching experiment was performed to show the potted flower electrochromically (Figure 2a). The solar panel was sufficiently exposed to the sun and then it was observed that the electrochromic glass changed to transparent color before the switch was left open (opaque) (Figure 2b) and after the switch was turned on, and the pot flower could be seen clearly (Figure 2c).

IV. CONCLUSION

While designing this study, a method was followed in order to present a different design that is both environmentally friendly and practical. In order for the world to be a more livable environment in the coming years, it is necessary to turn to renewable energy sources instead of energy sources that harm the environment. The device system obtained as a result of this study is aimed to use the electrochromic glass as a curtain by utilizing the energy of the sun, which is a renewable energy source, without any electricity costs. The system was designed by connecting the solar panel to the PDLC smart window film with the help of an intermediate switch and cable and creating a system. Experiments have tried to show how much such a system can be switched under different weather conditions and how long it has an electrochromic memory. This study is important as it will form a basis for our future studies and more detailed studies are continuing in our laboratory.

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