Transparent Solar Cells: A Powerful and Affordable Source of Energy

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Abstract:*Energy is essential for any society to advance economically. Effective alternative sources including solar, wind, and tidal energy are used to meet the depletion of existing sources as well as the growing needs of rapid urbanization and industrialization. Using a photovoltaic (PV) packaged module, solar energy is the most prevalent way to harness energy in nature. Building integrated photovoltaics, or BIPV, have recently been created for usage in both commercial and residential settings. By combining with existing window panes, transparent solar cells can collect and utilize extra light energy through windows in homes, offices, and automobiles. Although it requires installation, such clever architectural space utilization can be economical in terms of operation and maintenance.These cells are transparent to visible light and allow every visible photon to pass through while simultaneously absorbing all infrared and ultraviolet photons. Anti-reflective exterior coatings might be significantly more beneficial. To increase efficiency, lessen reflections.*

Key Words*: PV windows, Solar panels, BIPV (Building Integrated Photovoltaic)*

I. INTRODUCTION

Recent years have seen a surge in research into renewable energy, particularly solar energy, which is plentiful and can satisfy both home and industrial needs. Solar panels are machinery that convert solar light into electricity. Photovoltaic cells, which are a component of solar panels, employ the photovoltaic effect to absorb light energy. They are referred described as photo voltaic by certain scientists, which means "light-electricity."

Researchers have thought about creating solar panels that might take the place of every type of glass currently in use. Every building or cell phone has since evolved into an energy source as a result of this idea, which has caused a tremendous technological revolution. Although a transparent solar panel functions normally, all visible light passes through it and is absorbed by it. UV and infrared light.

Efficiency of a transparent solar-cell is only 2%, which is far lower than the average solar cell efficiency of 15–18%. However, "stacking," which involves stacking a lot of transparent solar cells together to boost solar cell efficiency, may be used to solve this problem. A study indicates that 1.4% of the power generated in the United States comes from solar cells. Simply replacing the 5-7 billions square-meters of the glass surface in United States (US) with transparent solar panels could produce up to 40% of the country's energy needs.

Recently, semi transparent solar cells made of plastic, also referred to as the building-integrated photovoltaics, have been developed as building supplies (BIPV). The transparent solar-cell made by Konarka has the potential to be helpful while built onto windows that produce power. Prototype windows had the solar cells placed between the two panes of the glass. The functionality of transparency will allow the *Building Integrated Photovoltaic* to be used for applications other than overhead ones. Even though they might be built into windows, certain grids collecting the current are clearly visible through plastic solar-cells. A plastic solar-cell semi transparent in nature might be created in one-step using electronic glue based lamination method and the interface modification. To maximize the use of solar energy, it is intended to stack the two or more devices with various spectrum sensitivities. In order to make solar energy consumption more effective, it is intended to stack the two or more devices with the different spectrum sensitivities.

Spraying a small layer of dye molecules onto glass causes it to absorb sunlight, retaining it and allowing it to pass through by perfect internal reflection until it's captured by the solar cells attached

to the glass edges.

