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GSCN was established in 2000 to promote research and development for the Environment and Human Health and Safety, through the innovation of Chemistry .

Polymer Science and Technology for the Global Society

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In his hard-style prose poem "On the New Year's Day", Yasushi Inoue wrote in effect: "Why the New Year' Day? Perhaps human life is so long that God placed a step in every 365 days where people take rest for a moment". The Society of Polymer Science, Japan (SPSJ) will see the 60th anniversary in 2011. This *Kanreki* anniversary would also be an arbitrary combination of old 5- and 12-year-cycle calendars, but we would like to take this as an opportunity to ponder whither polymer science and technology should go.

Upon a request by the Japan Chemical Innovation Institute in 2009, an SPSJ subcommittee under Vice President Kazunori Kataoka, University of Tokyo, made a proposal of the future roles of polymer science and technology, entitled "Roles Expected for Polymers in Contribution to Establishing a Sustainable Society". The proposal sets four principal targets, environment and ecology, low environmental-load processes, energy, and security and health, to discuss with examples how polymer science and technology should contribute thereto and where SPSJ should be directed.

This New Year, the Science Council of Japan issued a report "Japan Perspective: 2010 Proposal from Science Community", in which the Subcommittee of Polymer Chemistry under Professor Yoshio Okamoto, Nagoya University, also made a proposal "Chemistry to Contribute to the Sustainable Human Society and the Earth". The urgent subjects therein call for the promotion of fundamental research in materials science and technology for global challenges in energy, environment, and aging and information-oriented societies.

Though not very surprising nowadays, these proposals attest that both academia and the society have in common recognized the importance of "science for humans and the society". The "for humans and the society" should include the creation of new knowledge and not necessarily implies industrial applications alone, but we do have an array of "already visible" future-generation polymeric materials, such as conducting membranes for energy, composites for environmental protection, and designed macromolecules for non-invasive medicine. SPSJ will in turn be required to promote the genesis of new paradigms in polymer science and technology, by deeply recognizing the unique essence of polymers as assembly and of macromolecules as single molecules.

After a momentary rest and pondering, may our next step be steady and energetic.

Approach for Sustainable Society in Sweden

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Each year, the attention of the world turns to the triumph of Northern Europe, the Kingdom of Sweden, as Nobel Prize season arrives. Although the nation's population is mere nine million and less than the city of Tokyo, it is famous for the automobile manufacturers Saab and Volvo, and for high-quality Swedish steel. It combines a spirit of innovation with being a welfare state. Here, we introduce its efforts to be a sustainable society, including the use of biogas.

In late September 2009, I visited Uppsala, the fourth largest city in Sweden, located about 40 minutes north of Stockholm by train. Although the city has just under 180,000 people, it is home to Uppsala University (established in 1477), the oldest university in Northern Europe. The city is also famous as the birthplace of Carl Linnaeus, the father of plant taxonomy, and Anders Jonas Ångström, who is honored today with a physical unit bearing his name. This time, I visited the Swedish University of Agricultural Sciences (or Sveriges Lantbruksuniversitet; SLU). But what really surprised me was something that is almost unseen in most of Japan, only being used by some local governments there, but used regularly by the average citizen in Upsala: biogas cars.

Photo-1 School bus that moves by biogas

Biogas cars are positioned as the next-generation environment-friendly automobiles, following ethanol cars. Flexible-fuel vehicles, which can run with a mixture of ethanol and gasoline, have already gained complete approval of the city residents. To avoid problems when starting engines during the winter season, a mix fuel of 15% gasoline and 85% ethanol (ET85) is mainly used in Sweden. In actuality however, as I learned from talking with SLU faculty members, the fuel is mixed in whatever ratio based on the prices at the time. “My car is running today on ET63,” one of them said cheerfully, howing just how comfortable the people are with handling ethanol.

As for biogas, one-third of public buses in Uppsala are biogas cars, and all school buses like the one shown in the photo use biogas. The average resident has also begun using biogas cars. What was surprising was finding a biogas station in the middle of town. It felt just like visiting a gas station, and I filled up a biogas car myself. Until quite recently, I was hesitant about going to a self-serve stand, but this was Sweden after all, the first country to operate a biogas train. It made me realize how extremely accessible biogas is as an energy source.

Photo-2 Biogas stand in whole town

As I was filling my biogas, I spoke to a woman who was also there. The filling took about five minutes and cost about 12 Swedish krona (about 120 yen) per 1Nm3, and the woman told me that a car can run for about 200 kilometers on full tank. As you know, the fuel of biogas gas is methane. It is mainly produced by fermentation of materials such as animal excretions, raw garbage, biodegradable substances, and agricultural wastes. After refining to a high degree of purity, it is used in biogas cars.

Outside the city, I could see many fermentation tanks, which use microorganisms to produce biogas from raw garbage. I could see that biogas was stably being produced in the immediate environment.

Finally, I'd like to discuss a slightly different topic. A stable heat supply is a most critical issue for the Swedes, who endure long winters. In Sweden, willow trees are actively cultivated. In Japan, willow trees are quite large, often line riverbanks, and with their drooping branches, make one think of ghosts. The willow trees of Sweden, on the other hand, are altogether different. They are extremely thin, stand straight, and grow about five meters in three years. By dividing plots into thirds and planting these trees in rotation, Swedish farmers can obtain a steady supply each year. I learned that one hectare yields about ten tons per year. When I saw sites that produce energy using sustainable inedible biomass in short-term rotations, I was once again provoked to consider what Japan can do.

Photo-3 Willow grown for biogas

In certain ways, Japan trails behind other countries when it comes to the production of biomass energy, including bioethanol. My trip to Sweden showed me that to develop a petroleum-independent, sustainable society, it is necessary to re-think a comprehensive strategy to use of biomass, not just limited to bioethanol and including the production of biopolymers.

