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

## The role of GSCN

Kanji Shono, President of Society of Chemical Engineers, Japan

In 1972, the Club of Rome attracted global attention with a report called “The Limits to Growth” in which it pointed out the global issues of finite resource supplies, pollution and the population explosion. In the quarter of a century has passed since that time, it has come to be recognized that these are urgent issues that can only be solved by a concerted global effort. Many people are now asking how we can manage to implement the sustainable society in order to achieve this aim.

At the 34th G8 summit in Hokkaido back in July, Japan sent the world a strong message in the form of the Cool Earth 50 plan relating to issues that must be addressed by the year 2050. The goal of reducing $CO_2$ emissions to half their current levels while maintaining economic growth requires a dramatic increase in energy efficiency that will not be achieved if current technology trends continue, so revolutionary technological developments are called for.

On the other hand, the Ministry of Economy, Trade and Industry has played a central role in bringing together the technology roadmaps of business leaders and academics in 29 fields, and in ensuring that these roadmaps are kept up to date every year on a rolling basis There are strong demands for the technology in each of these fields to be studied in greater depth, and for closer cooperation between fields. Consequently, the ties established between chemistry-related organizations at the GSCN are becoming very important. Naturally, increasing the depth of knowledge relating to each technology will involve not just simple information exchanges and cooperative efforts, but also the development of active partnerships leading to revolutionary technological developments. This is exactly the sort of role that the GSCN should perform, and we are keen to fulfill our duty in this respect.

# Tackling global environmental issues

Masaaki Yamabe, Research Coordinator,
National Institute of Advanced Industrial Science and Technology

At the COP-14 conference, which was held in PoznaD, Poland in December 2008, many important issues relating to post-Kyoto Protocol negotiations were left unresolved. A lack of international leadership once again became apparent in the face of problems such as delicate differences in standpoints between scientific outputs, business speculations and government policies, and a conflict between developed and developing countries, Since 1989 I have been a member of the Technology and Economic Assessment Panel (TEAP) of the United Nations Environment Programme (UNEP), where I took part in international efforts to protect the ozone layer by phasing out chlorofluorocarbons (CFCs) and other ozone depleting substances (ODSs). Here, taking ODS phase out in the Montreal Protocol and global warming issues in the Kyoto Protocol as examples, I will consider how we might tackle global environmental issues in the future.

## Achievements of the Montreal protocol

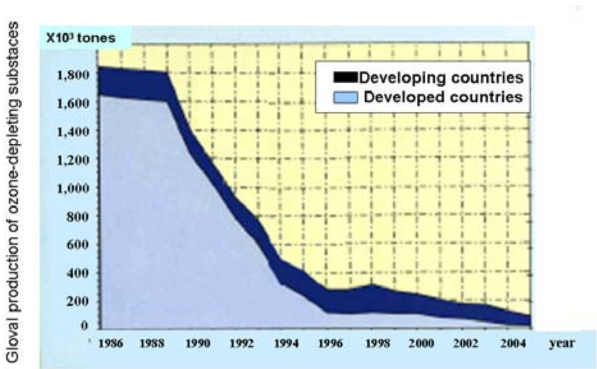


Fig1 : Reductions in the manufacture of CFCs and other ozone-depleting substances (souce:UNEP 2007 report)

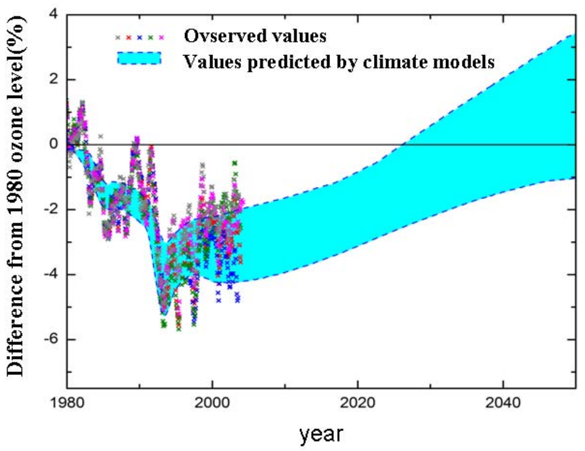


Fig2. Depletion of the ozone layer and recovery trends (source: IPCC/TEAP 2005 special report)

