Combination of Photovoltaics and Organic Light-Emitting Diode Display

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Abstract—Clean energy has the potential to deliver universal energy access in a way that is safe and powers bettering the environment for everyone. Photovoltaics, which transfer solar energy to electrical energy, can generate clean energy. This article introduces the internal structure, function, and working principle of each part of the system after combining photovoltaics and OLEDs. Then, this article concludes with some advantages: the system's energy source is clean energy and the system’s other expanded applications. This new material-plastic electronic also faces some challenges. For example, solar energy received by the system is affected by factors such as latitude, which affects sunshine hours in a particular region, and weather, which affects light intensity. Moreover, there are several concerns like battery thermal management and battery life in practical application scenarios. So, this article needs to do more research and further experiments to improve the efficiency of solar power and maintain the health of the battery. In the future, this article suggests doing regular experiments to observe the system's efficiency and find the direction for improvement.

1. Introduction
Burning fossil fuels, such as coal, petroleum, and natural gas, for their economic development, can cause serious environmental pollutions: light pollution, air pollution, water pollution, etc. Those problems will also cause chain effects, affecting human health, global climate change, or species diversity endangered. Excessive exhaust emissions contribute to the earth's greenhouse effect while bringing mudslides and other catastrophic natural disasters. To deal with these problems, people are finding a more sustainable way of conflict between increasing demand in energy and economic development. Recently, the trend of using solar energy has gone well. Solar energy is considered a type of sustainable energy. Building a specifically designated solar power station, however, may cause light pollution to some extent.

In 2012, BASF and Philips made substantial breakthroughs in OLED technology which can be integrated into in-car roofs. There are tentative plans in the paper to switch to cleaner energy sources, but they do not set out to study their feasibility. Using photovoltaics is a better way of collecting clean energy, which is environmental-friendly. Solar energy is the energy supplied by nature – it is free and abundant. However, solar energy has not been widely used, and the stability and efficiency of its energy supply are still questioned. So far, no industry uses solar energy for power supply in a wide range of civil use. People have not found a suitable direction to realize energy supply and environmental protection at the same time. Also, the plastic, organic layers of an OLED are thinner, lighter, and more flexible than the crystalline layers in an LED or LCD. However, OLED’s cost of production remains an
intractable problem. The cost of producing OLED is too high, which also leads to high prices of final goods. Therefore, the article thinks of combining the two to make up for each other’s defects. After the combination of the two, solar energy, which is clean and free energy, can be used more widely, and the cost of OLED products is greatly reduced by saving the cost of power supply.

In this article, this article provides a new idea, which is to install photovoltaics on glass buildings and cars to seek greater development and utilization of solar energy resources. The feasibility and specific design of the combination of solar power (photovoltaics) and OLED display are studied, and its advantages in energy, environment, and use are expounded. At the same time, the possible defects are pointed out, and the possible research directions are proposed to provide a reference for the combination of photovoltaic and OLED applications.

2. Using Solar Energy as a Source

2.1 Inside construction of the product

The panel of photovoltaics is designed to installed at the exterior part of the panel of Organic Light Emitting Diode. All panels should be put inside of the glass windows. The product can divide into four parts: photovoltaics, battery, wires, and OLED, and their functions are shown in Table 1. The working pattern is like using a charging phone. The detail of those parts will be presented below. Like a pump, the panel moves electrons through wires back into the battery and causes the recharge [1]. The detailed principle will be discussed in 2.2. Because the raindrop is a conductor, it will cause a short circuit and cause fire disaster if it touches the electric panel. Many natural phenomena like rain will damage the panel. Nowadays, many skyscrapers are made from glasses. To figure out this problem, installing the system inside the glasses can prevent outside erosions. Revealing photovoltaics could avoid the damage from rain or wind to reduce potential dangers, such as fire disasters, explosions, and installing problems. In addition, the position of the photovoltaics should be placed as Fig. 1, ensuring it won’t shield inside vision of outside. As the figure is shown below, one glass can divide into two parts----one is the main body part, which OLEDs display can install here; another part is a small part above or below one’s main body part, which can install solar panels to collect energy. Last but not least, to reach max energy, the size of the photovoltaic needs to be designed as large as possible (depending on the size of the glasses). Moreover, the size of OLED needs to fit the installation glass’s size to ensure the display resolution (the clarity of images). Systems’ revolution needs later scholars to test.

Table 1. Inside parts of the Combination of photovoltaics and OLEDs display and their main functions

| Part of the product       | Functions                                                                 |
|--------------------------|----------------------------------------------------------------------------|
| Photovoltaics (solar panel) | Receive the solar energy and convert it to electrical energy in certain efficiency |
| Battery                  | Store the energy                                                          |
| Wires                    | Connect the photovoltaics to the battery, and battery to OLED to form a circuit |
| OLED                     | Use as display in multiple ways, such as provide people information or images |
2.2 Working Principle
The glasses can be divided into two layers: the power layer (input) and the OLED displaying layer (output). The power layer is supported by some kinds of photovoltaic materials to gain energy. There are two typical kinds of photovoltaic materials: silicon class and organic polymer class, which enable the system to reach max energy input. To ensure the display effect, people need to reduce electroluminescence intensity by increasing the area of ITO transparent electrodes in organic LEDs [2].

