Award Accounts

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The Development of a Non-Fluorocarbon-Based Extruded Polystyrene Foam Which Contains a Halogen-Free Blowing Agent

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This technology is concerned with a new type of extruded polystyrene foam (**XPS**), which gives high performance of thermal insulation without containing any fluorocarbons as a blowing agent. Avoiding such typically harmful materials will help solve global environmental problems like ozone layer depletion and global warming. Kaneka Corporation developed this technology for the first time in the world. As a blowing agent of this new XPS in place of fluorocarbons we adopted isobutane, an excellent green gas that helps prevent ozone layer depletion and global warming. However, there is a problem: it is difficult to secure high performance of thermal insulation and flame retardation when isobutane is used. This originates from the fact that isobutane has a higher thermal conductivity than fluorocarbons, and is highly flammable. To overcome the former problem, we found a novel cell structure to secure high performance of thermal insulation, and we developed new technologies to control it. To solve the latter problem, namely securing flame retardation, we clarified the mechanism to suppress combustion of isobutane, and developed a new flame retardation technology by the addition of specific compounds. As a result of a combination of these technologies, we were able to develop and commercialize a new XPS with high performance of thermal insulation. These technologies directly contribute to prevent adverse effects on the global environment such as ozone layer depletion and global warming, by not using fluorocarbons. And, in addition, these technologies indirectly but more greatly contribute to global warming prevention by the reduction in carbon dioxide emissions through a high effect of energy conservation as a thermal insulator. Therefore, the thermal insulator with these technologies is valuable for environmental protection. And as the needs for a material for better energy conservation will increase, the contribution of this technology will expand much more in the future.

1. What Is Extruded Polystyrene Foam (XPS)?

Extruded polystyrene foam (XPS) is obtained by the following processes. Polystyrene, along with various additives as the occasional demands, is melted and mixed in an extruder. Then, blowing agent is injected into the mixture under high pressure and dissolved. Then, on releasing pressure to atmospheric level, one allows XPS to be continuously foamed and molded.[1,2]

The most important requirement for the physical properties in XPS is suitable thermal conductivity, as the performance of thermal insulation depends on it. Other requirements for physical properties are flame retardation and mechanical characteristics such as flexural strength and compressive strength. In Japan, the classification and the requirement for physical properties of XPS are provided in JIS A9511; so XPS is classified according to thermal conductivity and mechanical characteristics. The classification and the thermal conductivity of XPS in JIS A9511 are shown in Table 1.[3] The thermal insulating board No. 3 of XPS has the lowest thermal conductivity, 0.028 W/m K or less. It is the most excellent kind of thermal insulation. This thermal insulating board No. 3 of XPS is the target of this technological development.

Table 1. The Classification, Thermal Conductivity, and Combustibility of XPS in JIS A9511

Classification	Thermal conductivity W/m K	Combustibility
Thermal insulating board No. 1 of XPS	0.040 or less	The flame disappears within three seconds, there is no remainder dust, and it does not burn exceeding the combustion limit instruction line.
Thermal insulating board No. 2 of XPS	0.034 or less	
Thermal insulating board No. 3 of XPS	0.028 or less	

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In general, the thermal conductivity of a foam is determined by four factors; the thermal conduction of solid (bubble walls) (λ_s), the thermal conduction of the gas (chiefly blowing agents) in bubbles (λ_g), the thermal conduction by the radiation through bubble walls and bubbles (λ_r), and the thermal conduction by the convection of the gas in bubbles (λ_c). Thermal conductivity (λ) is expressed as the sum of these factors by the following Eq. 1:[4]

$$\lambda = \lambda_s + \lambda_g + \lambda_r + \lambda_c \tag{1}$$

Each factor is influenced by characteristics of XPS; the thermal conduction of solid (bubble walls) (λ_s): density of XPS and thickness of bubble walls, the thermal conduction of the gas in bubbles (λ_g): kinds and amounts of blowing agents, the thermal conduction by the radiation through bubble walls and bubbles (λ_r): cellular structure and thickness of bubble walls. Moreover, because the convection of the gas in bubbles is negligible in case the bubbles' diameter is small enough like XPS, λ_c can be disregarded.[4]