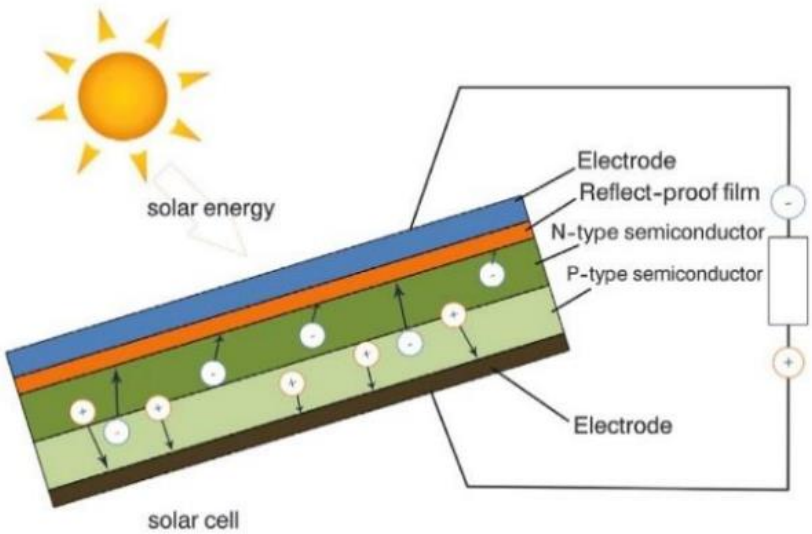

Fig1: A transparent solar cell in cross-section

II. SOLAR WINDOW TECHNOLOGY TIMELINE

Since its inception, tremendous advancements have been experienced in the field of solar-window technology. In relation to initial years of patent filings, several technological turning points are shown in Figure 2. Surprisingly, rather than windows, solar cell technology for windows initially appeared in shutters in 1977. The concept of focusing light onto solar cells has been patented four years later.

Solar cells were first incorporated into windows in 1983, laying the foundation for the now-common BIPV technology. In 1991, a battery was built into the slat beneath every solar cells to store electrical energy. Solar cells were up to that point distinct objects attached to or glued to window glass or shutter slat. In 1993, coatings were proposed to materialise solar cells on the window. A new technology known as BAPV was first investigated in 1993, which involved retrofitting solar cells to windows (Building Applied PV). BAPV is a technology that allows for the quick conversion of a regular window into a solar window by attaching pre-made sheets or glasses with solar cells to it.

A significant advancement in solar cells tracking the sun to maximise electricity production occurred in 1995. By the year 2000, solar cells were also included onto the roofs of four-wheeled vehicles. It has been noted that at the beginning of this century, significant developmental fields like Tracking, concentration of Light, BAPV, and BIPV had already been pioneered. Technical developments in these domains accounted for the majority of all milestones in the following years. The addition of an inverter to the solar window field occurred in 2005. Two years later, a tiny inverter was added to the window frame, which reduced the amount of space needed for an inverter and improved the functionality of solar windows. Second-generation solar cells, such as multi-junction or tandem solar cells, were helpful in 2008–2009 in absorbing light of various wavelengths to produce electricity. Multi-junction solar cells are made up of several p-n junctions, each of which may absorb photons with a certain band gap. As a result, photons with different wavelengths or energy can be absorbed, increasing efficiency in comparison to a single junction solar cell. In 2009, solar cells that produce energy by utilising infrared and ultraviolet wavelengths were also put into windows. Since 2010, AC power plugs and charging outlets have become standard. Smart windows, which have electrochromic layers and multimedia incorporated in them, are powered by solar cells.A significant advancement in the technology of light concentration involved the use of tiny structures to focus light. Microstructures, which are tiny pores etched onto window glass, help to redirect light that strikes them in order to direct it into solar cells.

Fig2:Timeline of Solar Window

This prevents the intentional insertion of other devices like dichroic mirrors and prisms within the glass panes. Third-generation solar cells like Organic PV are used in quantum dot technology because of its many advantages, such as transparency, high absorption efficiency, and power efficiency.

After installing solar panels on vehicle roofs for 16 years, Mitsubishi has developed a vehicle solar window with thin sheets of PV cells on the car window. In order to produce electricity, solar TEGs were incorporated into a foldable curtain in 2017. A 2019 patent application proposed the use of ventilation cavities configured to disperse heat produced by solar panels of a window. The architecture of a standard solar window and an upgraded version are covered in Section IV. The section also sheds some information on significant innovations like window and shutter design and lighting that contributed to greater efficiency.

III. SOLAR WINDOW TECHNOLOGY

This section offers a thorough examination of several components or strategies for getting the most out of the window. The development of the solar window has been researched over time, and depending on the state of technology generally, some significant observations have been made. For easier understanding of further study, an attempt is made to depict a solar window as a block diagram. Figure 3 shows a block diagram of a typical solar window at the time of the invention. An examination of the retrieved patents, however, revealed that the technology had undergone significant modifications to improve efficiency and satisfy the power needs of a developing globe. Consequently, a block diagram of a typical solar window at this time is depicted in Figure 4.

