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Highlighted Presentations Press Release

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Development and Prospect of Cu_2O/Si Tandem Solar Cells

Toward Carbon Neutrality
Development of high-efficiency Cu_2O/Si tandem solar cell

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Summary

- **Developed "Transparent Cuprous oxide (Cu_2O) Solar Cells" that achieved a world record power conversion efficiency of 9.5%.**
- **The power conversion efficiency of the Cu_2O/Si tandem solar cell, which consisted of a transparent Cu_2O solar cell and a high-efficiency silicon (Si) solar cell stack, was estimated to be 28.5%.**
- **Cu_2O/Si tandem solar cells in an electric vehicle (EV) are expected to have a range of about 37 km per day.**

A research group of Atsushi Wada and colleagues at Toshiba Corporation's Research & Development Center has developed a "transparent cuprous oxide (Cu_2O) solar cell" that achieved a world record power conversion efficiency of 9.5% (Toshiba Corporate Research & Development Center survey, as of February 2023). The results contribute to the research and development of "tandem solar cells," in which two solar cells are stacked to generate power and increase the overall power conversion efficiency, an area of focus for the company. The "Cu_2O/Si tandem solar cell" consists of a high-efficiency silicon (Si) solar cell with a power conversion efficiency of 25% stacked on the transparent Cu_2O solar cell developed by the company. It is estimated to have an overall power conversion efficiency of 28.5%. This power conversion efficiency is expected to provide a daily cruising distance of approximately 37 km when mounted on an electric vehicle (EV). The company has begun to develop larger transparent Cu_2O solar cells for efficient mass production of tandem solar cells. Moving toward practical use in FY2025, the company plans to gradually increase the cell size and eventually establish a cell manufacturing technology to produce cells having the same size as commercially available Si solar cells.

Detail

Tandem solar cells that realize the "best of both worlds

The widespread social use of renewable energy must be promoted to achieve carbon neutrality. Solar cells represent a promising power-generating technology. The Ministry of Economy, Trade, and Industry (METI) announced in its “Green Growth Strategy Accompanying Carbon Neutrality in 2050” a goal of increasing the share of renewable energy in Japan’s power generation to 50–60% by 2050 (*1). This growth strategy advocates the shift to renewable energy as the main source of electricity and the electrification of transportation. These results are expected to open new avenues for the use of solar cells.

Research and development of “tandem solar cells,” which realize high efficiency, low cost, and high reliability by overlapping two solar cells and combining the “best of two worlds,” is currently heating up. Tandem solar cells may also be useful in mobility systems such as electric vehicles, where the installation space is limited.

Prior studies on tandem solar cells include those using III-V solar cells (*2), such as gallium arsenide semiconductors (GaAs), and those using perovskite systems. However, GaAs semiconductors are hundreds to thousands of times more expensive to produce than Si solar cells. Moreover, perovskite systems have reliability issues compared with Si solar cells, which have an output guarantee period of 20 years or more.

The company’s transparent Cu_2O solar cells are characterized by their high potential for reliability while offering significant cost reductions. Transparent Cu_2O solar cells absorb short-wavelength light, such as green, blue, and ultraviolet light, and transmit long-wavelength light, such as red and near-infrared light. Thus, a Cu_2O/Si tandem solar cell is formed by combining a Si solar cell that efficiently generates power with long-wavelength light in the bottom cell and a highly transparent Cu_2O solar cell in the top cell. Therefore, it is possible to realize highly efficient power conversion over a wide wavelength range, from short to long wavelengths (Figure 1).

The company aims to develop an efficient mass-production technology with a target power conversion efficiency of 30% and establish a manufacturing process for Cu_2O solar cells having the same size as Si solar cells.

Cu_2O/Si tandem solar cells with 28.5% power conversion efficiency

The research team succeeded in improving the power conversion efficiency of transparent Cu_2O solar cells to a world-record efficiency of 9.5%, a 1.1% increase over the 8.4% efficiency announced in December 2021. One of the reasons for the higher efficiency is the suppression of carrier recombination at the Cu_2O generating layer wall, which causes a decrease in the power conversion efficiency.

The research team found that increasing the cell size effectively suppressed carrier recombination and expanded the cell area from the conventional 3 mm square to 12 mm × 3 mm. As a result, the number of photocarriers recombining at the cell wall was reduced, resulting in an approximately 10% increase in photocurrent and an increase in power conversion efficiency to 9.5%. The property of Cu_2O, in which an increase in cell size leads to an increase in power conversion efficiency, is advantageous for larger Cu_2O solar cells.

