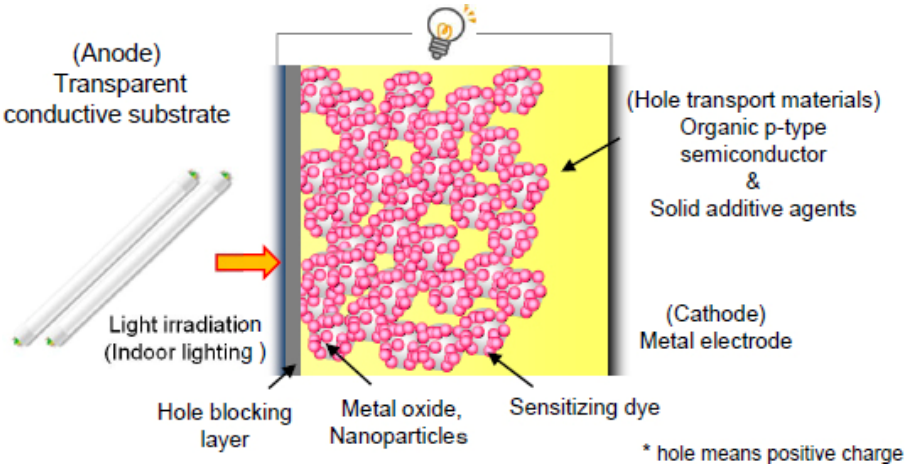
Ricoh Develops High-performance Complete Solid-State Dye-Sensitized Solar Cell Suitable for Indoor Lighting

Achieving safety and durability, and more than twice the generation capacity compared to existing amorphous silicon solar cells (*1)

Tokyo, June 11, 2014 —— Ricoh Co., Ltd. succeeded in developing a dye-sensitized solar cell consisting of only solid state material as an electrolyte, which substantially improves the power generation capacity under a weak light source. By using only solid state material as an electrolyte, the dye-sensitized solar cell ensures an advantage in safety and durability. In addition, this solar cell achieved more than twice the generation of electric output under standard white LEDs (200 lux) compared to the electric output of amorphous silicon solar cells which have high power generation efficiency for indoor use in the current market. Characteristics such as safety, durability and the ability to keep generating electric power with high efficiency under weak light make it an ideal candidate for stand-alone power sources (allowing power generation without an external power) for sensors which are expected to enjoy greater demand from now on.

The dye-sensitized solar cell is getting a lot of attention as a next-generation solar cell, because it can generate an electric power efficiently under weak light such as scattered and indoor lighting. A general dye-sensitized solar cell utilizes visible light absorbed by the pigment in order to generate electric power. It is composed of a transparent conductive substrate which has a porous layer consisting of titanium dioxide particles with nano (a billionth) meter size, a glass substrate which has metal film and iodine electrolyte encapsulated between these substrates. Despite being a promising candidate for next-generation solar cell, problems such as low generation efficiency, concern for safety (volatilization of iodine and organic solvent and electrolyte leakage) and durability (peeling-off of organic dye adsorbed on titanium dioxide) prevent it from being commercialized.

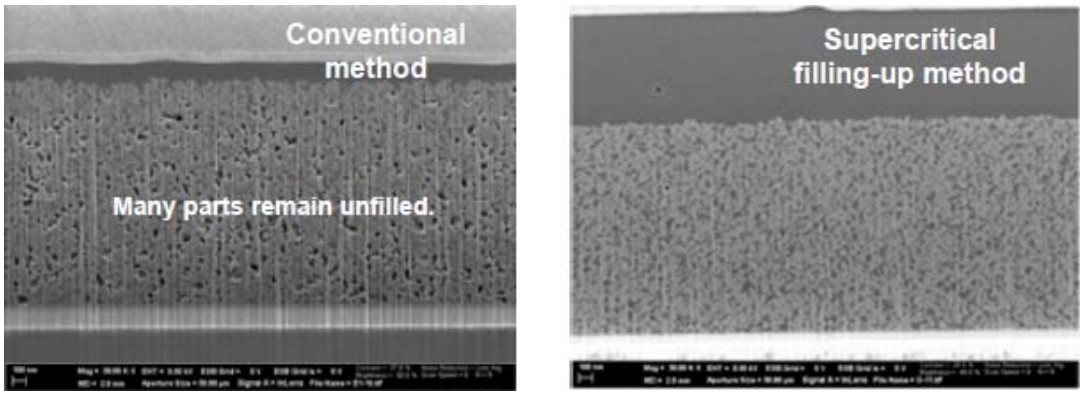
Ricoh found the solution to these problems by developing unique technologies in material, structure, and method for manufacturing. Since the structure of this solar cell device is similar to that of the organic photoconductor which is used for multifunction products (MFPs), Ricoh managed to make efficient use of its material and device technologies in developing this new cell.



