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Development of Electrode Catalyst for FCs Using 1/20 Platinum

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1. Governmental Measure

(1) Liberal Democratic Party of Japan

On November 22nd, the Hydrogen Society Promotion Committee of the Resources and Energy Strategy Investigation Committees of the Liberal Democratic Party of Japan compiled a proposal to use hydrogen energy which reduces greenhouse gas emissions for the 2020 Tokyo Olympics and Paralympics. Their actual suggestions are a cauldron with multi-colored flames and FCV transport between airports and venues. The proposal will be submitted to the Tokyo Metropolitan Government. It emphasizes the Tokyo Olympics is a "great opportunity to advertise Japanese hydrogen technology to the world". Hydrogen has no color, which makes easy to add colors to flame. Fuel cell (FC) buses and taxis use motors which are powered by fuel cells using a chemical reaction of hydrogen and oxygen, and the proposal suggests that they be used as a transportation mean for athletes and staff. Also, another suggestion is Tokyo Tower to be lit up using electricity generated by hydrogen, and the proposal suggests that the Olympics should be a live showcase of hydrogen energy society. (The Mainichi Newspapers, November 23, 2016)

2. Local Governmental Measure

(1) Tokyo

Tokyo will bring FC buses into its bus service by March 2017. As the beginning, two FC buses will work as a part of the operation in the coastal area. The local government plans to increase the number of FC buses to five by FY2017. Tokyo gets its Bureau of Transportation to use these buses to take the initiative in the environmentally-friendly public transport, and hopes this will lead to the vehicles being used by private bus service operators. According to the local government, this is the first time in Japan to use FC bus for actual commercial operations, and not experimental operation. A FC bus sells for a high price of ¥100 million, which stops private public transport operators using these buses. The first two buses will be leased. For 2020 Tokyo Olympics and Paralympics, 80 FC buses will be brought out for operation of Tokyo's public transport by FY2021. The local government is quickly trying to deal with increasing demand in public transport in its coastal area for the Olympics. They plans to enhance their public transport network as well as setting up a new branch of their Bureau of Transportation. (The Nikkei, December 14, 2016)

3. FC Element Technology Development & Business Plans

(1) JAIST& Tanaka Kikinzoku Kogyo

A joint research group of Tanaka Kikinzoku Kogyo and a team of Prof. Noriyoshi Matsumi of Japan Advanced Institute of Science and Technology has developed a catalyst for FC electrodes which reduces the amount of expensive platinum by between a fifteenth and twentieth. The catalyst was synthesized by applying only artificial sunlight, without using a sacrificial reagent such as alcohol, and exhibited the same level of specific activity which indicates catalytic performance as commercial ones. The group aims to commercialize the synthesis method of low-cost and low-environmental impact. FCs contain a considerable amount of platinum in the electrode catalyst of their cathodes. A common synthesis method of electrode catalysts requires alcohol, surfactant and a reactive condition of high temperatures to combine the platinum and carbon

material. The group mixed a carbon material such as graphite, carbon nanotubes (CNTs) and graphite oxide in water, and this dispersed fluid was exposed to ultrasound waves for about two hours. Then, anatase, a type of titanium oxide, was added to it, and this mixture had 15 minutes of ultrasound wave exposure. A chloroplatinic acid solution was added to the mixture, and this mixture was exposed to artificial sunlight while being mixed for five hours to deposit the composite materials. The group measured the amount of platinum in the composite materials, and the data between 1.6 and 4.3 wt% for all of the materials irrespective of which carbon material they bonded to. The transmission electron microscopy result shows that platinum particles are evenly distributed, and have the same reaction level of oxygen reduction as commercial material was confirmed by electrochemical analysis. The group expects that the catalyst can reduce the costs of eco cars, stationary FCs as power source at home and lithium–air battery, and will develop applications for the material. (The Chemical Daily, November 21, 2016)

