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Transparent sustainable energy platform: Closed-loop energy chain of solar-electric-hydrogen by transparent photovoltaics, photo-electro-chemical cells and fuel system

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ABSTRACT

Ultimate goal of the sustainable energy system is to support our current without compromising the need of future generation. Limitless and continuous energy from Sun offers the potential to realize solar-powered photovoltaics (PVs) and concomitant hydrogen production by water-splitting. We propose the use of transparent PVs (TPVs) and transparent photo-electro-chemical (TPEC) cells to combine the generation of electric power and energy storage of hydrogen fuel. Transparent metal-oxide ZnO/NiO heterojunction was applied for TPV-TPEC module with high transparency (64%) to generate high photovoltage (0.546 V), photocurrent (2.28 mA/cm^2) with power-conversion-efficiency (1.47%). This electric power is directly used and applied for the hydrogen production (Power-to-Gas, P2G). This onsite hydrogen production is effective to resolve the burden of hydrogen delivery and storage. Proton exchange membrane fuel cell (PEMFC) unit is linked to TPV-TPEC module to convert hydrogen to electric power (Gas-to-Power, G2P). This G2P mode is efficiently reduce the PV dependence on intermittent nature of sunlight and complete the closed-loop energy supply chain. We demonstrated TPV-TPEC-PEMFC energy system for the continuous energy production, supply and conversion for the transparent energy platform. In the future, it will be possible to obtain the continuous green energy from the window without losing vision.

1. Introduction

Photovoltaic (PV) energy production provides a great opportunity to support global energy demand. However, PV energy production occurs instantly from sunlight, and is therefore transient to light conditions. This in-born feature of PVs limits the energy continuity provided by solar power alone. There is a need for a permanent energy supply system that provides energy-sustainability from light-transient PVs in a permanent energy conversion system, which will enable the onsite use of convenient and independent energy supply systems.

Among the various energy storage systems [1,2], solar-to-hydrogen technology is considered as an efficient way to save the energy generated from the limitless and continuous solar source. Conventionally, the hydrogen is obtained artificially by chemical reformation. Recently, light energy has been applied for the natural production of hydrogen from water in the form of photocatalytic (PC), photo-electro-chemical (PEC), and photovoltaic-electrolysis (PV–EC) systems. Among these options, the PEC route is considered to be the most promising approach in terms of utility manipulation and cost-based performance. The PEC system has two photoelectrodes that generate hydrogen by splitting water. One is a photoanode to produce oxygen and the other is a photocathode to produce hydrogen. The force of the water-splitting can be driven by the light and water oxidation reaction (involving four electrons and two oxygen atoms), which is the normal rate-determining reaction for the overall water-splitting process [3–13].

Transparent conductive oxide (TCO) films are doped metal-oxides

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