JACI Textbook | Learning from social practice cases that have received the GSC Awards

Green and
Sustainable
Chemistry

Introduction to GSC

No.4 Revised Edition

Received the Minister of Economy, Trade and Industry Award of the 14th GSC Awards (2014)

Development and Commercialization of High Performance Transparent Plastics Derived From Plant-Based Raw Material

Mitsubishi Chemical Corporation

Mitsubishi Chemical Corporation succeeded in the development and commercialization of transparent engineering plastics whose main raw material is isosorbide derived from renewable resources. Not only was the environmental impact reduced by using a unique process utilizing renewable resources, but the performance of the product, such as excellent impact resistance and weathering resistance, was radically improved as well.

Outline of the GSC Awards and the award-winning company

The GSC Awards are bestowed upon individuals and organizations for their contribution toward the advancement of Green and Sustainable Chemistry (GSC), and several awards are conferred each year. Innovations that contribute toward the development of sustainable industrial technology are awarded the Minister of Economy, Trade and Industry Award; those that contribute toward the development and promotion of science are awarded the Minister of Education, Culture, Sports, Science and Technology Award; those that contribute toward the overall reduction of environmental impact are awarded the Minister of the Environment Award; while small and medium-sized businesses that contribute toward the development of industrial technology are awarded the Small Business Award (established in 2015; renamed to Venture Company Award, Small and Medium-sized Company Award in 2018 and Venture, Small and Medium sized Company Award in 2022). Additionally, innovations that exhibit high potential for future development are awarded the Incentive Award.

Mitsubishi Chemical Corporation has developed petrochemicals, etc. as a comprehensive chemicals manufacturer. In 2017, the company merged with Mitsubishi Plastics and Mitsubishi Rayon to form Mitsubishi Chemical Corporation (Head office: Chiyoda-ku, Tokyo).

Objective of the textbook series

Global issues, in areas such as resources and energy, global warming, water and food have increasingly become major and complicated concerns. Innovations for achieving both environmental conservation and economic development are needed in order to resolve these issues and realize the sustainable development of society, and expectations for GSC continue to rise. In this textbook series, technologies and products that have received the GSC Awards given to great achievements contributing to the progress of GSC are explained, so that everyone can understand “what is GSC?” and take responsibility for realizing a sustainable society.

*Please refer to The Statement 2015 at the end of the textbook.

What is GSC?

Acronym for Green and Sustainable Chemistry

Definition of GSC

Chemical sciences and technologies which are benign to both human health and the environment, and support the development of a sustainable society

Guidelines of GSC activities

- The chemistry community has been addressing future-oriented research and education, and development towards environmentally-benign systems, processes and products for the sustainable development of society.

- Specifically, in response to the Rio Declaration at the Earth Summit in 1992, the chemistry community has been working in a unified manner linking academia, industry and government to start up Green and Sustainable Chemistry and engage in its activities, in order to advance the pursuance of coexistence with the global environment, the satisfaction of society’s needs, and economic rationality. These goals should be pursued with consideration for the environment, safety and health across the life cycles of chemical products, their design, selection of raw materials, processing, use, recycling and final disposal.

- Long-term global issues, in areas such as resources and energy, global warming, water and food, and demographics have increasingly become major and complicated concerns in the present century. Therefore, expectations are growing for innovations, based on the chemical sciences, as driving forces to solve such issues and to achieve the sustainable development of society with enhanced quality of life and well-being.

- The chemistry community will live up to these expectations by strongly advancing Green and Sustainable Chemistry through global partnership and collaboration and by bridging the boundaries that separate industries, academia, governments, consumers and nations.

Examples of GSC

- The general classification is expressed in terms of a combination of the intended social contribution and the means to achieve this goal. With regard to the objectives, the efforts to achieve them have extended in stages from social challenges to difficult long-term challenges, beginning with manufacturing or utilization, and common/basic categories have also been established -

Minimization of resource consumption and maximization of the efficiency of reaction processes for production with reduced environmental impact

1. Chemical technologies and products that lead to reduction in by-product formation and avoid the use of hazardous substances
2. Separation, purification and recycling technologies that reduce the generation and emission of greenhouse gases like CO_2 or toxic/hazardous substances, thus lowering environmental impact
3. Chemical technologies and products that reduce the generation and emission to the environment of greenhouse gases like CO_2 or toxic/hazardous substances
4. Catalysts and reaction processes that realize the saving of energy and resource and improvement in product yields

Risk reduction of chemical substances beneficial to safe and secure living environment

5. Chemical technologies, products and systems that reduce waste generation
6. Chemical technologies, products and systems that inhibit the generation and emission of hazardous substances and pollutants

