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1000-h Light-Soaking Stability in Perovskite/Silicon Tandem Solar Cells

The next generation of solar cells, “tandem solar cells,” are accustomed to 1000 h of light durability

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Summary

- **Developed a perovskite/silicon tandem solar cell with an initial power conversion efficiency (PCE) of 21.2% and high light durability.**

- **Conducted a continuous light-soaking stability test with a perovskite/silicon tandem solar cell exposed to 1SUN-equivalent illumination including ultraviolet (UV) light without UV cut-off filter.**

- **Achieved the world's first high durability of perovskite/silicon tandem solar cells, with over 1000 h (T_{90} :>1000 h) required before the power output reached 90% of the initial value.**

The research group of Toshiba Energy Systems & Solutions et al. has developed perovskite/silicon tandem solar cells with a two-terminal structure. This research group has succeeded in improving the durability by applying a unique technology to increase the stability of ions that constitute the perovskite. The perovskite/silicon tandem solar cell with an initial power conversion efficiency (PCE) of 21.2% was continuously exposed to 1SUN-equivalent illumination including ultraviolet (UV) light without UV cut-off filter, resulting in a degradation rate of 9.57% after 1000 h. This is the first time in the literature that perovskite/silicon tandem solar cells have achieved such high photovoltaic durability and the time required for the power output to reach 90% of the initial value is over1000 h (T_{90} :>1000 h).

Details

Next generation tandem solar cells with high efficiency and reliability

For governments worldwide, carbon neutrality is a high priority goal. In its "Green Growth Strategy Through Achieving Carbon Neutrality in 2050," Japan's Ministry of Economy, Trade, and Industry (METI) has set a goal of increasing the share of renewable energy in Japan's power generation to 50–60% by 2050 (*1). To achieve this goal, it is necessary to promote renewable energy as the main source of electricity.

Sunlight is a renewable energy source, and the industry continues to innovate its photovoltaic (PV) technology. Currently, the development of "tandem solar cells," in which two solar cells are stacked on top of each other to achieve a higher power conversion efficiency, is accelerating. The higher power conversion efficiency and reliability of solar cells are essential in reducing the cost of power generation and promoting their widespread use in society. A research group by Toshiba Energy Systems & Solutions Corporation and others has developed perovskite/silicon tandem solar cells with a two-terminal structure to improve their power conversion efficiency (PCE) and durability.

The perovskite/silicon tandem solar cell which the research group has been developing, has a structure with a perovskite layer (band gap of approximately 1.7 eV) in the top cell and a silicon layer (band gap of approximately 1.1 eV) in the bottom cell. The perovskite and silicon layers absorb short-wavelength and long-wavelength lights, respectively, enabling more efficient power generation. The same perovskite/silicon tandem solar cell developed by the research group realized to add 8.2% abs by the perovskite layer from the 17.3% PCE of the silicon layer solely. The developers stated that the perovskite/silicon tandem solar cell they developed with a two-terminal structure achieves a PCE of 25.5%, which is one of the highest values worldwide for the add-on point to the PCE of the bottom cell.

World's first 1000-hour continuous light-soaking test

The research group conducted a 1000-hour continuous light-soaking test on a perovskite/silicon tandem solar cell under development. The perovskite layer of the tandem solar cell utilized in the continuous light-soaking test was prepared using a common anti-solvent method. The device were encapsulated in cylindrical glass tubes and continuously irradiated with 1SUN-equivalent illumination (AM 1.5 G, 1000 W/m^2, without ultraviolet (UV) cut-off filter).

The results of the continuous light-soaking test demonstrated that the degradation rate was less than 10% after 1000 h of testing using devices with an initial PCE of 21.2 % (Figure). The very low degradation rate was the result of the research and development for improving durability that the research group had conducted so far. Previous studies have reported that the migration (diffusion) of ions that constitute the perovskite layer has a negative impact on durability. It is important to suppress the migration of ions to improve durability. A research group has previously reported that ion migration can be blocked using the feature of sputtering films (*2); however, sputtering can damage the perovskite layer. Therefore, a research group has independently developed low-damage sputtering and is using it to improve durability while reducing damage to the perovskite layer. Furthermore, inside the perovskite layer, lattice defects in the grain boundary (*3) are passivated (*4) with PEAI (Phenylethylamonium iodide) to improve ionic stability. "The passivation of lattice defects prevents the migration of ions, and this leads to improved durability," researchers said.