(2) Daiichi Kigenso Kagaku Kogyo

Daiichi Kigenso Kagaku Kogyo will try to grow its businesses to achieve its long-term business plan. They are working on the second phase of their 10 year plan towards FY2022, and the plan includes targets of double the shipping volume of that of FY2012 and a 15% sales increase of newly developed products by FY2022. The firm is trying to reinforce its businesses to hit these targets. In the fine ceramics area, they will promote joint development of FC materials with users, and will develop dental materials which are in demand mainly in Europe. They aim to raise the market share of zirconium dioxide, their core product for automobiles, by riding on the strength of tightening environmental regulations. The long-term business plan "DK-ONE Project" was compiled for the period between FY2012 and FY2022. They got out from the deficit caused by China's restriction on the export of rare earth elements as a completion of the first phase. The second phase started to fortify the business foundation in FY2016. Their targets are ¥26 billion sales and ¥3 billion operating profit, and these are to lead to a developing period from FY2019. A fine ceramics product is under development for solid oxide fuel cells (SOFCs). They have jointly developed a material using expertize from their catalyst application with Kyushu University. This product can reduce carbon deposition on electrodes without sending hydrogen or carbonized hydrogen fuel such as natural gas to reformer, and allows the same performance level as a conventional product. Daiichi Kigenso Kagaku Kogyo expects this product to contribute to reducing size and costs of SOFC. The FC market seems to be developing slower than anticipated, but the manufacturer plans to establish a FC business by working on the joint development with its users. (The Chemical Daily, November 21, 2016)

(3) Stella Chemifa

Stella Chemifa will reinforce its research and development structure of batteries and next generation materials. They are considering unifying research and development by transferring the sections from the Sanpo Factory, Sakai City, to Izumi Factory, Izumiotsu City, both in Osaka Prefecture. This will make research and development of new areas including catalyst for FCs in separate plants more efficient. The firm plans to expand room and installation of the most advanced analysis equipment. The research and development in charge of products for semiconductors will move to the Sanpo Factory. The manufacturer aims to produce value-added products by accelerating fluorochemical-based research and development by reinforcing the organizational structure. Izumi Factory researches and develops fluorochemical products including lithium hexafluorophosphate ($LiPF_6$) for electrodes of lithium ion-batteries (LIBs) including additives, catalyst for FCs and nano particles of fluorochemical materials. The factory has a laboratory in the management building with 20 employees and three rooms by the production line for industrialization research such as process development. Sanpo Factory has a development section specialized in products for semiconductor, and section working on the other areas uses spare space there. The firm will integrate this section into the one in the Izumi Factory. The firm will transfer research and development subjects including new FC catalysts which allow a reduction in platinum use, new additives to extend life time of LIBs, highly dispersible CNTs and luminescent material for light

emitting diodes (LEDs) from the Sanpo Factory to the Izumi Factory. Six researchers in charge and the analysis facilities will also be transferred there. Research and development is expected to be more efficient by uniting the sections in one place. Izumi Factory is transferring the production line of $LiPF_6$ of which the annual capacity is 1,300 tons to a venture to start operating in 2017 in China. The firm is considering changing the plan of production lines, when the production line is to be added for additives for LIBs which is going strong. As a part of this, room for research will be expanded, including the most advanced analysis equipment the new X-ray photoelectron spectroscopy (XPS). Also, two researchers will be hired in April 2017. The research section in Izumi Factory will have 28 employees. (The Chemical Daily, December 7, 2016)

(4) Sumitomo Precision Products & Miura

Sumitomo Precision Products and Miura, a major boiler maker, will release FCs together in FY2017. The FC system is a generator for restaurants and welfare facilities, and also gives heat for hot water and heating. About an annual ¥0.7 million of electricity and gas use can be covered. Industrial use FCs produce less CO_2 than conventional independent generators, and the running costs are lower than boilers. Due to this, the Japanese government is promoting FC systems. The jointly developed product uses SOFCs. These cells generally have 20% higher generation efficiency than polymer electrolyte fuel cells (PEFCs) which are widely used for domestic FC systems. The new system outputs up to 5 kW. (The Nikkei, December 9, 2016)