The contribution of λ_g is the largest in these four factors; its contribution ratio is approximately 60% among these four factors. From immediately after manufacturing, air, which has comparatively high permeability to the polystyrene, flows into the bubbles of XPS, and the partial pressure of air in bubbles will reach the atmospheric pressure before long. Meanwhile, a blowing agent, if it has high permeability to the polystyrene, diffuses gradually out from bubbles, and scatters and loses out from the foam. On the other hand, if it has low permeability to the polystyrene, a blowing agent stays long in bubbles, and it is filled with the mixture gas of the blowing agent and air in bubbles (in this case, the diffusion of the blowing agent is very late compared with the inflow of air). Because the contribution ratio of λ_g (the thermal conduction of the gas in bubbles) is high in the thermal conductivity (λ) of XPS as mentioned above, it is important to select the blowing agent which stays long in bubbles, and lowers λ_g even when becoming a mixture gas with air, in order to obtain XPS that the thermal conductivity is low. Thus, until this technology was developed, fluorocarbons had been used as blowing agents for thermal insulating board No. 3 of XPS, because they have low thermal conductivity and do not diffuse easily out from the bubbles. No thermal insulating board No. 3 of XPS without fluorocarbons had been obtained.

In the bubbles of conventional XPS which uses fluorocarbons as blowing agents, it is filled with the mixture gas of fluorocarbons and air. Because the thermal conductivities of fluorocarbons (about 0.010 W/m K) are much lower than the thermal conductivity of air (0.026 W/m K), λ_g (the thermal conduction of the gas in bubbles) of conventional XPS is lower than the thermal conductivity of air; λ_g is assumed to be dependence on the molar fraction of each gas. As a result, conventional XPS which uses fluorocarbons has low thermal conductivity and high performance of thermal insulation. In addition, the characteristic is maintained long because fluorocarbons stay long in bubbles.

The application area of XPS is mainly the thermal insulator for buildings or houses. As XPS has advantages in properties such as high performance of thermal insulation and low moisture permeability, it is especially used for the floors, walls, and roof of residences and other structures. About 6–70000 tons/year XPS is produced in Japan in recent years (64562 tons in fiscal year 2002: Extruded Polystyrene Foam Industry Association). The thermal insulating board No. 3 of XPS, which gives the highest performance of thermal insulation, accounts for approximately 30–40% of the total.

After the oil shock, the Japanese Government has worked on the energy saving by establishing the standards of some performances in houses such as thermal insulation. These days, the standard of the energy saving is further reinforced, corresponding to the global warming issue, such as the reduction in carbon dioxide emissions described later. XPS is deemed to contribute to the energy saving of houses greatly with the effect of thermal insulation. The effect of thermal insulation depends on the thermal conductivity and the thickness of the thermal insulator. As for the thermal insulating board No. 3 of XPS with especially low thermal conductivity, an increase of demand in the future is expected. This is because high performance of thermal insulation is demonstrated by a comparatively small thickness compared with other thermal insulators with thermal conductivity than the thermal insulating board No. 3 of XPS.

2. Meaning of This Technological Development

Recently, environmental problems in the earth scale such as the ozone layer depletion and the global warming are taken up on a large scale. In both cases, fluorocarbons have been enumerated as causative agents.

Therefore, for the ozone layer depletion problem, "The Montreal Protocol on Substances that Deplete the Ozone Layer" (1987) was adopted based on the Vienna agreement; afterwards, abolition of all chlorofluorocarbons (CFCs) by 1996 was decided. CFCs were converted into hydrochlorofluorocarbons (HCFCs); as for HCFCs, however, the abolition by 2020 has been decided because they are also ozone-depleting substances.

Moreover, in the global warming issue, "United Nations Framework Convention on Climate Change" came into effect (1994); based on this, the "Kyoto Protocol" was adopted (COP 3: 1997). This provided a legally binding promise about the emission reduction of the heat-trapping gases such as carbon dioxide. HCFC is not just an ozone-depleting substance, but also one of heat-trapping gases, so its emission influences global warming. Though there are trials for the conversion from HCFC to hydrofluorocarbons (HFCs), HFC is specified as a target material of emission reduction because it is also a heat-trapping gas. In Table 2, ozone depletion potentials (ODP: relative values when the ozone depletion effect of CFC-11 for each unit weight is assumed to be "1"), global warming potentials (GWP: relative values when the effect of carbon dioxide for each unit weight to global warming is assumed to be "1", and the values of integration for a 100-year period are shown in the table), and various characteristics of CFC, HCFC, and HFC are shown.