In 1974 professor Sherwood F Rowland and Dr. Mario Molina as a postdoctoral fellow at the University of California, Irvine, proposed a hypothesis of depletion of stratospheric ozone by CFCs based on experiments in the laboratory. This was subsequently confirmed by further scientific observations such as the discovery of an Antarctic ozone hole, resulting in the Montreal Protocol being adopted in 1987. The 20th anniversary of this protocol was celebrated in Montreal in September 2007. During these two decades, the Montreal Protocol has shown itself to be the most successful international environmental treaty ever to involve joint cooperation between scientists, engineers and governments, as demonstrated by the achievements that have been made in phasing out all the ODSs in developed countries (Fig. 1), and the steps that have been taken towards phasing out them even in developing countries by 2030 at the latest.

Although the science of the ozone layer still remains unclear in many aspects, it is expected that if everything goes according to plan, the ozone hole will have disappeared by about 2065 (Fig. 2).

**Regarding HFC as greenhouse gases**

We remember the 2007 Nobel Peace Prize which was jointly awarded to the IPCC (Intergovernmental Panel on Climate Change) and the ex-vice president Al Gore of the United States of America. The IPCC is an international organization established in 1988 with the aim of providing policy makers with the latest scientific knowledge relating to climate change. Its reports played key roles in the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the guidelines for the prevention of global warming in the adoption of the Kyoto Protocol in 1997.

The Kyoto Protocol set out to prevent global warming by emission reduction of six types of greenhouse gases including carbon dioxide. Although carbon dioxide was the main target of this protocol, it is closely related to the Montreal Protocol in that it also calls for reduction of other gases including CFC substitutes that are recommended by the Montreal Protocol for protecting the ozone layer. These other gases include hydrofluorocarbons (HFCs), which are still being used in automobile air conditioners and insulating foam materials (Fig. 3). To address this issue, the TEAP and IPCC collaborated to investigate future HFC issues, and in 2005 they jointly published a special report on HFCs. Based on the forecast emissions of HFCs up to the year 2015, this report stressed the importance of recovering, reusing and disposing of existing HFCs and developing technology for substituting them with HFC-free alternatives or new HFCs with very low global warming potential.

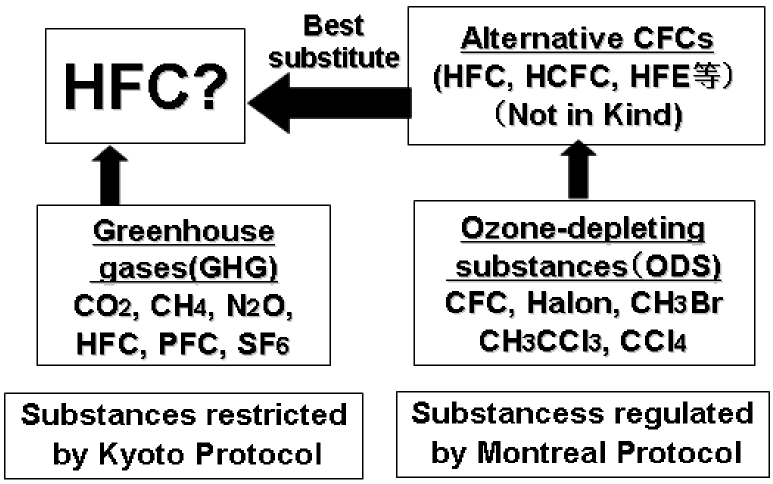


**Fig.3: Correlation between the substances to be coltrolled by both Protocol**

**Lessons of the Montreal Protocol that could apply to the Kyoto Protocol**

Arguments where the Kyoto Protocol is claimed to be difficult to implement resemble the path once taken by the Montreal Protocol. In addition to the strong international leadership provided by the likes of US ambassador and chief negotiator Richard Benedick, and the Egyptian scientist and former UNEP Executive Director Mustafa Tolba at the early stages of this unprecedented international environmental treaty, the factors behind the success of the Montreal protocol can be summarized by the following three points:

- **Flexible regulations:** The phase out schedule for ODSs was made fairly loose at first and was later tightened up gradually after the protocol had come into effect.
- **Establishment of an assessment panel with autonomous functions:** Proposals were made for the selection and introduction of substitute technology based on science and technology by technical committee members from different sectors centered on industry experts.