Challenges to solve energy, resource, food and water issues

7. Chemical technologies, products and systems to utilize low-grade heat sources, non-conventional resources, and other similar alternatives
8. Chemical technologies, products and systems whereby un-utilized energy and resources can be converted into available energy, transported and stored
9. Chemical technologies, products and systems which decrease the dependence on exhaustible resources such as fossil fuels and scarce minerals and promote the shift to renewable energy and resources, including their storage
10. Chemical technologies, products and systems that contribute to the Three R's: Reduce, Reuse and Recycle
11. Chemical technologies, products and systems that promote the efficiency of production and supply of food, and utilization of water resources

Pioneering challenges to long-term issues aiming to realize a safe, secure and sustainable society with enhanced quality of life

12. Chemical technologies, new products and new operational systems that contribute to the introduction of new social systems, for instance based on ICT, and aimed at solving social issues such as energy and resource consumption, food and water security, disaster prevention and infrastructure improvements, transportation and logistics, medical and health care, education and welfare, and other mega-trends of society
13. Chemical technologies, new products and new operational systems that contribute to the improvement of social and individual comfort whilst reducing and preferably inhibiting environmental impact

Systematization, dissemination, enlightenment and education of GSC including its metrics to be established

14. Systematization of GSC practices and concepts
15. Dissemination, enlightenment and education of GSC practices and concepts
16. Establishment and dissemination of GSC metrics

(Definition from JACI GSCN Council https://www.jaci.or.jp/english/gscn/page_01.html)

"Isosorbide," a plant-based raw material, was the key in developing high performance engineering plastics

Mitsubishi Chemical Corporation

The Minister of Economy, Trade and Industry Award of the 14th GSC Awards (2014) was given to the "Development and Commercialization of a High Performance Transparent Plastic Utilizing a Plant-Derived Raw Material" by Mitsubishi Chemical Corporation.
"DURABIO™," the transparent engineering plastic synthesized from renewable resources by Mitsubishi Chemical Corporation, exhibits not only a low environmental impact but better performance (including optical characteristics and weathering resistance) than conventional engineering plastics.

Picture 1: DURABIO™ (left) and a car body fabricated using DURABIO™ (Right: image provided by Mazda Corporation)

1 The Path to Technology Development

~ What were the intentions that started development toward realizing the sustainable progress of society?

*1
Degree of change in dimensions owing to expansion and contraction that occur when there is a change in the temperature, humidity, etc.
*2
When light enters into a different medium (e.g.: from air to water), the direction of light travel bends at the interface. This is called "refraction of light."
In calcite, etc. the light refracted at the interface splits into two. Such a phenomenon is called "birefringence."
A specimen that shows birefringence exhibits "optical anisotropy," whereas a specimen that does not show birefringence (such as glass) exhibits "optical isotropy."

Plastics are widely used to manufacture daily necessities, electrical parts, and packaging materials, and have become indispensable to modern society. At present, almost all plastics are derived from petroleum-based raw materials, which are associated with several environmental issues (such as the exhaustion of resources and a high environmental impact during disposal). Consequently, it is crucial to promote the practical application of plastics with a low environmental impact, such as those synthesized using raw materials from renewable organic resources and biodegradable plastics (Column ①).

Mitsubishi Chemical Corporation aims to make a conversion to "zero fossil resources" by developing plastics from bio-based raw materials. On the other hand, the company offers an impressive lineup of products and engineering plastics with excellent mechanical strength and heat resistance, and has developed a wide range of products that meet the needs of the market and consumers (Column ②). Among these products, polycarbonate, which is used to fabricate DVDs and CDs, exhibits a high impact resistance (250 times greater than that of glass) along with excellent transparency, heat resistance, and dimensional stability*1. However, polycarbonate has disadvantages such as optical anisotropy*2 and a surface prone to scratching. To eliminate these disadvantages and "create a novel material for replacing glass," the polymer structure of polycarbonate was re-examined.

Polycarbonate refers to a polymer having a carbonate group, and the polycarbonate which is commonly used today is an aromatic polycarbonate made from polymerization of bisphenol A (Fig. 2).