Though difluorodichloromethane (CFC-12) was used as a blowing agent in XPS so far, it has been converted to 1,1-difluoro-1-chloroethane (HCFC-142b) because of the ozone layer depletion problem.[5] However, HCFC-142b is still an ozone-depleting substance, and a material with very high greenhouse effect, too (Abolition has been decided as for HCFC-142b in

Table 2. Various Characteristics of Blowing Agent (Fluorocarbons and Isobutane)

Blowing agent	CFC-12	HCFC-142b	HFC-134a	Isobutane
Chemical formula	CCl_2F_2	CH_3CClF_2	CH_2FCF_3	$CH_3CH(CH_3)CH_3$
Boiling point/°C	−30	−10	−27	−10
Gas conductivity (mW/m K) at 25 °C	10	11	13	16
Flammable limits in air/vol %	None	6.7–14.9	None	1.8–8.44
GWP (100 years)[a)]	8500	2000	1300	4
ODP	1	0.065	0	0

a) IPCC-Report 1996. GWP: Global warming potential. ODP: Ozone depletion potential.

2010). In Japan, approximately 3500 tons of HCFC-142b was used to the entire XPS in fiscal year 2000. This converts into 228 ODP tons based on its ODP (0.065), and 7000000 CO_2 tons based on its GWP (2000). In the fiscal year 1990, the total carbon dioxide emissions in Japan are 1200000000 tons, and 7000000 CO_2 tons of HCFC-142b reaches the value which corresponds to approximately 0.6% of it. If the whole quantity can be reduced, one understands that the effect is very large, because the reduction target value in COP3 of Japan is 6%.

Because the abolition of HCFC was decided, the use of HFC, 1,1,1,2-tetrafluoroethane (HFC-134a, ODP: 0), is examined for XPS instead of HCFC-142b.[6] However, GWP of HFC-134a is 1300 and very high. Therefore, if we keep using HFC-134a for XPS in the future, the XPS will come to emit the heat-trapping gas, the causative agent of global environmental concerns, voluminously and continuously into the environment. In a word, even though XPS can contribute to the carbon dioxide emissions reduction through the energy saving with its high performance of thermal insulation, it influences harmfully to the environment by emitting fluorocarbons.

From the above-mentioned aspects, it is understood that the development of the technology which uses no hydrofluorocarbons as the blowing agent in XPS has an extremely big meaning. So, we decided to challenge the development of this new XPS.

3. The Development of a New Thermal Insulating Board No. 3 of XPS Which Does Not Use Fluorocarbons at All

3-1) Selection of Blowing Agents and Related Technological Subjects. As mentioned above, the performance of thermal insulation of XPS is evaluated by the thermal conductivity, and the lower thermal conductivity means the higher performance of thermal insulation. Moreover, the thermal conductivity of XPS is shown by Eq. 1, and the contribution ratio of λ_g (the thermal conduction of the gas in bubbles) is very high in the thermal conductivity of XPS. Air flows into the bubbles of XPS soon after manufacturing, and if blowing agent has low permeability to polystyrene, it is filled with the mixture gas of blowing agent and air in bubbles. When the thermal conductivity of the mixture gas is low, the thermal conductivity of XPS is low and the performance of thermal insulation of XPS is high. So, it is important to select a blowing agent which has low thermal conductivity and low permeability to the polystyrene, like a fluorocarbon such as HCFC-142b, to obtain the thermal insulating board No. 3 of XPS, which has high performance of thermal insulation.

At the beginning to develop a new thermal insulating board No. 3 of XPS, we investigated various compounds to find the blowing agent that has similar characteristics to fluorocarbons but has no influence on ozone layer depletion and global warming. As a result, we reached a conclusion that hydrocarbons, especially isobutene, are suitable for polystyrene. The isobutane is a blowing agent whose ODP is 0 and GWP is 4; it has a characteristic to decompose in several weeks in the atmosphere (Table 2). Therefore, isobutane can be called an extremely excellent green gas in point of the ozone layer protection and the global warming prevention. In addition, permeability to the polystyrene of isobutane is very low as well as HCFC-142b. Thus, we adopted this isobutane as a blowing agent, and advanced the development of new thermal insulating board No. 3 of XPS.