2.2.1 Mechanism of Solar Power
There are four major steps during the mechanism over time, which eventually provide energy for the battery, which will be discussed below. The first step is light absorption. Some amount of light with a certain frequency will be absorbed, creating pairs of electrons and holes called excitons; Second step is charge separation over time. The excitons would make a separation, which means the electrons and holes will leave each other. The third step is diffusion, have been separated, the holes and electrons would diffuse towards different directions, creating an electromotive. In this step, electrical energy is generated. The final step is charge collection. The charge would get collected by the storing battery. The displaying time and energy collecting time are not happening simultaneously. To solve this, inserting a small battery at the edge of each glass to store the energy to release at the working time is good. To be elaborated, there are three features of the battery: to avoid the battery obstructing the light, the location of the battery is all around the edge [3-8]. The duration of the battery would be more than five years to keep the maintenance frequency down. The storing ability would be more than the daily consumption.

2.2.2 Mechanism of OLED Display
There are also four major steps of the mechanism of the OLED display. When OLEDs devices get electricity energy, holes and electrons will be injected by anode and cathode, as Fig. 2 shown below. Secondly, holes and electrons will transport to the emission layer (EML). Then, electrons meet a hole in the EML. Finally, electrons fall to a lower energy level to fill the hole emitting a photon because of the gap of layers’ voltage. As the light emits, the OLED works.
3. Advantages

3.1 Clean Energy

Human beings are now facing several urgent problems that are the scarcely available resource and the resulting climate changes. As the major source for society’s economic growth and development, fossil fuels are likely to cause sharp increases in temperature, wet-bulb temperature, and precipitation when burned. Extreme climate change will dramatically harm the health of adolescents and the elderly [9]. Apart from this, traditional energy like fossil fuels and oil is running out day by day. It is estimated that it would take about 1.5 piles of earth to supply the resources that humans are expected to consume [10]. The abuse of these carbon-containing energy sources has also caused many environmental hazards [11]. At the same time, residents living in resource-intensive areas are chronically exposed to potential pollution, and their incidence of endemic diseases such as pneumoconiosis is more than six times the average [12]. Over the long term, increases in resource extraction activities are associated with net increases in overall local mortality, cancer, and infant mortality. There is preliminary evidence that extraction activities are positively correlated with local pollution levels [13]. Compared with these resources, solar energy and environmentally friendly, recyclable and clean energy have a promising future due to their inexhaustible supply, universality, and high capacity [14]. The Sun provides the Earth with about 100,000 terawatts of energy, which is about 10,000 times the world's current energy consumption rate. Because of the many advantages of solar energy, photovoltaic cells are being used more and more widely. The article suspects that solar energy will play a key role in the sustainable energy system of the future [15].

3.2 Visibility

When OLED is not emitting light, it can be a transparent medium. Therefore, when OLED is applied to a transparent panel like the transparent solar panel, it can see the displayed information and see the scenery behind the panel. As our OLED used in the display is made of transparent OLEDs and transparent POVs, its visibility is very high, and it has different advantages in different application areas. When installed in the windows of subways, it will not affect the original lighting of subway cars. Also, passengers in the subway can simultaneously look out and touch the transparent display to learn more.
about current events and traffic conditions. This is the combination of new display technology and traditional Windows. The appearance of the OLED used in the display can improve the informatization of rail transit, accelerate its digital development, and offers travelers a better journey [16]. When installed in the windows of the car, it is different from the one installed in subways in functions. The OLED installed in the car's sunroof is a lighting system when switched on at night, and it turns back into a transparent panel that does not affect visibility when turned off during the day [17]. POVs can generate electricity in the daytime while the driver’s visibility will not be affected.

3.3 Multiple Applications
The first one is displayed in different situations: usually, we would apply the glasses to display a big picture in the city. The big picture would be the advertisement of some public information that the government wants the screen to play. The advertisement part would be easy to imagine: the owner of the building would be paid if some other enterprises want to show something. The government information part is that when natural disasters are happening, the big screen would be a warning sign to warn the citizens to take cover or stay at a safe place. The performance part is that the screen takes the role of a live stream video display. Performing on display, it can provide information to passerby in this building. Then, separated glass could also do their jobs. They mainly act as an information passenger inside of the building. Managers inside the building could use it as a warning sign and messenger when there are accidents in the building or information to pass down. Also, using it as a meeting screen allows people to have a meeting without going upstairs or downstairs when it takes them a lot of time.