Plastics containing aromatic rings are

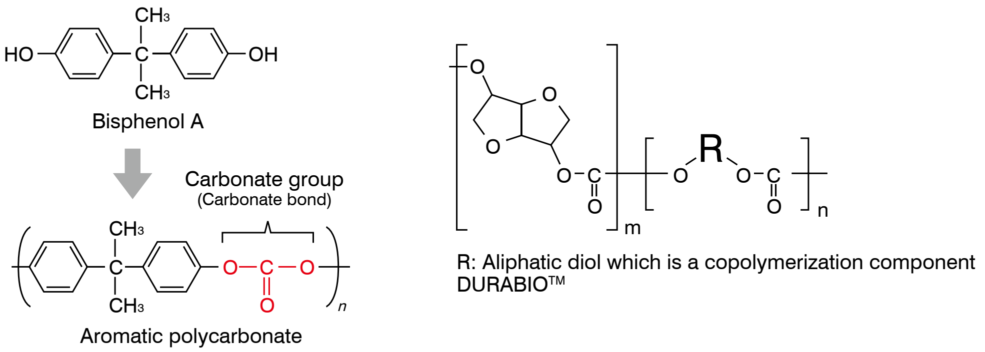


Figure 2: Structures of polycarbonates and DURABIO™

characterized by large birefringence. Therefore, aliphatic compounds*3 which do not contain aromatic rings can be used to improve the optical characteristics of a material.

Aliphatic polycarbonates synthesized from aliphatic monomers exhibit a low melting point and softening point, and cannot be used as practical molding materials. The excellent properties of aromatic polycarbonates are attributed to the bisphenol A monomer. Is it possible to create a new material with excellent physical properties without using bisphenol A? To resolve this issue, the development team in Mitsubishi Chemical Corporation began investigating suitable monomers (alternatives to bisphenol A) for the process.

*3
Carbon atoms that constitute an aliphatic compound are linked in chains, while aromatic compounds contain benzene rings.

Column 1

Bioplastics

Bioplastics is a general term for biomass plastics and biodegradable plastics. Biomass plastics are synthesized using renewable organic resources derived from organisms (biomass) instead of materials derived from petroleum (which is a fossil fuel). The properties of biodegradable plastics are similar to those of ordinary plastics. After use, these plastics are decomposed into water and carbon dioxide by microorganisms. Biomass plastics include nonbiodegradable plastics.

The starch in corn, polyamino acids produced by microorganisms, cellulose and lignin in thinned timber, fats and oils produced by plants, and chitin and chitosan in the external skeleton of Crustacea such as shrimp and crab are used as raw materials for bioplastics.

Column 2

Engineering plastics

Plastics can be classified into thermoplastic and thermosetting plastics (see Introduction to GSC No. 2). Among the thermoplastic types, plastics with improved heat resistance and mechanical strength are called engineering plastics. Although the definition of engineering plastics is not clear, in general, they have a heat resistance temperature of 100°C or more, tenacity of 50 MPa or more and a bending modulus of elasticity of 2.5 GPa or more.

The molecular chain (main chain) of general-purpose plastics such as polyvinyl chloride, polyethylene, and polystyrene comprises only carbon. Contrarily, engineering plastics contain other elements (such as oxygen and nitrogen) along with carbon and benzene rings. In a carbon-only structure, the molecules rotate easily, resulting in low heat resistance. The introduction of different types of elements makes molecules inert, improving the heat resistance of the structure. Engineering plastics include polyamide (PA), polyacetal (POM), polycarbonate (PC), modified polyphenylene ether (m-PPE), polybutylene terephthalate (PBT), etc.

2 Toward Resolution of Issues

~ What types of technological challenges did the developers face and how did they resolve them?

Searching for an excellent monomer to replace bisphenol A

Polycarbonate synthesis can occur via an "interfacial method" that involves interfacial polycondensation and a "melting method" that involves transesterification*4 (refer to Introduction to GSC No. 2). The interfacial method, which utilizes bisphenol A and phosgene, is commonly used. However, general aliphatic compounds cannot be

*4
Reaction for producing another ester by reacting alcohol and ester. An acid or a base is used as a catalyst.

polymerized by the interfacial method because of their properties; thus, the melting method is used for this process. In the melting method, the transesterification of alcohol (in this case, aliphatic diol) with diphenyl carbonate (an ester) is used to synthesize polycarbonates (see "In More Detail"). This method not utilizing a large amount of solvent and exhibits a lower environmental impact than the interfacial method.

However, the reactivity and properties of polymers synthesized from aliphatic diols vary with the structure of the monomer used. Straight-chain aliphatic polycarbonate using straight-chain aliphatic diol has a structure in which the molecules move easily, causing the heat resistance to be insufficient. On the other hand, if annular aliphatic diol is used as the raw material, the reactivity drastically decreases and the polymerization reaction will not proceed.

A tradeoff relationship exists between polymerization and heat resistance. After investigating several aliphatic diols for high heat resistance and good reactivity, "isosorbide" was identified as optimal for polycarbonate synthesis (Fig. 3).