However, the thermal conductivity of isobutane is approximately 1.5 times as high as the one of HCFC-142b. Therefore, thermal conduction of the gas (λ_g) inside the bubble, whose contribution ratio is high in the thermal conductivity of XPS, rises (However, in the amount of use in which uniting the thermal conductivity and the flame retardation of XPS is considered), and the thermal conductivity (0.028 W/m K or less) needed for the thermal insulating board No. 3 of XPS does not appear by merely replacing the blowing agent from a conventional thermal insulating board No. 3 of XPS.

In addition, because isobutane is more combustible than fluorocarbons, it causes a problem in flame retardation; one can not satisfy the standard provided in JIS A9511 only by adding a conventional flame retardant. The reason for this is that the combustion of isobutane which remains in bubbles of XPS happens.

That is, in order to develop a new thermal insulating board No. 3 of XPS with isobutane, it was necessary to solve two problems: about thermal conductivity (thermal insulation) and flame retardation, and to unite the answers.

3-2) Technologies for Securing High Performance of Thermal Insulation. Because isobutane's thermal conductivity is higher than those of fluorocarbons, as mentioned above, many have assumed that it was difficult to secure high performance of thermal insulation of XPS only by using isobutene (in the amount of use of the isobutane from which the flame retardation of XPS is considered). The reason is that the thermal conductivity of the foam, shown by Eq. 1, rises because λ_g rises as one converts the blowing agent from fluorocarbons to isobutane.

We studied whether the high performance of thermal insulation of XPS would be secured if the rising amount of λ_g lost with the conversion to isobutane was made up by the decrease of the thermal conduction by the radiation through bubble walls and bubbles (λ_r). As the approach to decrease λ_r, we advanced,

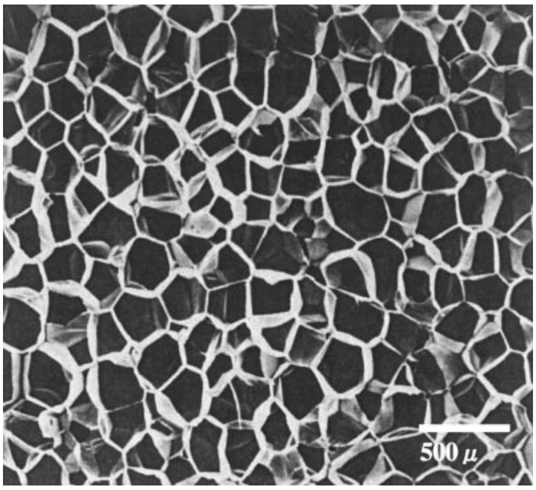

Fig. 1. SEM photograph in section of conventional XPS (accelerating voltage: 20 kV).

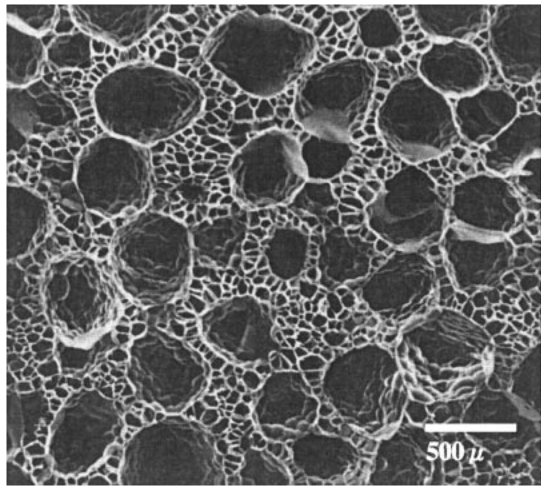

Fig. 2. SEM photograph in section of new XPS "Complex cell structure" (accelerating voltage: 20 kV).

Table 3. Comparison of Cell Structure and Thermal Conductivity in Various XPS with Different Blowing Agent

XPS	Previous XPS		New XPS
Blowing agent	HCFC-142b	Isobutane	Isobutane
Cell structure	Previous cell structure	Previous cell structure	Complex cell structure
Thermal conductivity (W/m K)	0.0270	0.0300	0.0270

the study with attention to a so-called cell structure like the bubble diameter or the shape of XPS.

