TOYOTA CENTRAL R&D LABS

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Solar-Driven CO_2 Recycling Technology! Dramatic Breakthrough in Artificial Photosynthesis – World's Highest Solar-to-Formate Conversion Efficiency of 7.2% with Practical-Sized Cell –

Toyota Central R&D Labs., Inc. (TCRDL, Nagakute, Aichi Prefecture, President: Noboru Kikuchi) has successfully developed a practical-sized (36 cm × 36 cm) artificial photosynthetic cell [1] that uses solar energy to produce useful chemicals from CO_2 and water. This cell achieves a solar-to-formate conversion efficiency (h_{STC}) of 7.2%, the highest level for a cell of this size [2]. The details of this cell were published in Joule (Vol. 5 No. 3, 2021), an international energy-related academic journal [3].

[1] Artificial photosynthesis: technology that uses solar energy to produce useful organic compounds from CO_2 and water, and stores them as chemical energy. [2] Source: TCRDL [3] Joule: an academic journal published by Cell Press (an imprint of the Elsevier international publishing house) that specializes in the field of energy research. Joule was first published in 2017 and its journal impact factor in 2019 was rated at 29.155.
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Features of this technology:

1. Basic principle of artificial photosynthetic cell

The artificial photosynthesis technology developed by TCRDL uses a semiconductor/metal-complex hybrid catalyst in combination with electrodes that perform reduction reactions with CO_2 and oxidation reactions with water to produce an organic compound (formate: HCOOH) at ordinary temperatures and pressures.

In 2011, when TCRDL demonstrated this principle for the first time in the world, it achieved an h_{STC} value of only 0.04%. By 2015, TCRDL had achieved an h_{STC} of 4.6% using a 1 cm × 1 cm cell, the world's highest figure at the time that greatly exceeded the h_{STC} of plants.

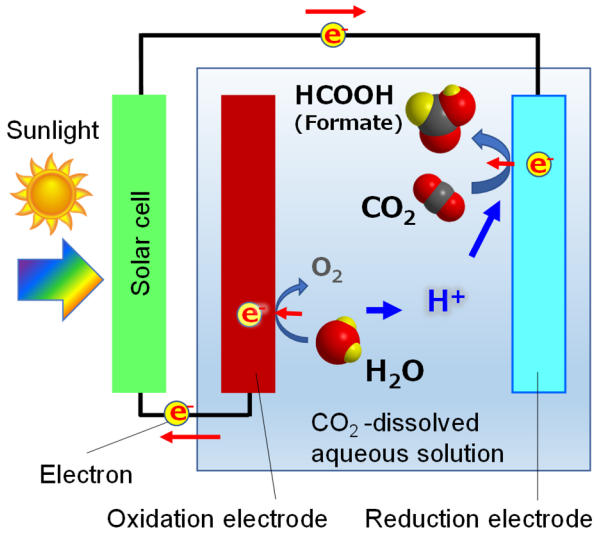

Fig. 1 Basic principle of artificial photosynthetic cell

2. Development of practical-sized cell

To enable the implementation of this technology, it was necessary to achieve an excellent balance between achieving a high h_{STC} and scaling up the cell. However, this was technically difficult to accomplish. Therefore, based on the same fundamental principle, the research team proposed a new cell structure and electrode catalysts capable of synthesizing formate by fully utilizing the electrons generated by sunlight. This approach accelerates the reactions by scaling up the electrode area to achieve a good balance between the quantity of electrons generated by the solar cell and the substances required for formate synthesis (i.e., electrons, hydrogen ions, and CO_2), and by supplying them quickly and continuously across the whole surface of the electrodes. This practical-sized cell (36 cm × 36 cm) yields a h_{STC} of 7.2%, the highest level for a cell of this size. The newly developed cell structure can also be applied to even larger cells.

In the future, the aim is to realize a system in which CO_2 emissions from factories and other facilities are captured and recycled into useful chemicals by artificial photosynthesis.

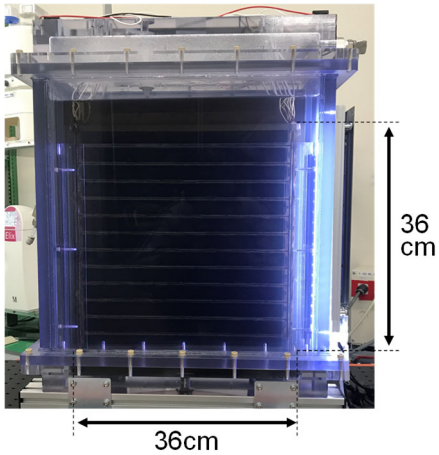

Fig. 2 Practical-sized cell (36 cm × 36 cm)