Isosorbide, derived from starches and sugars from plants such as corn and wheat, is commonly used a raw material for pharmaceuticals such as diuretic drugs. Isosorbide exhibits a secondary heterocyclic diol structure that contains carbon atoms and an oxygen atom. As isosorbide is not a straight-chain aliphatic diol, polymers derived from isosorbide exhibit acceptable heat resistance and stiffness. Moreover, the oxygen atom in the ring structure imparts high reactivity to polycarbonates derived from isosorbide (see "In More Detail").

Thus, the development of high-performance engineering plastics using renewable resources began by integrating two research projects on "making plastics from bio-based raw materials" and "making strong, novel engineering plastics with high transparency like glass that are resistant to breaking."

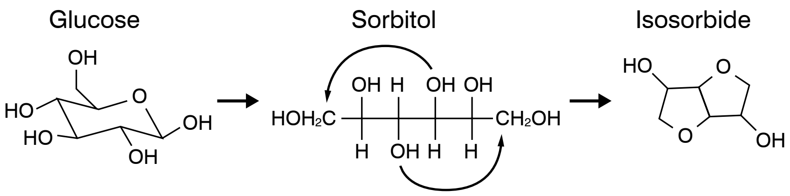


Figure 3: Production of isosorbide from glucose
The reduction of glucose (from starch) generates sorbitol, which is used to synthesize isosorbide.

Brittleness, brown color -- issues raised one after another

Although it was finally found that isosorbide is a monomer which has both heat resistance and reactivity, there was a large number of issues before the completion of the resin. First, when a polycarbonate with a structure having only isosorbide as the diol was synthesized, the resulting polymer had low flexibility and was brittle. The result was far inferior to the physical properties of aromatic polycarbonates. The molecular design had to be redone again.

Subsequently, the copolymerization of isosorbide with other aliphatic diols was proposed. The physical properties of the polymer were calculated by a computer, and investigations were made to improve brittleness while maintaining heat resistance. As a result, it was found that the glass transition temperature*5 could be adjusted by changing the type of copolymerization components and the ratio of copolymerization with isosorbide.

During product development, experiments are first developed in the laboratory and then repeated in progressively larger facilities. Even if an experiment is successful on a small scale, unexpected side reactions may occur when the scale of an experiment is increased. In this case, it became clear that the synthesized polymer developed a brown color and produced impurities. Moreover, the melting method requires reactions that last for a long period of time at high temperature, but the yield must be increased by efficient reactions for commercial production.

Therefore, a simulation of the polymerization reaction was utilized, and the catalyst was improved by using alkaline earth metals such as calcium and magnesium. After meticulously re-examining the polymerization process, several improvements (such as stabilizer optimization) were carried out. In the production process, the raw material isosorbide is melted and mixed with the copolymerization component aliphatic diol, and diphenyl carbonate. Phenol, which is produced as a by-product, is subjected to pressure reduction and removed from the system in the presence of a catalyst, enabling the polymerization reaction to proceed.
It was found that if the polymerization is carried out at a high temperature in high vacuum from the start, the raw material became distilled out of the system before the reaction took place, and the polymerization ceased to proceed midway.

Thus, in the early stages of polymerization, the reaction proceeded at a comparatively low temperature in low vacuum. Toward the

*5
The temperature at which glass transition occurs is called a glass transition point or a glass transition temperature, which is expressed as Tg.
At temperatures higher than Tg, the resin transforms into a rubbery state (liquid); at temperatures lower than Tg, the resin transforms into a glassy state (solid).
For non-crystalline resins such as polycarbonates, the glass transition temperature indicates the practical heat resistance of the material.

end of the reaction, the phenol concentration in the system was reduced at a comparatively high temperature in high vacuum, and macromolecule quantification occurred on shifting the equilibrium toward the polymerization side. In an industrial aspect, production is carried out by using several reactors with different reaction conditions in the early and final stages of the polymerization.

In the thus completed process, the reaction time was shortened and the reaction could be proceeded at a low temperature. The coloring of the resin is caused by the low thermal stability of isosorbide, and the resin becomes further prone to coloring at a high temperature. When it became possible to make the polymerization proceed in a short time even at a low temperature, a colorless resin could be obtained, and reduction of energy also became possible (Fig. 4).

Using a plant-based raw material will amount to nothing if the process causes a large environmental impact. By reusing purified by-product phenol as a raw material for diphenyl carbonate, it is possible to produce it in a completely closed cycle without emitting emissions (Fig. 5). Minute amounts of impurities are used as heat sources for the boiler.