4. Hydrogen Infrastructure Element Technology Development & Business Plans

(1) Actree

Actree, Hakusan City of Ishikawa Prefecture, will expand research on renewable energy. Their research complex will be completed on the premises of their head office in March 2017 to study an air conditioning system using a photovoltaic generator and geothermal with ¥1.2 billion investment. Experiments of agricultural greenhouse combining renewable energy and FCs will start in January 2017, and waste heat use of industrial waste incinerator will be tested for agricultural and fishery use from the spring of 2017. They aim to grow the business to follow the industrial waste processing plant, their core business, by enriching research. The greenhouse experiment will be carried out in Ishikawa Prefectural University from January 2017. In this experiment, hydrogen will be produced by water electrolysis for FC use as well as power and hot water production by solar power and heat as same as the research complex. (The Nikkan Kogyo Shimbun, December 1, 2016)

(2) Sumitomo Electric Industries & Shibaura Institute of Technology

Sumitomo Electric Industries and a research team of Shibaura Institute of Technology have developed a membrane which filters hydrogen from mixed gas at 10 times the efficiency of the conventional product. Improved penetration performance makes it easier to produce a carrier which safely stores hydrogen for FCs. The research team will continue the project through membrane module production, and the product is aimed to be commercialized in 10 years. The developed membrane uses Sumitomo Electric Industries' silica, a material for optical fiber, as its base. Zeolite crystals of a few μm thickness were formed on a 1 to 2 mm silica base. Pores of zeolite layer are 0.5 nm diameter, and the layer lets hydrogen of 0.3 nm diameter through. Because a zeolite layer for hydrogen filtering is very thin and difficult to handle, the base is generally alumina, aluminum oxide, which has finer holes. Aluminum melts and comes out from aluminum oxide base during the heat process for zeolite crystal formation. This seems to result in the blockage of hydrogen. Prof. Mikihiro Nomura of the university thinks that changing to silica improved permeation rate to 10 times of that of conventional aluminum oxide ones. During the heat process, the zeolite crystal layer gets thin by melting and mixing with silica. This also gives the membrane the property of easier hydrogen permeation. The Japanese government aims to spread the use of environmentally-friendly hydrogen energy in order to stop CO_2 emissions by 2020. Hydrogen has a risk of explosions. To use it as energy source, a method needs to be established for safe storage and transport. A transport method combines hydrogen with compounds to turn into a liquid form. This gets attention for FCs due to easier handling. To extract hydrogen at higher efficient rate, the key is

permeation membrane improvement. The research group discovered that fluorine additive during silica production pushes permeation rate up further. They will look into the optimum conditions. (The Nikkei Business Daily, December 5, 2016)

5. ENE- FARM Business Plans

(1) Osaka Gas & Sekisui House

On November 24th, Osaka Gas and Sekisui House announced that their smart energy house was being tested in Oji-cho of Nara Prefecture, and would start the second live experiment. In this experiment, ENE-FARM will operate at the rated output level, and heat will be supplied for air conditioning as well as hot water for efficient cogeneration. Excess power production of the FC system and photovoltaic generator will be sent to the grid and more the meter back. The experiment will start on December 1st, and they will check the effect until March 2019. The firms aim to achieve zero CO_2 emissions and energy by renovating an established house in the second phase. To operate the FC system at its best performance, heat and power will be supplied at higher efficiency by continuous rated operation. The firms will add a new use for a large amount of heat and electricity produced by rated operation. To extend heat usage to air conditioning, 50% of heat will be used for dehumidification in summer, and 30% will be used for heating in winter. Excess electricity from photovoltaic generator and the FC system will be sent back to the grid assuming the feed-in tariff (FIT) to apply to excess power production of both power sources to be sent to the grid at the same time in the future. The live smart energy house experiment started on November 2nd. In the first phase, annual zero CO_2 emissions was achieved by an energy control system combining ENE-FARM, FC systems, and photovoltaic generators on top of EVs as vehicle to home (V2H). (The Denki Shimbun, November 25, 2016)