Device structure of a complete solid state dye-sensitized solar cell developed by Ricoh

- Safety

The dye-sensitized solar cell developed by Ricoh is characterized by the utilization of hole transport materials composed of organic p-type semiconductor (*2) and solid additive agents. Ricoh succeeded in filling up inside the porous layer consists of nano-sized oxidized titanium particles with hole transport materials densely by using Ricoh's unique film forming technology (supercritical fluid carbon dioxide (*3): film forming under SCF-CO2). This unique technology provided a solution to the problems associated with general liquid-state dye-sensitized solar cell such as safety hazards and the corrosion caused by the leakage of liquid and iodine.



The supercritical filling-up method enabled hole transport materials to be densely filled compared to the conventional method (electron microscopic picture).
*The electron microscopic picture is shown in the direction rotated 90 degrees counterclockwise from the pattern diagram of the device structure.

- Improved power generating efficiency

Power generation efficiency of the dye-sensitized solar cell is substantially improved by optimizing the solid additive agents and the device structure. Furthermore, designing an organic dye in order to absorb the wavelength region of indoor lighting enables this solar cell to have high generating electric output. Ricoh's new solid-state dye-sensitized solar cell achieved 13.6 μW/cm^2 power generation performance, which was more than double that of the

amorphous silicon solar cell (6.5 μW/cm^2). This performance indicates that the new solar cell has the highest electric output in the current market under the standard white LEDs (200 lux), and more than 1.6 times compared to the highest efficiency electrolytic liquid-state dye-sensitized solar cell (8.4 μW/cm^2).

- Durability

Ricoh conducted various durability tests, which revealed that there is no degradation of maximum-power-output at 85℃ after 2,000 hours.

Ricoh believes that realization of a stand-alone power source (energy harvesting device) to generate power from the natural environment will be significant for the Internet society (Internet of Things: IoT) (*4). The number of things to be sensed is growing exponentially, which means it is essential for an area without power source to get electric power from the surroundings by using a stand-alone power source. Ricoh will aggressively pursue the application of solid state dye-sensitized solar cell as an energy harvesting device.

Ricoh will announce detailed information at "Image Conference Japan 2014" (The Imaging Society of Japan) annual meeting: June 11th to 13th). In addition, a solid-state dye-sensitized solar cell serial module using this technology will be exhibited at the Ricoh Booth of Tokyo Big Site of Design & Manufacturing Solutions EXPO (June 25th to 27th).

(*1) Amorphous silicon solar cell: A solar cell having a thin silicon amorphous layer of chemical vapor phase epitaxy of silane gas on the substrate: An amorphous silicon solar cell has about a 1.8eV energy gap, and absorbs and generates short wavelength light of 700 nm or less. Amorphous silicon is mainly used for solar cells under natural indoor lighting as the output under weak light is high compared to crystalline silicon solar cells.

(*2) Organic p-type semiconductor: An organic material having broad conjugated bonds (overlap of electron orbit of adjacent nucleus in molecule), which can electrify by moving electron holes (positive charges) on an electron orbit.

(*3) Supercritical fluid carbon dioxide: Carbon dioxide is a supercritical fluid (in a state of substance under temperature and pressure above the critical point, and has properties of both gaseous diffusibility and solubility of liquid). Critical temperature is 31.1℃ and critical pressure is 7.37MPa.

(*4) IoT society: Society of the near future, where all things will be equipped with sensors and telecommunication functions, and where big data analysis of mass intelligence emitted by sensors will be conducted for harnessing.

* A part of this research was conducted with the assistance of the project leader: Professor Hiroshi Segawa of Research Center for Advanced Science and Technology, the University of Tokyo of the project "Development of Organic Photovoltaics toward a Low-Carbon Society: Pioneering Next Generation Solar Cell Technologies and Industries" under Funding Program for World-Leading Innovative R&D Science and Technology" of Japan Society for the Promotion of Science.

| About Ricoh |

Ricoh is a global technology company specializing in office imaging equipment, production print solutions, document management systems and IT services. Headquartered in Tokyo, Ricoh Group operates in about 200 countries and regions. In the financial year ending March 2014, Ricoh Group had worldwide sales of 2,236 billion yen (approx. 21.7 billion USD).

The majority of the company's revenue comes from products, solutions and services that improve the interaction between people and information. Ricoh also produces award-winning digital cameras and specialized industrial products. It is known for the quality of its technology, the exceptional standard of its customer service and sustainability initiatives.

Under its corporate tagline, *imagine. change.* Ricoh helps companies transform the way they work and harness the collective imagination of their employees.

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