July 7, 2021

Press Release

Toda Kogyo Corp.

Air Water Inc.

Adoption for NEDO Advancement of Hydrogen Technologies and Utilization Project

- Research and development of a high efficiency hydrogen production system using ferrous catalyst by direct methane reforming -

Toda Kogyo Corp. (headquartered in Minami-ku, Hiroshima; hereinafter, "Toda Kogyo") and AIR WATER INC. (headquartered in Chuo-ku, Osaka; hereinafter, "AIR WATER") announce their proposal for the research and development of a high efficiency hydrogen production system using a ferrous catalyst and direct methane reformation in response to the New Energy and Industrial Technology Development Organization (NEDO)'s public solicitation of commissioned projects for the utilization and advancement of hydrogen technologies and the development of oxygen production technologies emitting zero CO_2 using carbon hydride and other means has been approved.

This R&D project will develop a hydrogen production process and system capable of efficiently producing CO_2 emission-free hydrogen from the raw material methane, which is a major component of natural gas, biogas and other fuel gasses, using the DMR (Direct Methane Reforming) method, which uses a high-activity iron catalyst. In the future, the two companies will aim to provide CO2 emission-free hydrogen as turquoise hydrogen by using a heating fuel for DMR reacting furnaces.*

During the R&D period (FY2021 to 2022), the companies' goals will be to realize the stable production of hydrogen whose purity is 99.99% or greater, which is generally used for industrial purposes, and complete a high-efficiency hydrogen production system capable of creating highly conductive multi-wall carbon nanotubes (hereinafter, "CNT") as a by-product, based on the DMR catalyst preparation technique and DMR responsive technology of Toda Kogyo and the gas purification technology of AIR WATER. In addition, the companies will work to achieve a hydrogen production cost of 30 yen/Nm^3 or less, which is a target for 2030 laid out by the Japanese government in their Basic Hydrogen Strategy, using sales of the by-product, CNT, to reduce costs.

The goal of the high-efficiency hydrogen production system the companies will build in this R&D project is to achieve the supply of inexpensive CO_2-emission-free hydrogen by fully leveraging the existing city gas infrastructure to quickly clean up the existing industrial hydrogen supply chain. Toda Kogyo and AIR WATER will push forward with the development of this system, expecting that it will accelerate the companies' efforts to realizing a carbon-free society by 2050, increase the value provided by companies using hydrogen, and also contribute to development of domestic industries.

*Turquoise hydrogen

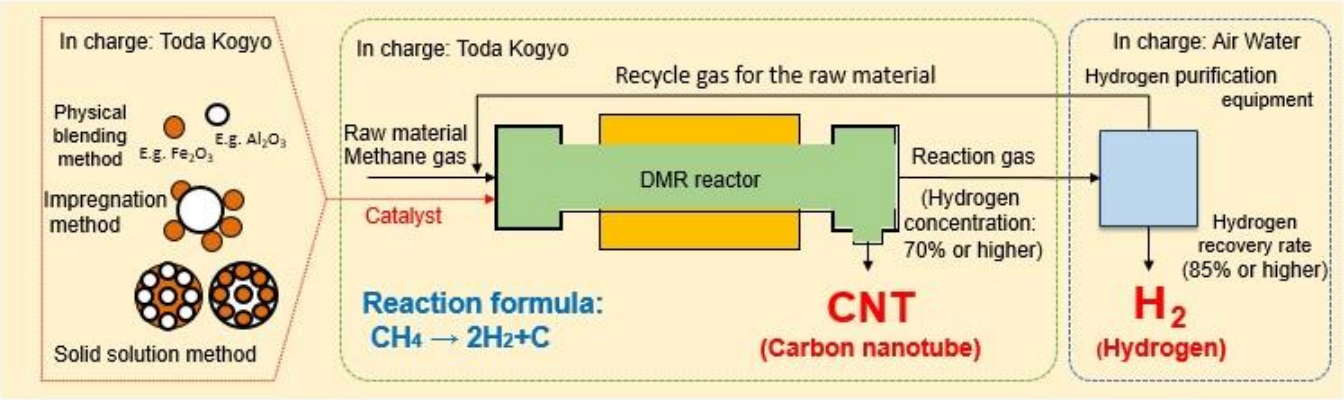
Turquoise hydrogen is hydrogen generated through the thermal decomposition of methane. There are multiple ways to generate hydrogen. A method of distinguishing them that has been gathering steam is the categorization of the generated hydrogen by "color" as determined by the environmental load during the generation. When a renewable or carbon-neutral energy source is used for thermal decomposition and the solid carbon generated in the production process is not released into the atmosphere as CO_2, the generated hydrogen is called turquoise hydrogen.