(2) Panasonic

Panasonic will reinforce development of FC products. They plan to introduce ENE-FARM, domestic FCs, using no platinum catalyst by the early 2020's. Also, pure hydrogen FCs using solely hydrogen is planned to be mass produced by 2020. The firm is trying to contribute to realization of hydrogen society by reducing costs of FCs to promote the systems to households. They have sold ENE-FARM which generates power using hydrogen produced from natural gas since 2009. The latest model is the fourth generation released in 2015. To achieve the simpler system, the number of parts was reduced by 50% of that of the first generation, and the amount of platinum for catalyst was reduced by 75% of the first one. As of March 2016, 160,000 units of ENE-FARM are in used at home. Panasonic shipped over 50,000 units out of the total number. However, Mr. Hideo Ohara, the General Manager of Hydrogen and Energy Research Laboratory of the Advanced Research Division, emphasizes "reduction in system costs is essential for further expansion of use". As a way to cut down costs, they have planned to gradually reduce the amount of platinum catalyst. Their "strategy is to cut down the amount of platinum from current model first", and the next generation model is likely to reduce platinum use further. Also, they intend to introduce a platinum free version into the market as early 2020's. This market introduction is expected to be two generations ahead or later. As an introduction of the new system, the manufacturer plans mass production of pure hydrogen FCs. ENE-FARM produces hydrogen from natural gas by its built-in fuel processing unit. However, pure hydrogen FCs eliminate the need of the unit due to its ability to generate power using solely hydrogen. This allows a compact product design. The manufacturer installed three units of these FCs outputting 700 W each in Yamanashi Prefecture, and is testing efficient operation by coordination control. They "plan to commercialize pure hydrogen FCs by 2020" to extend the product range. As well as the 700 W system, the scope of the commercialization includes a 5 kW system. Additionally, they show an intention to use hydrogen produced by renewable energy in the future. For example, technological development will be carried out to produce hydrogen by splitting water directly using photocatalyst and sunlight. Since the Japanese government aims to set up a CO_2 free hydrogen supply system by 2040, Panasonic is progressing its own development of the FC system early as possible in order to complete the project ahead of time. (The Chemical Daily, December 14, 2016)

6. Cutting Edge Technology of FCVs & EVs

(1) Toyota

Toyota Motor will accelerate research and development of next generation eco cars. They will start construction to expand the research and development center in China, and will also investigate feasibility to use FCs for large lorries, semi-trailer trucks, in California, USA. An in-house venture will be launched to develop EVs directly under Toyota's management in cooperation with Toyota Industries, Aisin Seiki and Denso in order to build a business foundation in the EV market by bold actions. The expansion will start at the Toyota Motor Engineering & Manufacturing which was set up to establish localized development in 2010 in China. The reinforcement will be an expansion of an established testing building, construction of a new testing building, a battery evaluation building and a test driving course as the investment planned when it was launched. The completion of the construction is planned by the end of 2018 or later. In China, Toyota started sales of "COROLLA Hybrid" and "LEVIN Hybrid" both with a locally produced hybrid unit in October 2015, and will work on preparation of a plug-in hybrid (PHV) market introduction, test of FCV and EV market introduction there. On the other hand, their FC technology application will be expanded to large lorries for contribution to "zero-emission for logistics". Toyota Group determines hydrogen to be a promising energy for the future, and has worked on a wide range of technological and product development including FC forklift and stationary FCs for home as well as commercial product "MIRAI". Their plan is to start the sales of the first FC bus in Japan in early FY2017, and to achieve over 100 FC buses to be used mainly in Tokyo for the 2020 Olympics and Paralympics. They will announce their actions in the US as the project progress. (The Chemical Daily, November 21, 2016)