- **Support for compliance by developing countries, including a multinational funding system and grace period:** Developing countries were allowed a grace period of at least 10 years, and a new multilateral funding system was set up by developed nations to promote technology transfers.

These are clearly all issues that currently affect the Kyoto protocol, and I hope that these lessons will be taken into consideration to construct a more effective framework for the post-Kyoto era.

### Expectations to GSC

Global environmental issues like ozone depletion and global warming are not things that have a direct effect on our current daily lives, and are based on forecasts of crisis for the years 2020–2050 and beyond. The goal of GSC is to bring together the scientific and technical know-how so that we can pass on a sustainable society to our descendents. We hope that strategic international cooperation between industry, governments and academics will actively promote and develop this activity.

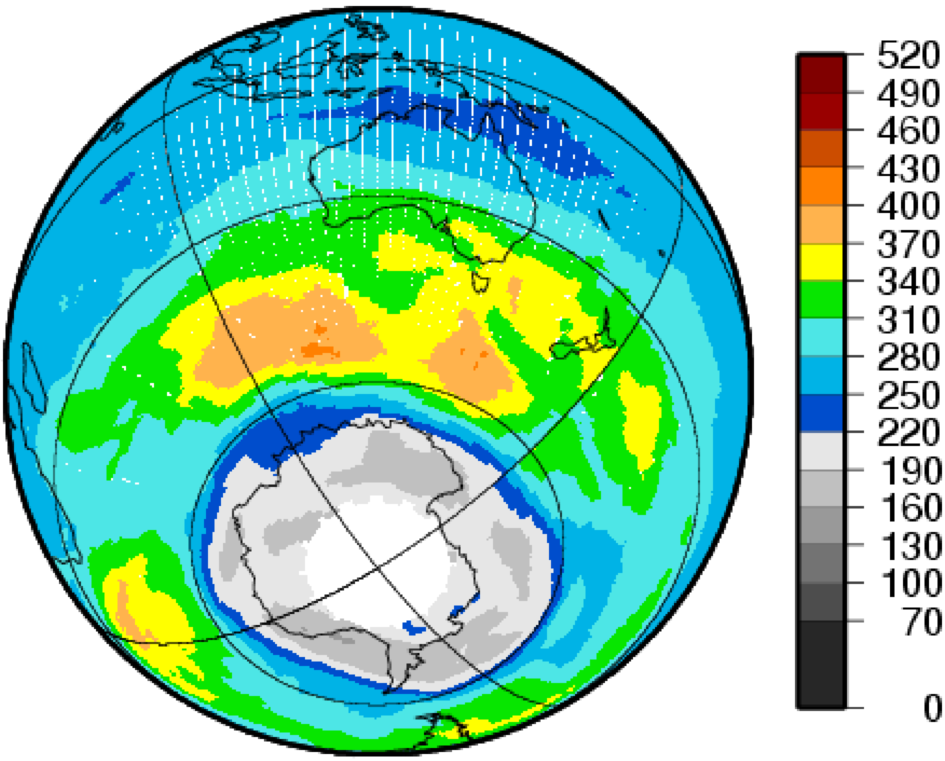


**Fig4: Size of the Antarctic ozone hole on 8th September 2008 (source: Meteorological Agency)**

# Development of Green and Sustainable Polymers Using Lipases

**Shuichi Matsumura**
Department of Applied Chemistry,
Faculty of Science and Technology, Keio University

The enzymatic synthesis of polymers has attracted much attention from the standpoint of green and sustainable chemistry. Polyesters, polythioesters and polycarbonates are directly prepared using lipases without recourse to special activating groups. Such polymers are enzymatically transformed into repolymerizable cyclic oligomers by the backbiting mechanism, thus allowing a sustainable production and chemical recycling system to be established using lipase catalysts.