The power conversion efficiency of the Cu_2O/Si tandem solar cell developed in this study was estimated to be 28.5%, where transparent Cu_2O with a power conversion efficiency of 9.5% was applied to the top cell and a 25%-efficient Si solar cell was applied to the bottom cell. In addition, the company introduced large sputtering equipment capable of depositing films on large-area substrates and produced a prototype 40 mm square cell with a power conversion area approximately 180 times larger than that of a 3 mm square cell (Figure 2). The company is looking toward mass production in the future.

Achieves a range that eliminates the need for home-recharging facilities for short-distance drivers.

The company also details the trial calculation of the case in which the developed Cu_2O/Si tandem solar cell was installed in an EV (Figure 3). Assuming the Cu_2O/Si tandem solar cell has a power conversion efficiency of 28.5%, a target efficiency of 30%, a theoretical maximum efficiency of 42.3%, and a vehicle installation area of 3.33 m^2, the daily driving distance without recharging is estimated to be approximately 37 km (power conversion efficiency), 39 km (target efficiency), and 55 km (theoretical maximum efficiency) (*3). In other words, according to estimates, an EV equipped with Cu_2O/Si tandem solar cells can travel more than 30 km without recharging. This range covers the entire daily driving distance of a short-distance user. Therefore, this eliminates the need to install recharge facilities at home for short-distance drivers. For long-distance users, this range reduces the amount and frequency of recharging at the recharging facilities. In other words, our calculations show that the Cu_2O/Si tandem solar cell can be used as a realistic power source for EVs.

Cu_2O/Si tandem solar cells are expected to contribute to the main source of renewable energy and electrification of transportation in the Green Growth Strategy Accompanying Carbon Neutrality in 2050. The company is conducting joint research with Toshiba Energy Systems Corporation and aims for practical use in FY2025.

Annotation

*1 https://www.meti.go.jp/press/2020/12/20201225012/20201225012.html

*2 **Group III-V solar cells:** Compound semiconductor solar cells composed of group III elements such as gallium (Ga), indium (In), and aluminum (Al) and group V elements such as phosphorus (P) and arsenic (As).

*3 EV electricity costs are based on the assumed value of 12.5 km/kWh in 2030 used in the NEDO calculations.

Figures

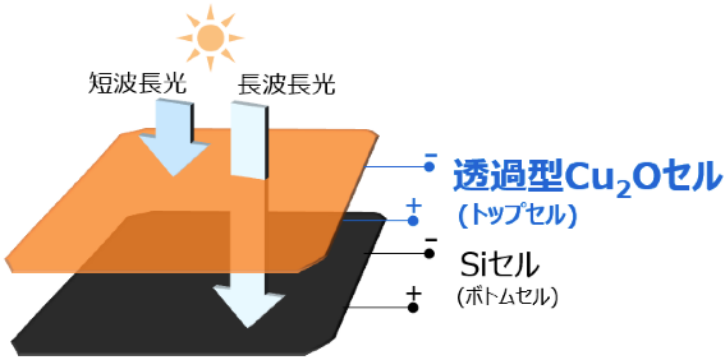

Figure 1 Schematic of Cu_2O/Si tandem solar cell (4 terminals) (courtesy of Toshiba)

Figure 2 Prototype of 40 mm square transparent Cu_2O solar cell (courtesy of Toshiba)

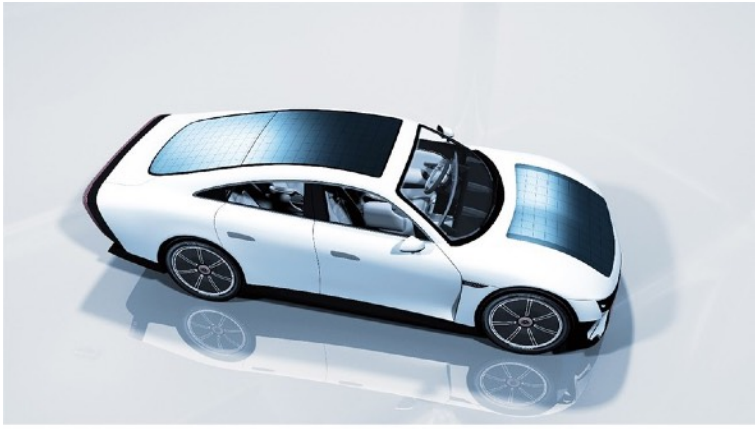

Figure 3 Image of a Cu_2O/Si tandem solar cell installed in an EV (courtesy of Toshiba)