Another one is head-up visibility: when the OLED combines with a head-up display in the car, drivers don't have to look down to see speed, navigation distance, or navigation direction, which may avoid some traffic accidents to some extent. The OLED installed in the windshield has a similar working function to the one installed in the sunroof. They both can generate electricity through POVs when switched off, and a head-up display with OLED and POVS will not affect the sight of the eyes watching the outside lane. However, when the one installed in the windshield is switched on, it can show the real-time driving conditions of the car and nearby traffic conditions. Drivers can easily change routes or adjust the driving mode just through the head-up display.

4. Future Concerns

4.1 Energy Efficiency Limitation
Since the system will be installed in glass buildings, it is hard to make sure the building system could always receive the same amount of solar energy. Therefore, several efficiency-influencing factors need to be considered in future system’s improvement. Because of the Earth’s revolution, the daytime will be different in different seasons (the same reason with latitude impact). Therefore, it will cause energy inefficiency at a particular time and influence the systems' function. So, people need to install the system in a more useful way to raise the cost performance. For example, the high-ranking company administers always need to get in-time information; therefore, installing the system in their office is high cost-performance. Additionally, the technique of installing and cleaning the power layer, or photovoltaics, depends on real usage. We can see some solar power plants use mirrors to concentrate sunlight to gain higher energy.

4.2 Cell Thermal Management
Like phones, some devices with an electric circuit will be hot after a long-time of use. This is called the flow phenomenon, which may have a lot of potential risks. So, if a display is used intensively, that’s dangerous. Its energy efficiency and lifetime will be reduced. Some solar power plants use mirrors to concentrate sunlight to gain higher energy; however, they always cause a temperature in the panel. With higher temperatures, the vibration of an atom will be increased; therefore, the bandgap size will be reduced. Consequently, the energy transfer efficiency will be lower. Conditions of high radiation, say 700–750W/m, modules can reach up to 40°C above ambient, 70°C, but this will obviously depend on
module design and building context. With the temperature higher, the voltage will be higher as well [18]. The high temperature and voltage may have potential risks, such as fire disasters and explosions. During the early time of the day, the temperature and sunlight’s intensity is relatively low. Stop cooling solar panels in the early and last hours of the day can prolong the lifetime and increase the energy transfer efficiency [19]. Thus, in the future, the wire used in transport electricity needs to choose high-temperature resistant insulating materials to eliminate potential security risks. Besides, people need to control photovoltaics’ use time depending on the intensity of sunlight to ensure the system’s lifetime and energy-transfer efficiency.

4.3 Cell’s Lifetime
What is excel of photovoltaics over conventional battery is its long life span and high-security level, but there are also some potential problems. Although the lifetime is longer than conventional one’s, the efficiency cannot reach such a high after several years of usage. An electric product’s lifetime depends on its battery. Therefore, prolong the cell’s lifetime become an improvement in the future. In common cases, people choose to turn the e-product off to make sure the battery’s healthy. But it is not a long-term plan. Table. 2 shown below, provides some influence factors of a cell’s lifetime and use. Nevertheless, it is impossible to use mirror concentrating sunlight in metropolitan areas widely. Designing sunlight receiving device is an important future improvement plan. Because the life period of photovoltaic is around 15 years, the battery capacity and lifetime are needed to be tested every five years. After several years of usage, people can test the efficiency using time length, resistance, and highest working temperature to find out the highest efficiency factors in different stages. By doing so, users can control the photovoltaic and OLED combination system adjusting its position to get sufficient energy. Also, they can find the problems in time to prevent potential risks. Last but not least, as this technique mature, people can try to connect the internet to the display for a further application that needs internet access. For example, in the building, people inside can receive real-time news events around the world.

| Table 2. Analyze of influencing factors and potential problems |
|---------------------------------------------------------------|
| Influence factors | Potential problems |
| High temperature | Lower the resolution of the OLED device, and high temperature might damage the circuit. |
| Low temperature | Lower the energy transfer efficiency |
| Frequently use | The current flow might burn the circuit and cause the operating system to break down. |

5. Conclusion
This article provides ways to balance the conflict between increasing demand both in energy and economic development. This article designs a system that combines photovoltaics and OLEDs. Revealing photovoltaics in the glass could avoid damage from outside. Then, solar energy will be transferred to electrical energy for people to use by installing photovoltaics and OLEDs combination system in glass buildings or cars. This system has advantages in different aspects. In terms of energy supply, it has the benefits of free, environmentally friendly, sufficient energy resources. In terms of display, it has the advantages of a lighter material and higher visibility. This innovative system will have many expanded application. For example, it can be applied to the building wall for playing the news. It can also be installed in front of the car windshield to help drivers understand real-time traffic and car driving faster and more labor-saving. In the future, as this technique mature, people can try to connect
the system with internet access to further its applications. At the same time, we also encountered some limitations and possible disadvantages in the research and design process, such as the impact of time and geographical location on efficiency. More deep research is needed in the future on the sustainability of energy supply and reducing the impact of external factors like climate change. Because this technology is immature, there are many challenges. We concern about the combination of photovoltaics and OLEDs’ display effect, position influences, battery’s thermal management and provide other possible applications and future improvements.

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