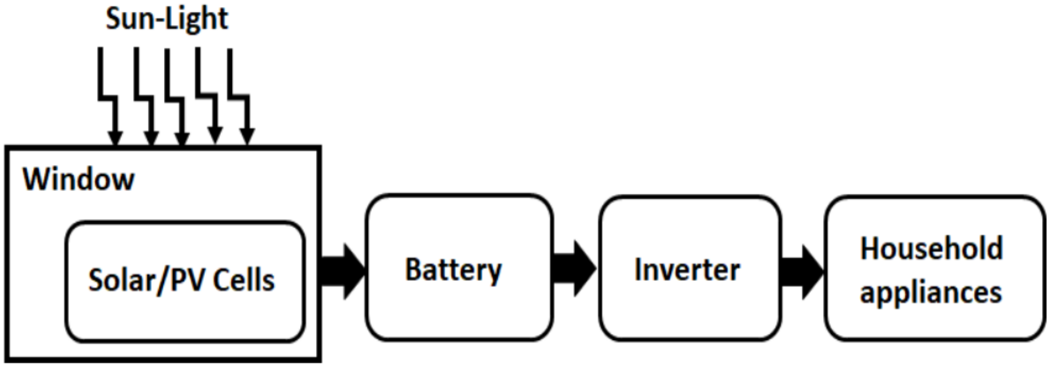

Fig. 3: Block diagram of a Solar-Window

In the past, sunlight would strike solar cells installed on window panes or shutter blinds, producing electricity that was used for domestic purposes to achieve partial grid independence. However, because the efficiency of a typical solar cell is about 46%, it is challenging to convert 100% of the light energy incident on a solar cell into electrical energy. Additionally, covering the glass with solar cells would obscure what is seen through the window. In order to increase efficiency and give higher transparency, optical elements or layers are used, which results in a new development known as light concentration. Solar cells are positioned at specific locations on windows using these layers or optical components to gather light that is incident on them and direct it onto the solar cells. Additionally, as the sun's inclination angle changes during the day, so does the amount of electricity produced. The solar window's effectiveness was enhanced in this regard by the well-known tracking system. Thus, two key technologies aiding in increasing the efficiency of a solar cell in a window are light concentration and tracking. In recent years, the solar cells' energy has been transformed into AC power and supplied to the power grid. In addition to these two developments, window/shutter design is another category under which patent documents are divided. In order to generate power, such records significantly altered the design of a window or a shutter. A summary of the Window/Shutter design patent documents is provided in Subsection IV-A. A thorough examination of light concentration and tracking is provided in Subsection IV-B.

IV. PHOTO-VOLTAIC GLASS

A method called photovoltaic glass (PV glass) enables the conversion of light into power. Transparent solar cells built on semiconductors are integrated into the glass to accomplish this. They are referred to as solar-cells. The cells are sandwiched between two sheet of the glass. Photovoltaic glass allows some of the available light to flow through, but it is not entirely transparent. It is possible for structures with a lot of solar glass to produce some of their own energy through the windows. Because its source is renewable and does not harm the environment, the electricity produced by solar panels is referred to as green or clean electricity.

In addition to cutting energy costs, installing photovoltaic glass may also help facilities become more sustainable, reduce their carbon footprints, and boost their branding and public relations (PR) initiatives. In regions where excessive heat penetrates through light, less transparency can reduce air conditioning costs. For situations that call for additional light, variations have been developed. For enhanced light penetration, Sharp, for instance, has developed a slitted solar glass product featuring gaps between solar cells. A different company, Onyx Solar, produces double- or triple-glazed products in addition to photovoltaic glass in a variety of hues, gradients, and patterns. Different architectural design options are possible due to these devices' differences in photovoltaic efficiency and light penetration.

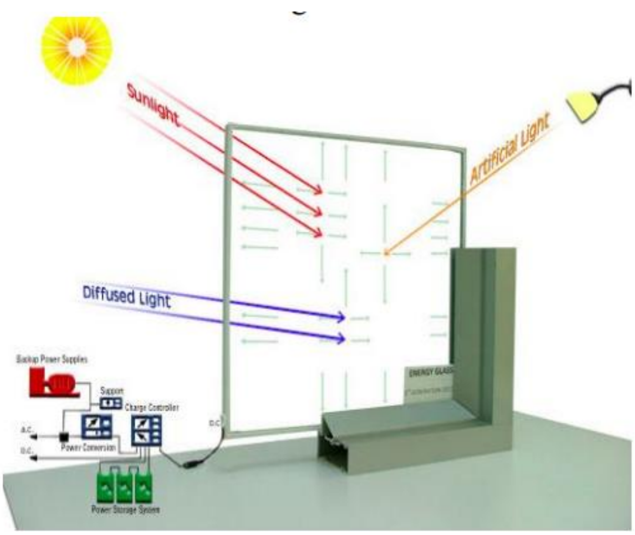

Fig.4: Light energy is converted into electrical energy.