Green Oxidation with Aqueous Hydrogen Peroxide

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More than 30 percent of all chemical processes in the world include oxidation process among them; therefore, oxidation processes play one of critical roles in our chemical industries today. Unfortunately those important processes are not environmentally friendly. For example, nitric acid, an oxidant generally used for mass-scale oxidation in industry, concomitantly produces notorious greenhouse gases, nitrous oxide and nitrogen oxide (NOx), as by-products. Heavy metals such as chromium used for high selective oxidation processes produce heavy metal waste more than equivalent amount of the target products. In this paper we describe our effective and selective oxidation technologies using hydrogen peroxide, an environmentally friendly oxidant, and their application to development of innovative high-insulation materials.

Hydrogen peroxide (H2O2) is a water-soluble liquid oxidant commonly used in our daily lives as low-concentration aqueous solution (disinfectant Oxydol, contact lens cleaner, etc.). It is also used as non-chlorine bleach powder and washing machine cleaners in the solid form safely combined with several inorganic substances. Hydrogen peroxide is a safe and clean oxidizing agent, producing only water as its by-product through oxidation process. Despite this great advantage, its activity as oxidant is not so strong that it requires some activating reagents to oxidize compounds of petroleum industry. We have discovered a lot of new catalytic systems that dramatically enhance the oxidation activity of hydrogen peroxide. These oxidation systems are elaborately developed for each transformation to obtain aiming products with high yield and high selectivity, and without producing any hazardous by-products. (See figure 1. Catalysts written in red.)

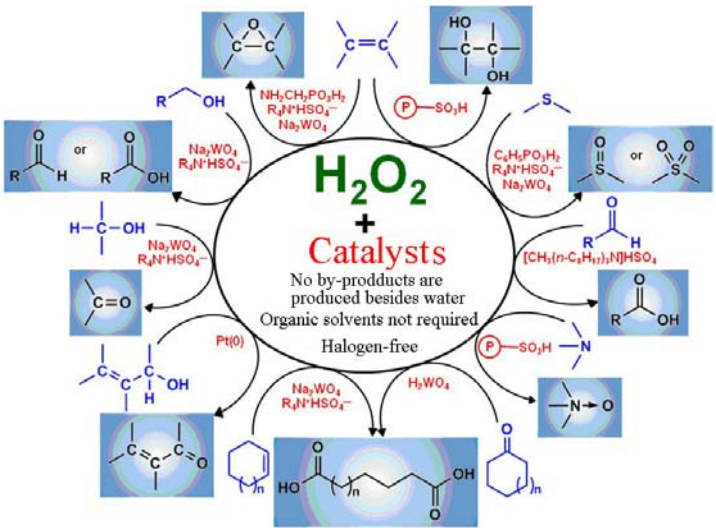

Figure 1 Selective oxidative reactions using hydrogen peroxide

In spite of our effort there have been a lot of difficulties we encountered chemically and non-chemically so far for applying some of our systems to the real industrial processes for commercial products. However, we have achieved some goals with our system. Here is an overview of NEDO project to introduce one of our successful examples in Joint R&D with Showa Denko K.K. where collaboration of our chlorine-free epoxidation technology and Showa Denko's hardening reagent technology has sublimed to development of an innovative insulating material that can be used for next-generation electronic products. Insulating material is used for all kinds of electronic components, from liquid-crystal displays (LCDs) to mobile phones. General insulating materials are made from epoxy resins and the resins are conventionally made from organochloride compounds. The latter process produces a large amount of chlorine compounds as waste. Additionally, even a negligible amount of the initial organochloride remained in the insulating material causes hydrogen chloride during its long term use, ending up with short-circuit. This has been a significant problem for the durability of conventional insulators. For providing lightweight, high performance electronic devices, it is now inevitable to develop technologies for creating more flexible print circuits and microscopic wiring technique. Hence, insulating material with high flexibility and durability are, at the same time, highly demanded for protecting these sensitive circuits safely. We have successfully developed a new catalytic system for epoxidation that meets high demands; 1) mono-epoxidation of compound across its one of two olefinic moieties, which has been designed for electronic material use, with high yield and selectivity, 2) being applicable to mass-production and 3) using aqueous hydrogen peroxide as oxidant. Our catalytic system was successfully carried out for the chlorine-free epoxidation on the 100 kg scale. Finally, combination of oligomers obtained from our epoxy monomers and well-tuned hardening agents from Showa Denko realized high-performance flexible resin (insulating material). This material showed extremely higher insulation capability (>×102) than conventional one and maintained the capability for very long-term use without any deterioration. Now, this material has been used as high flexible insulator for COF (see Figure 2). With this material we can make products such as LCDs slimmer, more lightweight and highly energy-saving.

Figure 2　Sample of COF (Chip-on-Film)

The success in the Joint Research has opened up an opportunity for us to start the new national project, “Development of Fundamental Technologies for Green and Sustainable Chemical Processes” directed by the Ministry of Economy Trade and Industry from 2008. This project was ranked as “S” (“Selected Priority Project”) by the Council for Science and Technology Policy (CSTP). Our green chemical technologies, which include hydrogen peroxide technology, were also selected as innovative technologies by CSTP. We have set up intensive R&D lab at AIST for developing next basic technologies toward innovative green oxidation process collaborating with four companies since September 2008. Some of our systems are also being employed as part of educational curriculums at universities and other institutions to learn what the green chemistry is (e.g. “Let’s Experience Green Chemistry!” at the National Museum of Emerging Science and Technology [Miraikan]).