The necessary requirements for green and sustainable polymers are: good mechanical properties, use of renewable raw materials such as biomass, environmentally benign polymerization processes, chemical recyclability and biodegradability. There are many advantages of using lipases for polymer synthesis with respect to green and sustainable chemistry: enzymes are renewable bio-based catalysts; enzymatically synthesized polymers contain no catalyst-derived metals; and metal-free polymers are attractive as environmentally and physiologically benign materials.

Lipases are catalysts that hydrolyze triglycerides in the presence of water to produce glycerol and fatty acids. The reaction is reversible, and under anhydrous conditions, the reaction equilibrium shifts towards ester formation. This characteristic feature is applicable to the production of sustainable polymers and chemical recycling. That is, under anhydrous and concentrated conditions, polymerization is favored. Additionally, in a more dilute organic solvent the equilibrium shifts towards degradation to produce repolymerizable cyclic oligomers, thus establishing a sustainable polymer production and recycling system. In addition to producing polyesters, the use of a lipase permits synthesis of polycarbonates by a phosgene-free process, poly(ester-urethane)s by a diisocyanate-free process and polythioesters by a halogen-free process. The aliphatic polymers thus produced are expected to be biodegradable.

Lipases are biomaterials, thus exhibiting a high affinity for natural substrates, and effective in the production of bio-based polymers from biomass-refinery products. Figure 1 shows the general concept for the production of green polyesters using biomass-refinery products, such as organic acids and diols. Poly(butylene succinate) (PBS) is prepared from succinic acid and butanediol produced by fermentation, and possesses certain advantages as a soft biodegradable plastic. High-molecular weight PBS (molecular weight > 200,000 g/mol) was prepared by the lipase-catalyzed polymerization of cyclic oligomers (Figure 2). Polyricinoleate with a molecular weight greater than 100,000 g/mol was produced by the lipase-catalyzed polymerization of methyl ricinoleate derived from the methanolysis of castor oil. Using a conventional cross-linking procedure, an elastomer was produced having both ready biodegradability and good mechanical properties (comparable to those of natural rubber). In addition, a copolymer of 12-hydroxystearic acid and ricinoleic acid was prepared by a lipase-catalyzed polymerization. This copolymer was a physically cross-linkable (non-cross-linking type) thermoplastic elastomer, and was both chemically recyclable and biodegradable.

Enzymes show selectivities towards functional groups such as hydroxyl and thiol groups. Thus, a polyester with free pendant thiols was produced by the direct enzymatic polymerization of an unprotected thiol-containing hydroxy acid monomer. This polyester was readily cross-linked by air oxidation to form a gel, which was de-cross-linked by the reduction of the disulfide linkage to regenerate the linear polyester (Figure 3). Such a polymer is expected to find uses as a biodegradable gel that also qualifies as a green plastic.

The history of enzyme-catalyzed polymerization is relatively recent and at present, there is no large-scale production of a polymer using an enzyme. However, lipases can act as a powerful catalyst for both green polymer production (polymerization) and chemical recycling (depolymerization). These results suggest that a sustainable polymer production system can be developed using biocatalysts, thus establishing a biochemical industry that can partially replace the conventional petrochemical industry.