(2) Sanden AS

Sanden Automotive Climate Systems (Sanden AS) in Chiyoda-ku of Tokyo, a member of Sanden Holdings, has announced that it had developed a new electric compressor and water heater for automotive air conditioners of FCVs. The new electric compressor achieves operation at a wide range of temperatures by multi-polarization of its motor and improvement of magnetic force and output density. The manufacturer designed it to last a long operation under various conditions by ability of heating and dehumidification and start operations of air conditioning system using a heat pump under very low temperatures. An originally developed special bracket enables the compressor to be fixed on EV frames. The water heater was developed not only for supplemental heating but also heat management for automotive electrification. Both products are produced at the Yattajima Plant in Isesaki City, Gunma Prefecture. The manufacturer will sell them to automakers worldwide. (Nikkan Jidosha Shimbun, November 29, 2016)

(3) Tesla

US-based EV producer Tesla Motor will expand its charger network in Japan. On December 1st, a quick charging facility was opened for their products in Hashima City, Gifu Prefecture. Another quick charging facility will be open in the Kyushu region in this year. They will quickly prepare the infrastructure by doubling the number of standard charging stations in 2017. The facility in Gifu is called "Supercharger", and was unveiled to the press on the day. This is the 12th location after Tokyo and Osaka. The new facility is located close to the Gifu-Hashima Interchange of Meishin Expressway, and gives the drivers easier access to Osaka or Nagoya. (The Nikkei, December 2, 2016)

(4) Honda

Honda will reduce the costs of FCVs to the same level as hybrid vehicles (HVs). They will accelerate reduction in cost in FCV system under joint development with US-based GM, and parts and components will be shared with HVs. Honda's business plan is to increase the sales of electric powered vehicles to two thirds by 2030, and their FCVs and EVs are planned to take 15% of the target sales. They will use a platform compatible for electrification. As well as this development, their own hydrogen refueling station will be developed to progress infrastructure preparation for early growth of the FCV market. These actions are expected to lead to a volume effect for reduction in the costs. In July 2013, Honda announced the partnership with GM for development of the next generation of FC systems and hydrogen storage systems. This partnership includes joint development of a FC stack system and high

pressure hydrogen tanks for the introduction of next generation FCV in 2020, and the two firms are considering cooperation in system production and procurement. Honda plans sales expansion of electric powered vehicles including HV and PHV, and vehicle development for the sales expansion. A next generation platform will be developed for automotive electrification in five years. At the same time, the firm aims to establish production line suitable for electric powered vehicles. A PHV to be released in 2018 will use the same platform of "CLARITY FUEL CELL", a FCV currently available on lease. In this way, the manufacturer will use more common components with HVs and PHVs of which sales are expected to be larger in order to achieve significant reduction in costs. (Nikkan Jidosha Shimbun, December 1, 2016)

(5) Hitachi Chemical

Hitachi Chemical will invest ¥10 billion over five years to increase its production capacity of anode materials, a core material of LIBs, by four times. While the EV related material market has been expanding due to anticipation of EV growth, the manufacturer is trying to compete with Chinse firms rising in the market. Their supply system will be prepared for highly functional anode materials to strengthen themselves to compete in the market. The manufacturer appears to dominate the global market of anode materials with 30% share. Many EVs including Nissan's "LEAF" use Hitachi Chemical's material. Hitachi Chemical has production facilities for anode materials in Japan and China, and the sales of the product are ¥16 billion for FY2015. Mr. Hisashi Maruyama, the president, says the product sales has "risen by 30% each year" due to increasing use for EVs. The manufacturer is fortifying facilities of its two plants in Ibaraki Prefecture. Their production capacity will be increased to double of that of current one in 2017, and their production facilities outside and inside Japan will gradually be improved over next five years. As the Chinese government is promoting EVs, Chinese manufacturers of LIB materials have been stretching their shares in the market. "Chinese producers are tough competitors, but materials for LIB require high reliability", Mr. Maruyama emphasizes. He also shows an intention to focus on research and development of silicon materials for anode suitable for large capacity batteries as well as conventional graphite one. (The Nikkei, December 14, 2016)