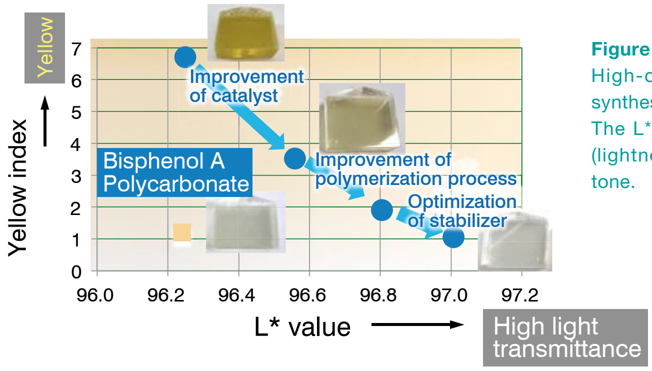


Figure 4: Process improvements
High-quality resins with high transparency were synthesized by tuning the polymerization conditions. The L* value indicates the brightness of the color (lightness); a larger value indicates a higher color tone.

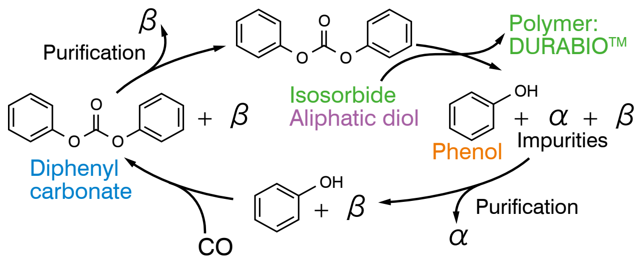


Figure 5: A completely closed cycle
After melting and mixing diphenyl carbonate, isosorbide, and an aliphatic diol, phenol (generated as a by-product) was removed from the system by pressure reduction; this facilitated the polymerization reaction.

3 Contribution to Society

~ What is the contribution of this novel technology to society?

The developed resin was named DURABIO™ and put on the market. DURABIO™ uses isosorbide as the main starting material and contains carbons derived from CO_2 in the atmosphere within its framework. Therefore, the CO_2 produced by burning the resin does not increase the amount of CO_2 in the atmosphere, and the exhaustible resources emitted during the disposal process generate low CO_2 emissions (Fig. 6).

Furthermore, the development of a hyperactive catalyst and improvement in the production process, which enabled polymerization at a low temperature and in a short time, led to the reduction in primary energy usage, i.e., fossil resources usage. Furthermore, not using solvents such as methylene chloride and realizing a completely closed cycle have resulted in drastic reduction in environmental impact.

Unlike conventional polycarbonates, DURABIO™ exhibits high transparency, weathering resistance, and resistance to scratching (Fig. 7). And despite being a plant-based polymer, it is not biodegradable but is rather highly durable. It has excellent optical properties and is comparable to acrylic resins which are transparent, highly durable and used as a substitute for glass. It exhibits ductility*[6] which is not a property of acrylic resins, and thus its application is expected to expand to optical films, etc., in addition to applications utilizing the initially-sought high transparency. Furthermore, owing to negligible yellowing due to UV light, it can be used for outdoor-type sheets and surface films that require resistance to weathering.

Although DURABIO™ (with the advantageous properties of both polycarbonates and acrylic resins) showed several potential applications, its optical-property-based applications expanded slowly, possibly owing to its high cost. However, an unexpected application in automobile parts was discovered while advancing development to answer to customers' requests. Since DURABIO™ is a highly transparent resin, it exhibits good color development, and was thus appraised for being able to express "smoothness like a mirror surface and deep hues" that surpassed the conventional coated parts, simply by adding pigments. Moreover, its hard surface and resistance to abrasion make the painting process unnecessary, reducing the volatile organic compounds (VOCs) generated from paints, and it is a thermoplastic resin that can be melted and reused, even if the molding fails.

DURABIO™ also showed a germ-repelling ("Germrepelling") property; it repelled microorganisms that adhere to the material surface and enabled their facile removal by washing with water. Although the clarification of the detailed mechanism is still in the works, its application is expected to expand to medical equipment, etc.

The development of high performance resins using renewable resources probably would not have been realized without the design and production technologies for resin established by the company over the years, in addition to the efforts of the persons in charge. Moreover, the marketing power of the company enabled an expansion of the applications of DURABIOTM. However, issues still remain. The raw materials for isosorbide are edible materials such as corn, but must be switched to inedible raw materials in the future. Furthermore, continuing efforts are made for a production process with further reduced environmental impact.