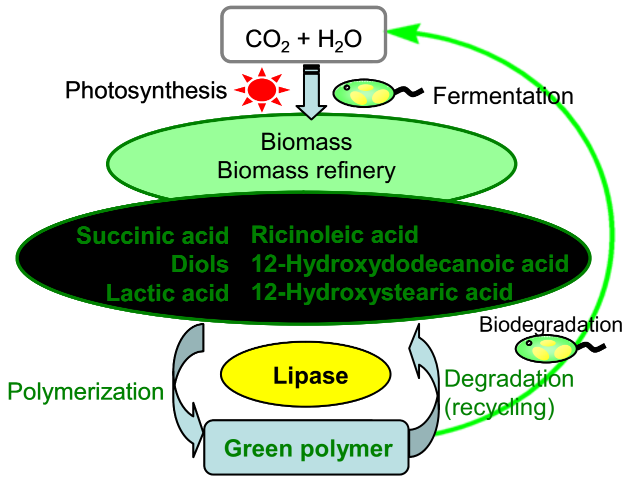


**Fig 1 : General concept for the production of green polyester**

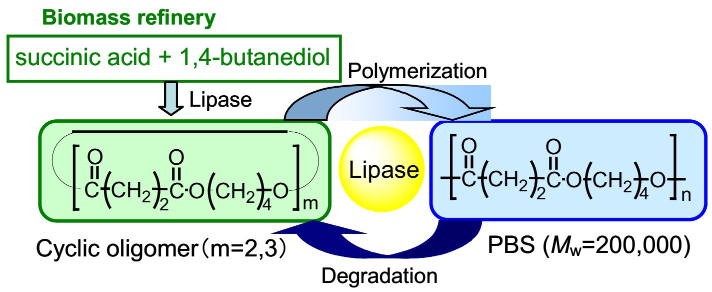


**Fig 2 : Sustainable synthesis and chemical recycling of PBS**

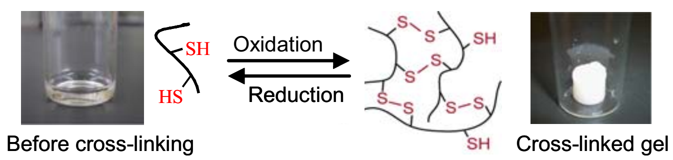


**Fig 3 : Reversibly cross-linkable polyester**

## Guide to the 9th GSC Symposium

**When:** Monday 9th and Tuesday 10th March 2009

**Where:** Hitotsubashi Memorial Auditorium, National Center of Science, Tokyo

**Organizer:** Green Sustainable Chemistry Network

**Sponsors:** Ministry of Economy, Trade and Industry
Ministry of Education, Culture, Sports, Science and Technology
Ministry of the Environment
Science Council of Japan
New Energy and Industrial Technology Development Organization
Japan Science and Technology Agency
(among others)

**Main program:**

March 9th (Monday)

• Lectures

| | |
|---|---|
| GSC in academia (provisional title) | Chisato Kajiyama<br>Former president, Kyushu University |
| An R&D strategy based on the viewpoint of attacking a low-oxygen society | Satomi Takahashi<br>Vice chairman, The Chemical Society of Japan |
| Polymerization reactions that use carbon dioxide as a co-monomer | Professor Kyoko Nozaki<br>Tokyo University Graduate School |
| Chemistry for society — the development and prospects of green oxidation techniques | Kazuhiko Sato<br>Senior researcher, National Institute of Advanced Science and Technology |
| Catalysts for making hydrogen from water and sunlight — solar hydrogen production | Professor Akihiko Kudo<br>Tokyo University of Science |
| Nano-biomaterials for environmental sensing | Mizuo Maeda<br>Senior researcher, RIKEN |

• Poster session

• Poster award ceremony

• 8th GSC award ceremony and reception (venue: Josuikan Star Hall)

March 10th (Tuesday)

• Lectures

| | |
|---|---|
| Policy issues pertaining to the 34th G8 summit (tentative title) | Atsushi Fukuda<br>Ministry of Economy, Trade and Industry |
| Future trends in the management of chemical substances | Hirotsugu Kimura<br>Ministry of the Environment |
| Supercritical water as a reaction site for the synthesis of green materials | Professor Tadafumi Adschiri<br>Tohoku University Graduate School |
| Efforts to implement a circulatory society at Teijin Limited | Hideshi Kurihara<br>Teijin Limited |
| Introduction to GSCN4-AON2 | Professor Buxing Han<br>Institute of Chemistry Chinese Academy of Sciences |
| The future of the GSC network | Koji Oe<br>GSC Network Chairman |

• 8th GSC award lecture

**Registration:** To register for a place at this event, please apply via the GSC Network website in the same way as for poster presentation applications.

**Registration charges:**

| Until 31st January 2009 (Saturday)* | From 1st February (Sunday) |
|---|---|
| Regular: ¥15,000 | ¥18,000 |
| Student: ¥7,000 | ¥9,000 |

(*Please ensure that your registration fee is transferred on or before this date.)

**Contact:** GSC Network Office
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