V POWER OF SOLAR GLASS

Solar panels use toughened glass, also referred to as tempered glass. Tempered glass has qualities that make it ideal for solar panel manufacturing. First of all, tempered glass is far more durable than other types of glass. Second, tempered glass falls under the category of safety glass. If it breaks, it will disintegrate into countless little, harmless pieces. Solar panel installation calls for both power and safety.

VI SOLAR GLASS PERMANENCE

Solar panel glass, which serves as the front sheet of a solar PV panel, must offer weather resistance over an extended period of time. PV panels are therefore covered with tempered glass, which is four times stronger than conventional plate glass. A solar panel's essential parts must be designed and placed to withstand extreme temperatures, as well as dust and water particles, to provide at least 25 years of electricity production.

VII TRANSPARENT SOLAR CELL TYPES

Transparent solar cells may be created using about seven different technologies. The maximum transparency achieved by this method is less than 80%.

(a) PHOTOVOLTAICS ON THIN FILM (TPVs)

The most often used technology is the TPV, which can be acquired in a number of ways. A few nanometers to tens of micrometres thick, TPV is simply a thin layer of active material applied to glass using various processes. Because it is straightforward to deposit thin films on a variety of substrates, from rigid to the flexible, and from insulators to metals, thin film photovoltaics lowers the cost of solar cells by conserving the resources required in their manufacturing. This opens up new applications. In some substances, like titanium dioxide, increasing transparency requires a thinner covering. The most popular method for applying thin films is screen printing, which is also the best strategy overall.Transparency is controlled by screen printing using a mesh screen that is stretched across a frame, and the properties of the screen have an impact on the film's thickness and porosity.

Transparency can also be changed by changing the squeegee's speed and pressure. Particle size, film thickness, semiconductor oxide material structure, and dye colour can all be altered to control transparency. Dye can come in a variety of colours to absorb more light at different wavelengths.

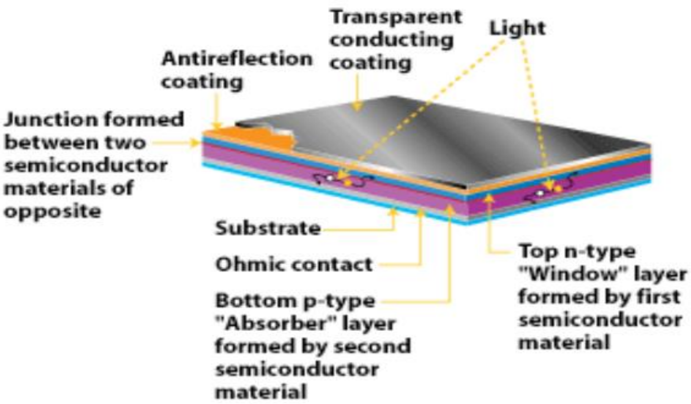

Fig.5: Cross-section of photovoltaics

(b) NEAR INFRARED TRANSPARENT SOLAR CELLS:

It is challenging to combine both features in a single material since, as we all know, the main function of a solar cell is to absorb photonic energy and the main property of transparency is to enable photons to pass through. Most research focuses on developing transparent, thin layers that also absorb visible spectrum light; as a result, cells often have less than 30% transparency while yet being reasonably efficient. In order to create a transparent solar cell, researchers decided to go a different route by modifying the dye's molecules to absorb ultraviolet and near-infrared wavelengths.

VIII RESULT

Transparent solar panels are used far less frequently than conventional energy sources. However, sunshine is abundant in Asian and African countries, where it can be captured and used as a backup energy source. Asiatic countries have the densest populations, which results in the highest energy use. As a result, installing transparent solar panels may allow for a global reduction in energy usage of more than 40%. This project will aid in energy conservation and global pollution reduction, which will help to slow the rate of global warming when nonrenewable energy sources become less abundant.

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