Item		Unit	DURABIO™
Greenhouse gas emissions*	CO_2	kg	4,500
	Total	kg	4,770
General environmental impact	BOD	kg	0.01
	SOx	kg	0.63
	NOx	kg	3.53
Energy consumption	Crude oil	GJ	95,800

*Excluding CO_2 absorbed by raw material plants

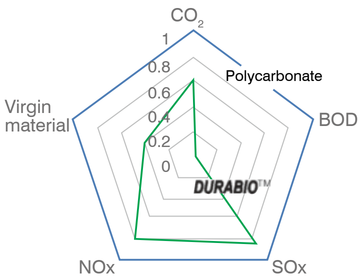


Figure 6: The low environmental impact of DURABIO™
Left: Environmental impact index calculated according to the Green Value Chain Platform of the Ministry of the Environment (serves as an indicator of LCA: life cycle assessment)
Right: Comparison of environmental impactindexes with existing polycarbonates
Green Value Chain Platform of the Ministry of the Environment
https://www.env.go.jp/earth/ondanka/supply_chain/gvc/en/

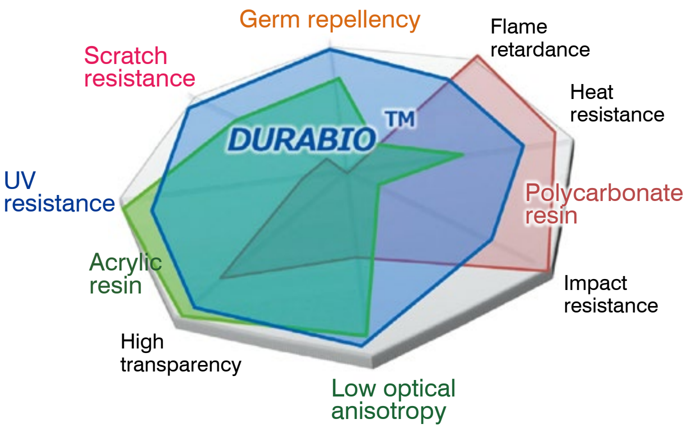


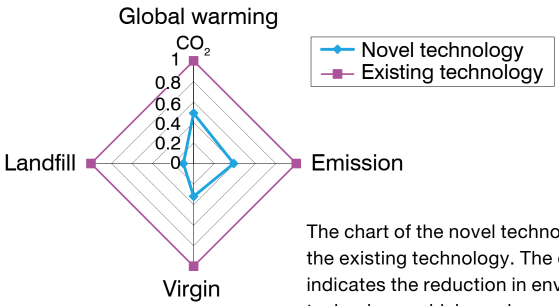
Figure 7: Characteristics of DURABIO™
A high-performance resin was derived from a plant-based raw material with novel functions (such as excellent optical characteristics and germ repellency). This new resin exhibits the heat resistance and impact resistance of polycarbonates and the high transparency and UV resistance of acrylic resins.

Column 3

GSC Assessment

To promote GSC, a technology must be assessed according to GSC standards in parallel with its research and development. In the selection of the GSC Awards, the "4-axes method" using a simplified radar chart is used as the LCA (life cycle assessment) method.

The 4-axes method assesses technology using four variables: (a) energy (or CO_2), (b) virgin resources (virgin), (c) landfill amount (landfill), and (d) general environment (emission). For all variables, the degree of improvement is expressed as a relative value based on the standard product (existing technology); the variables of the standard product are all assigned a value of 1. The final results are shown as a radar chart. Please refer to the following website for details (in Japanese): http://www.jaci.or.jp/gscn/page_01_03.html



The chart of the novel technology is smaller than that of the existing technology. The difference between the two indicates the reduction in environmental impact by the new technology, which can be seen at a glance.

In more details

Polymerization of isosorbide

❶ Interfacial method

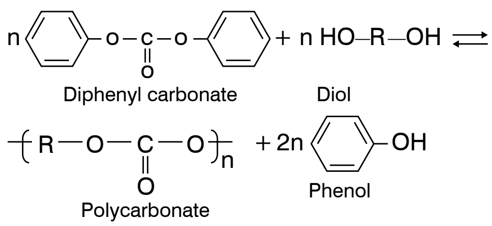
In the interfacial method, an alkaline metal salt (usually a sodium salt) of bisphenol A and phosgene undergo polymerization in a two-phase system comprising an alkaline aqueous solution of bisphenol A and methylene chloride. It is difficult to polymerize isosorbides using the interfacial method because they do not form alkaline metal salts under these conditions.

❷ Melting method

Polymerization of aromatic diols such as bisphenol A and primary aliphatic diols can be proceeded by transesterification with diphenyl carbonate and removing the phenol produced as a by-product under high vacuum out of the system. However, general secondary aliphatic diols and secondary alicyclic diols have low acidity and steric hindrance, and thus transesterification with diphenyl carbonate is difficult, preventing the polymerization from proceeding. However, the heterocyclic structure of isosorbide containing an ether bond activates the hydroxyl group and exhibits high acidity in spite of being a secondary diol. Thus transesterification with diphenyl carbonate can be carried out to proceed polymerization.