(6) Hitachi

Hitachi has developed a LIB which allows EVs to drive about 400 km on a single charge. The new battery has double the capacity of the existing one, and can extend current driving range of EVs by 40%. The firm uses a nickel alloy for the electrodes to increase the thickness so that the battery can store a large amount of electricity. The battery has improved durability in order to slow down performance degradation by repeated charging and discharging. The manufacturer aims to commercialize the product by 2020. As commercial EV, Nissan "LEAF" can drive 280 km on a single charge. If an EV with 400 km driving range were achieved, it would promote the market growth. In LIB, lithium ions move between the electrodes to charge and discharge power. To increase charging and discharging capacity, the amount of ions stored at electrodes has to be increased. The firm uses material containing nickel as the largest part which can store lithium ions better for the cathode of the product. Furthermore, the thickness of the electrodes has been doubled from the existing one to raise the capacity. A carbon material is normally used for anode. However, the firm uses silicon which can store and release lithium ions better as the major part of the electrode. These improvements achieved the higher power capacity. Now, the firm's attainable performance is 320 kWh/kg per single cell, which is the basic unit of energy density of a battery, double that of the existing product performance. The figure is close to the highest achievable performance of LIB. The battery would allow EVs to drive about 400 km, longer than between Tokyo and Nagoya in standard conditions. As LIB is used, a layer builds up on electrode surfaces by reaction with the electrolytic solution, which reduces performance. The firm also has found a solution for this issue. The cathode surfaces will be coated with oxide, and a fluoride additive will be added to the electrolytic solution of the anode in order to prevent this layer. The capacity stayed over 90% of the initial figure after 100 cycles of charging and discharging. The New Energy and Industrial Technology Development Organization (NEDO) which supports the development estimates that LIBs with this level of capacity performance

would be commercialized around 2020. The battery developed by Hitachi is expected not to go much higher in the cost than conventional ones. The manufacturer plans to check safety to lead to commercialization. LIB is currently considered to be the best storage battery, but the performance is reaching the ceiling. There are projects looking into new types of storage battery to commercialize by 2030 in order to extend EV driving range further. (The Nikkei, December 19, 2016)

(7) Hyundai Motor

South Korean-based Hyundai Motor will aggressively work on FCVs. Their FC bus and new sport utility vehicle (SUV) will be released in 2017 and 2018. The new FC SUV has a 30% longer driving distance than current model on a full tank. The manufacturer aims to catch up with Japanese firms by improving its product range to of that of Toyota. The new FCV will be introduced into the market in January 2018, and be the second commercial product after "Tucson ix". According to the firm, the FCV can drive 560 km on a full tank of hydrogen measured under the US standards, which outruns 520 km of Toyota's "MIRAI". The Hyundai's first FCV drives 426 km. The new one will sell for ₩60 million, about ¥6 million, level, and the firm plans to offer an actual price of ₩30 million level including subsidy. FC bus will be released in 2017. The details are closed. Toyota will also introduce FC bus in the same year, and Hyundai will be competing in the market. (The Nikkei, December 21, 2016)

7. FC Ship Elemental Technology Development

(1) Toshiba

NREG Toshiba Building and the Tokyo University of Marine Science and Technology are jointly developing a testing ship "Raicho N", and gave out an order for pure hydrogen FCs for the ship to Toshiba. Toshiba has delivered its FCs. The delivered products are two units of stationary pure hydrogen FCs outputting 3.5 kW. Because pure hydrogen FCs directly use hydrogen as fuel, the power generation emits no CO_2. Furthermore, this system allows a shortened start-up time. NREG Toshiba Building and the Tokyo University of Marine Science and Technology aim to commence hydrogen FC ship operation in 2020. The pure hydrogen FCs are installed to Raicho N, and a ship operation test started in October. These two organizations will pick up issues for marine operation of pure hydrogen FCs through this experiment. The results from the experiment will be used to produce safety guidelines for FC ships which are under development by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). (Dempa Shimbun, November 28, 2016)