Color	Feature
Green hydrogen	Hydrogen generated through water electrolyzation using electricity generated from renewable energy.
Turquoise hydrogen	Hydrogen generated through the thermal decomposition of methane, which generates solid carbon, not CO_2, as a by-product. The reacting furnace must be operated using power from a renewable energy source or carbon-neutral energy.
Blue hydrogen	Hydrogen is generated from coal, natural gas, or other fossil fuels. The generated CO_2 is separated and sequestered in the ground or sea, not released into the air.
Gray hydrogen	Hydrogen is generated from coal, natural gas, or other fossil fuels. The generated CO and CO_2 are released.

Source: the German government's National Hydrogen Strategy

Please note that turquoise is the color of the stone also known as Turkish stone and is an intermediate color between blue and green.

Diagram of the production system



〔Inquiries about this press release〕

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Attachment (Reference)

1. Overview of the companies

(1) Business name	Toda Kogyo Corp.
(2) Location	1-23 Kyobashi-cho, Minami-ku, Hiroshima City, Hiroshima
(3) Representative	President Shigeru Takaragi
(4) Business	Production and sales of functional pigments and electronic materials
(5) Capital	7,477,000,000 yen
(6) Date of Establishment	November 30, 1933
(7) Website	https://www.todakogyo.co.jp/

(1) Business name	Air Water Inc.
(2) Location	12-8 Minami Semba 2-chome, Chuo-ku, Osaka-shi, Osaka
(3) Representative	Chairman, CEO Kikuo Toyoda
(4) Business	Expanding businesses such as medical, energy, agriculture, and foods from supply of industrial gas
(5) Capital	55,855,000,000 yen
(6) Date of Establishment	September 24, 1929
(7) Website	https://www.awi.co.jp/

2. Hydrogen production through direct methane reforming

Direct methane reforming is a clean reaction (formula 1) that generates hydrogen and carbon materials such as CNT in the presence of an iron catalyst and other catalysts using natural gas and other gasses as raw materials.

The DMR method generates half the hydrogen per methane molecule produced by the steam reforming method (formula 2) currently commonly used for industrial purposes, but it does not generate CO_2 from the methane during production, which means it can be considered a CO_2-emission-free reaction. This is the reason the companies are pushing forward with its development as a hydrogen production method that has the potential to greatly contribute to a low-carbon society.

Direct methane reforming

$CH_4 \xrightarrow[\text{Catalyst (600 to 750 °C)}]{} 2H_2 + C$ (such as CNT) ... Formula 1

Steam reforming

$CH_4 + 2H_2O \xrightarrow[\text{Catalyst (600 to 850 °C)}]{} 4H_2 + CO_2$ ... Formula 2

3. High-activity iron catalyst

A high efficiency iron composite catalyst able to generate hydrogen through the DMR reaction. The catalyst is superior both in initial activity and sustained activity.

4. Hydrogen purification technology

Since the purity of the hydrogen gas generated through the DMR method is approximately 70%, we will establish a purification system to improve the purity to 99.99% or greater, which is commonly used for industrial purposes, using membrane separation and adsorption separation technologies.

5. Carbon nanotubes (CNT)

There are great expectations for CNT as a new wonder material because it is strong, lightweight, and a great conductor of electricity and heat, among other features. It is expected to be used in a wide range of applications including lithium-ion battery conductive auxiliary agents, conductive fillers, reinforcement materials, and electromagnetic wave absorption materials. CNT can be categorized into single-wall CNT (SWCNT), which is formed by rolling a single graphite hexagonal mesh plane; dual-wall CNT (DWCNT), which laminates those planes together; and multi-wall CNT (MWCNT). the diameters of CNT structures roughly range from several nm to several dozen nm, with lengths of several dozen μm.