❸ Catalyst for the melting method

For aromatic diols such as bisphenol A, a catalyst with high basicity (such as a metal salt of sodium or cesium of Group 1 and onium) is used because bisphenol A has a phenolic OH group with high acidity. A catalyst with high basicity produces phenolate anions that attack the carbonyl carbon of diphenyl carbonate, initiating polymerization. In contrast, for isosorbides with low acidity, the metal salts of Group 2 that exhibit a comparatively low basicity, such as calcium and magnesium, facilitate polymerization. It is speculated that these catalysts accelerate the polarization of the carbonyl group of diphenyl carbonate, and the oxygen of isosorbide makes a nucleophilic attack on the $\delta+$ carbonyl carbon to make the polymerization proceed.



Polycarbonate production by the melting method

Questions

For deeper understanding

Through this case study, discuss the following questions from the viewpoint of GSC (Green and Sustainable Chemistry).

Q1 Discuss which of the GSC cases best applies to the technologies and products of this teaching material, along with the reasons.

Q2 Implementation in society is vital for any technology to meet the goals of GSC. This involves the simultaneous fulfillment of coexistence with the global environment, the satisfaction of society's needs, and economic rationality.
In the examples of technologies and products in this teaching material, summarize what measures have been taken to meet not only environmental and social satisfaction but also economic rationality.

Q3 Summarize the reasons why isosorbide is a suitable monomer for manufacturing transparent engineering plastics derived from plant-based raw materials.

Q4 State some issues that may arise on using edible-biomass raw materials.

Q5 Isosorbides are synthesized from glucose. Which technology is required to manufacture glucose from inedible raw biomass?

Q6 Discuss what kind of plastics uses biomass as a raw material.

Q7 The production process for polycarbonates is also described in Introduction to GSC No. 2. Please compare it with the technology discussed here in terms of the LCA and GSC assessment methods (see Column ❸).

Introduction of literature

Helpful materials

1) F. Fenouillota et al., Prog. Polym. Sci., 35, p.578 (2010)
2) Takashi Komaya et al., POLYMERS, 61, p.203 (2012)
3) S. Chatti et al., Macromolecules, 39, p.9064 (2006)
4) S. W. Karickhoff et al., Quant. Struc. Act. Rel., 14, p.348 (1995)
5) KAITEKI Management: Mitsubishi Chemical Holdings https://www.mitsubishichem-hd.co.jp/english/kaiteki_management/
6) Takashi Komaya et al., "The State of the Art on Bioplastic Technologies 99" (CMC Publishing Co., Ltd., 2014)
7) Kazuko Ogino et al., "Environment and Chemistry - Introduction to Green Chemistry, 3rd edition" (Tokyo Kagaku Doujin, 2018)

The Statement 2015

We, the participants of the 7th International GSC Conference Tokyo（GSC-7）and 4th JACI/ GSC Symposium make the following declaration to promote “Green and Sustainable Chemistry（GSC）” as a key initiative in the ongoing efforts to achieve global sustainable development.

The global chemistry community has been addressing future-oriented research, innovation, education, and development towards environmentally-benign systems, processes, and products for the sustainable development of society.

In response to the Rio Declaration at the Earth Summit in 1992 and subsequent global Declarations, the global chemistry community has been working on challenges in a unified manner linking academia, industry, and government with a common focus to advance the adoption and uptake of Green and Sustainable Chemistry. The outcomes include the pursuance of co-existence with the global environment, the satisfaction of society’s needs, and economic rationality. These goals should be pursued with consideration for improved quality, performance, and job creation as well as health, safety, the environment across the life cycles of chemical products, their design, selection of raw materials, processing, use, recycling, and final disposal towards a Circular Economy.

Long-term global issues, in areas such as food and water security of supply, energy generation and consumption, resource efficiency, emerging markets, and technological advances and responsible industrial practices have increasingly become major and complicated societal concerns requiring serious attention and innovative solutions within a tight timeline. Therefore, expectations are growing for innovations, based on the chemical sciences and technologies, as driving forces to solve such issues and to achieve the sustainable development of society with enhanced quality of life and well-being.

These significant global issues will best be addressed through promotion of the interdisciplinary understanding of Green and Sustainable Chemistry throughout the discussion of “ Toward New Developments in GSC. ”

The global chemistry community will advance Green and Sustainable Chemistry through global partnership and collaboration and by bridging the boundaries that traditionally separate disciplines, academia, industries, consumers, governments, and nations.