(2) Suzuki Shokan

Suzuki Shokan has joined a university research and development project for the coming hydrogen society. This is a part of their contribution to the society, and the firm is working on a hydrogen supply system for experiment of FC ships carried out by the Tokyo University of Marine Science and Technology. The firm uses its flexible business structure to give facility assistance to the academic organization. (The Chemical Daily, December 15, 2016)

8. Hydrogen Refueling Station Element Technology Development & Business Plans

(1) Toshiba

On November 28th, Toshiba announced construction start of a hydrogen energy center in its Fuchu Complex, a production and development facility for energy and social infrastructure. The operation will start in April 2017. The new facility will produce hydrogen using power from a photovoltaic generator, and hydrogen will be compressed and stored. The firm will supply FC forklifts with hydrogen in the complex. They will use the project to show actual hydrogen usage in the center as sales activity. The center will also show hydrogen production equipment using renewable energy such as solar power and hydrogen refueling stations as well as a management system which efficiently supplies hydrogen and electricity. The energy management system will be installed with an algorithm to calculate hydrogen demand of vehicle usage including FC forklifts. By estimating hydrogen demand for forklifts, the system optimizes the amount of hydrogen produced and compressed. (The Nikkei Business Daily, November 29, 2016)

(2) Solar Frontier

Solar Frontier has supplied modules of copper, indium and selenium (CIS) thin-film solar cells, a total of 10 kW to the experiment of "70MPa Smart

Hydrogen Station" started in Koto-ku, Tokyo, carried out by Honda from October 24th. This is the first time for the firm to provide its product to a FCV related project. The experimental project uses a high pressure water electrolysis system, which was originally developed by Honda to eliminate the need of a compressor, for high pressure hydrogen production and supply. The solar cell modules supplied by Solar Frontier generates power, which plays an important role of power source for the high pressure water electrolysis system. The solar cell modules of Solar Frontier generate a large amount of electricity, and its generation performance is not greatly reduced by high temperatures and shadow. Therefore, the system can perform excellently under actual use environment. Because of this, the system is expected to give a significant contribution to test results. "FCV generate power from hydrogen is an ultimate eco car. We are glad that our CIS thin-film solar cells are used in this experiment." Mr. Shinji Kato, Director and Executive Officer of Solar Frontier, commented. (Dempa Shimbun, November 23, 2016)

(3) Nippon Denko

Nippon Denko has a monitoring system for water purification facilities for hydrogen production at hydrogen refueling stations using the internet of things (IoT) which is an internet network connecting all sorts of products. This product allows taking actions such as replacing parts before break down by detecting abnormal signs in water flow and pressure. The firm aims to improve the function of water purification production equipment, a core component, for growing hydrogen refueling stations for FCVs. The new remote monitoring system will be sold specifically for "on-site" hydrogen production facilities of refueling stations. Natural gas which contains methane is commonly used for on-site hydrogen production of refueling stations, and methane gas and water are reacted to produce hydrogen. The water purification facility removes impurities from tap and spring water to make high purity water. Nippon Denko takes a 70% share in the water purification equipment market. They newly developed the system with sensors to detect water flow, quality and pressure installed in the water purification process, and the data of seven items will be sent to a dedicated server. The state of water purification equipment can be checked by managers of hydrogen refueling stations wherever they are by accessing the server through PCs or smart phones. Previously, these data needed to be checked by physically visiting the facilities, which delayed problem detections. When a problem arise, the new system allows taking appropriate actions such as adjustment of valves by sharing data between facility managers and Nippon Denko operators on a real-time basis. The first product was installed to the hydrogen refueling station in the Fukuoka City Central Sewage Treatment Center in October. Being an on-site facility, the station uses biogas coming from sewage sludge as material. The water purification equipment producing pure water at 400 L/h sells for about ¥3 to 4 million. If the remote monitoring system is chosen, ¥0.4 to 0.5 million is added to the purchase as well as monthly subscription of about ¥3,000 for the server use. The monitoring system can also be retrofitted to existing hydrogen refueling stations. The core business of Nippon Denko is alloy production for steel material. As well as water purification equipment for industrial water use, they deal with a wide range of businesses including environmental system businesses like waste water processing equipment and material recycle. (The Nikkei Business Daily, December 1, 2016)