It is also important to note that the continuous light-soaking test is an evaluation without the use of UV cut-off filters by developers. “In tandem solar cells, the perovskite layer absorbs short-wavelength light, including ultraviolet light, to increase the power generation efficiency. However, in the case of perovskite, a few materials can be degraded by ultraviolet light. To avoid degradation due to testing, UV cut-off filters that cut ultraviolet light may be attached to the outside of the solar cell for continuous light-soaking test; however, we did not use these filters. In other words, this experiment proves that our perovskite/silicon tandem solar cells can combine high-efficiency power generation with high durability in natural sunlight,” researchers said.

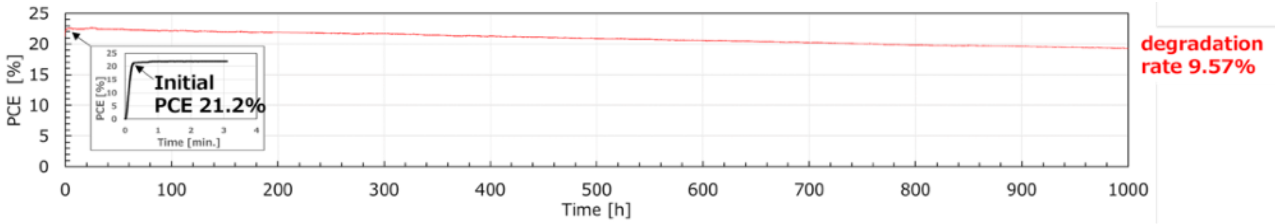
There are precedents for continuous light-soaking tests, and research institutes worldwide have published their results (*5). Looking solely at the evaluation time, the German research institute HZB (Helmholtz-Zentrum Berlin) has 300 h, EPFL (Ecole Polytechnique Fédérale de Lausanne) at the Swiss Federal Institute of Technology Lausanne has 250 h, the University of North Carolina in the US has 100 h, the University of Toronto has 400 h, and the same study has 1000 hour. Comparing the results of 1SUN-equivalent illumination (AM 1.5G, 1000 W/m^2, without UV cut-off filter) expose to devices with initial PCE of 20% or higher among these precedents as well as this study, the University of Toronto showed no degradation at 400 h, while the same study also showed no degradation at 400 h. Furthermore, the same study did not utilize lithium fluoride (LiF), which causes low durability instead of high efficiency, or MA (methylammonium) ions, which constitute perovskite that is another low-durability material, was maintained a low level content. Therefore, the degradation rate after long-term continuous light-soaking test was kept low by combining it with the aforementioned ion migration suppression technology. This research is the first demonstration test worldwide to report a degradation rate of 10% or less over 1000 h, far ahead of other research institutes globally.

The achievement of world-class demonstration time and durability for tandem solar cells, whose development is currently accelerating, is an important result, stated the developers. We will continue to aim for even higher efficiency and durability in the future, and the developers, are enthusiastic. Tandem solar cells with a two-terminal structure that offers high efficiency and high durability are expected to replace conventional crystalline silicon PV facilities for private power generation and medium- and large-scale applications. It is an innovative technology that can be applied to infrastructure to support society.

Annotation

*1 https://www.meti.go.jp/english/press/2020/1225_001.html
*2 **Sputtering:** A physical vapor deposition (PVD) method is used to form thin films on the surface of materials.
*3 **Grain boundary**: A boundary created by grains with different crystal orientation.
*4 **Passivation**: Surface inerting. Stabilization of the surface energy state of a material.
*5 A. A.-Ashouri et al., Science 370, 1300(2020)
F. Sahli et al. Nature Materials, 17, 820-826 (2018).
B. Chen et al, Joule, 4(2020).
Y. Hou et al, Science 367, 1135(2020)

Figure



Continuous light-soaking test degradation rate was within 10% after 1000 H of light exposure with 1SUN-equivalent illumination (AM 1.5G, 1000 W/m²[2], without UV cut-off filter). Initial PCE was 21.2%. No degradation after 300 H. Degradation rate after 750 H was 5.59%. Degradation rate after 1000 H was 9.57%. (T_{95} : >718 h, T_{90} : >1000+ h)