July 8, 2015
Kyohei Takahashi
on behalf of Organizing Committee
Milton Hearn AM, David Constable,
Sir Martyn Poliakoff, Masahiko Matsukata
on behalf of International Advisory Board
of 7th International GSC Conference Tokyo (GSC-7),
Japan July 5-8, 2015

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GSC : Green and Sustainable Chemistry

Chemical sciences and technologies
which are benign to both human health and the environment,
and support the development of a sustainable society.

Introduction to GSC

Learning from social practice cases that received the GSC Awards

Global issues, in areas such as resources and energy, global warming, water and food have increasingly become major and complicated concerns. Innovations for achieving both environmental conservation and economic development are needed in order to resolve these issues and realize the sustainable development of society, and expectations for GSC continue to rise. In this textbook series, technologies and products that have received the GSC Awards given to great achievements contributing to the progress of GSC are explained, so that everyone can understand "what is GSC?" and take responsibility for realizing a sustainable society.

Special Edition

"Introduction to SDGs" Sustainable Development Goals GSC plays a driving role in SDGs

Let's change the world towards a sustainable future!

The SDGs are global goals adopted by the United Nations, and it is essential to harmonize the three elements of economy, society, and the environment in order to achieve sustainable development. This way of thinking is shared with the GSC, which aims to achieve both environmental conservation and economic development for the sustainable development of society. As a special issue, this text aims to explain the SDGs from the perspective of the GSC and encourage everyone to think about and put them into practice.

No.1

New laundry proposal for pioneering a sustainable society

Kao Corporation

The "new laundry proposal for pioneering a sustainable society" of Kao Corporation, which received the Minister of Economy, Trade and Industry Award of the 12th GSC Awards (2012), is characterized by the introduction of Life Cycle Assessment (LCA) into the development of laundry detergents, and the proposal to reduce laundry-related environmental impacts together with consumers by using just one rinse cycle in laundry. How was this innovation generated that simultaneously satisfies environmental friendliness, social contribution and economic rationality?

No.2

Novel Non-phosgene Polycarbonate Production Process Using By-product CO_2 as Starting Material

Asahi Kasei Corporation

The great success of this technology is that unlike the conventional polycarbonate production process, it does not use toxic phosgene as a starting material. At the same time, the technology was revolutionary because it achieved saving of both resources and energy. More than 10 years have passed, and the technology has been widely commercialized all over the world. This worldwide use was highly regarded, and the process became the first technology by a Japanese company to receive the Heroes of Chemistry Award from the American Chemical Society in 2014. What kind of technology is involved in this world-renowned polycarbonate production process?

No.3

Development of Carbon Fiber Composite Materials for Lightweight Commercial Airplanes

Toray Industries, Inc.

TORAY's carbon fiber reinforced plastic developed through over 40 years of research and development has features of high toughness (material tenacity) in combination with light weight and flexibility. The high toughness carbon fiber reinforced plastic (high toughness CFRP) realizes weight reduction of airplanes which is effective in improving fuel consumption, and makes a substantial contribution to reducing environmental impact.

No.4

Development and Commercialization of High Performance Transparent Plastics Derived from Plant-Based Raw Material

Mitsubishi Chemical Corporation

"DURABIOTM", the transparent engineering plastic made from renewable resources developed by the company, not only contributes to the reduction of environmental impact, but also realizes performance exceeding that of conventional engineering plastics in terms of optical characteristics, weathering resistance, etc.

No.5

Development of High-Performance Reverse Osmosis Membrane Contribution to the solution of global water issues

Toray Industries, Inc.

This reverse osmosis membrane can be used in not only seawater but also river water, sewage wastewater, and various other water treatment systems, providing high quality water while saving energy.

No.6

Development of Low Environmental Load Battery for Idling-Stop System Vehicle with High Charge Acceptance and High Durability

Hitachi Chemical Co., Ltd.
(Currently Energywith Co., Ltd.)
Hitachi, Ltd.

Idling-stop systems heavily burden on the battery, causing existing batteries to rapidly degrade, with short battery lifetimes. This technology resolves this problem and contributes to the reduction in CO_2 emissions.

No.7

Development of Water-based Inkjet Ink for Food Package

Kao Corporation

Kao Corporation developed a "water-based inkjet ink" for printing on the plastic films used for packaging daily commodities and food.
The ink maintains a high image quality and has lower volatile organic compound emissions, thereby reducing its environmental impact.

No.8

Development and Commercialization of a New Manufacturing Process for Propylene Oxide Utilizing Cumene Recycling

Sumitomo Chemical Co., Ltd.

Sumitomo Chemical Co., Ltd. developed a new manufacturing process for propylene oxide, which is used as a raw material for polyurethane and other materials.
The new process enables high yields of propylene oxide while reducing its environmental impact.

You can read them in "PDF" and "HTML" that is easy to read on mobile phones.

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