(4) Seven-Eleven Japan & Iwatani

Seven-Eleven Japan has been working on convenience stores with hydrogen refueling stations attached in cooperation with Iwatani. The first two stores with refueling stations were opened in Japan in February at the same time. The refueling stations are currently not used by many consumers, but the Seven-Eleven Japan plans to expand the number of shops to 10 to 20 over a next few years. They will "connect currently spots of refueling facilities to make a network by increasing the number", and are preparing their business for growing FCVs. When you drive Route 1 north from Kawasaki City direction, you will see a big sign of "Hydrogen Station Ikegami" with blue letters on white background next to "Seven-Eleven Ikegami 8-chome", Ota-ku, Tokyo. (The Nikkei Business Daily, December 6, 2016)

9. Hydrogen Detection, Measuring & Accident Proof Technology Development

(1) Chino

Chino has developed a hydrogen detector with the measuring range between 0 to 2,000 ppm (0.2%). The product has a suction fan to take air in to promptly detect hydrogen which is easily diffused. It can be used as a safety measure to notify workers of hydrogen plants or transport operators on hydrogen leaks from piping by buzzer or vibration. Because hydrogen use is expected to expand, Chino plans to increase users by preparing the range of sensors suitable for various concentrations of hydrogen and purpose. The detector will be available from 2017. When hydrogen concentration reaches 4%, it can explode by catching fire. The developed sensor can detect a very small amount of hydrogen, while it can also always go around with users due to its chest-pocket size. This allows workers to notice hydrogen leaks instantaneously. The sensor continuously operates for 400 hours on a single AAA battery. The manufacturer also developed an explosion proof sensor detecting hydrogen concentration of 0.3 to 4%. This product can pick up low concentrations of hydrogen by using technology of micro electro mechanical system (MEMS), and can operate stably for a long time. The firm plans the product to be used for hydrogen refueling stations of which number is anticipated to rise due to FCV growth. Furthermore, they commercialized hydrogen sensors detecting a wide range of 1 to 100% concentration, and this can be used for measuring hydrogen piping. Over 1,300 pieces of FC evaluation equipment with the sensors are in use. Since hydrogen is expected to be used more as energy, the manufacturer aims to take safety needs by preparing three sensors for different concentration. (The Nikkan Kogyo Shimbun, December 1, 2016)

(2) Shikoku Research Institute

Shikoku Research Institute in Takamatsu City, a research and development subsidiary of Shikoku Electric Power Co., has developed a technology to visualize hydrogen flames which are difficult to see and hydrogen gas leak. This uses image processing technology and lasers to identify the location of flames or gas and the concentration, and will support safety operations of hydrogen refueling stations essential for FCVs. The firm will carry out experimental operation in some projects to aim for early commercialization of the product. They succeeded to display hydrogen flames on a monitor by merging thermal and visual images taken by ultraviolet and infrared cameras to capture light. The product allows a determination of the size of the flames in a way that you look at candle light. The firm commercialized stationary and portable types. The stationary product can be installed at hydrogen refueling stations. As well as spotting fire, this version can show the high temperature areas at risk. It can be connected to monitoring and control system to automatically detect and extinguish fires. The portable one is small and light 15 cm cube size, and is designed for patrolling inspections. Both versions can detect fire at a 30 cm distance. Hydrogen gas has no color or smell, and burns rarely in the visible range. This property makes visual checks extremely difficult. Fire detectors are installed in facilities dealing with hydrogen, but it cannot distinguish flame when hydrogen catches fire. (The Nikkei Business Daily, December 2, 2016)

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*Dr. Kazuo Onda, Prof. Emeritus Toyohashi University of Technology, Auditor of FCDIC, succeeds Dr. Takuya Homma, Prof. Emeritus of University of Tsukuba, Adivisor of FCDIC, as an arranger from the next issue.