Conventional XPS has a cell structure in which the bubble diameters are almost uniformly equal. As SEM photograph of conventional XPS's section is shown in Fig. 1. It is composed of bubbles whose diameters are almost uniformly equal to 200–300 µm. Then, we found a tendency that the thermal conductivity would decrease by equally reducing the bubble diameter. But there was a limit on this approach, and when isobutane was used, the value did not reach to the thermal conductivity of thermal insulating board No. 3 of XPS.

We also found that the thermal conductivity decreases in a peculiar situation when a peculiar cell structure was present. Here the bubbles whose diameters are much smaller than conventional bubble diameters (For instance, the diameter of the bubble is 100 µm or less: This is called "Small cell") and the bubbles whose diameters are much bigger than conventional bubble diameters (For instance, the diameter of the bubble is 300 µm or more: This is called "Large cell") existed together. Figure 2 shows the SEM photograph in a section of XPS that has the peculiar cellular structure. It is like the islands–sea structure where the large cells of 300 µm or more diameters are distributed among the small cells of 100 µm or less diameters. We call such a cell structure "Complex cell structure". It is understood that this complex cell structure is a very effective structure for achieving high performance of thermal insulation when isobutane is used as a blowing agent.

Table 3 shows the thermal conductivity in a conventional cell structure and the complex cell structure when isobutane is used as a blowing agent. The standard of thermal insulating board No. 3 of XPS is met in the complex cell structure though it is not met in a conventional cell structure.

To form this complex cell structure, one can use a certain specific associate blowing agent, which acts in concert with the blowing agent. We were able to find the technology to form the complex cell structure by using various additives to stabilize the assistant foaming agent, and by controlling the processing condition carefully. In addition, one can achieve the thermal conductivity provided for the thermal insulating board No. 3 of XPS by optimizing the ratio that small cells occupy in the entire bubble.

The technology about this complex cell structure was originated in the Kaneka Co.; thanks to this technology, we were able to move forward greatly toward the development of the new thermal insulating board No. 3 of XPS which does not use fluorocarbons at all.

3-3) Technologies for Securing Flame Retardation. When XPS is used as thermal insulator for construction, it is necessary to secure the safety of the building against fire. Therefore, it is usual to give XPS the flame retardation by adding flame retardant.[7] In Japan, the above-mentioned JIS A9511 has been provided for the standard and the test method of the flame retardation of XPS for thermal insulator.

In the thermal insulating board No. 3 of XPS that uses isobutane as blowing agent, it is necessary to make a certain constant amount of isobutane remain in the bubbles to secure the target of thermal conductivity while forming the complex cell structure. When the combustibility of such XPS is examined, it might be not conformable to the flame retardation standard provided in JIS A9511 if one only adds the flame retardant used conventionally. This is because the combustible isobutane that remains in the bubbles of XPS burns with the combustion of polystyrene, as found when the combustibility of XPS is examined. Therefore, it was necessary to develop a new technology that will suppress the combustion of isobutane to secure the flame retardation of the thermal insulating board No. 3 of XPS that used isobutane.

We were able to find a mechanism that would suppress the combustion of isobutane by advancing the search for a new flame retardant. As a result of further examinations, we found that the flame retardation can be secured by adding certain specific compounds in the thermal insulating board No. 3 of XPS that used isobutane. And we finally succeeded in the development of the technology for securing flame retardation of the new thermal insulating board No. 3 of XPS.

The test pieces after combustion examination A in the JIS A9511 for one case that uses this technology and for a conventional technology in XPS that used isobutane are shown in Fig. 3. Because the combustion of isobutane which remains in the bubbles of XPS cannot be suppressed by a conventional technology, the upper surface of the test piece that uses a conventional technology melts with burning isobutane, and it is not conformable to the flame retardation standard provided in JIS A9511. On the other hand, this novel technology suppresses the combustion of isobutane, and makes XPS satisfy the standard of the flame retardation.

This technology has an unparalleled creative skill of suppressing the combustion of isobutene, which is an easily flammable gas. We obtained the prospect of developing the new thermal insulating board No. 3 of XPS that does not use fluorocarbons at all by having this technology.

3-4) Making a New Thermal Insulating Board No. 3 of XPS Fit for Practical Use. So as to obtain the thermal insulating board No. 3 of XPS that uses isobutane as blowing agent, one must unite the technology for securing the flame retardation with the technology which forms the complex cell structure to secure high performance of thermal insulation. Therefore, we developed detailed processing technology such as additives and processing conditions with machines for industrialized production. As this result, we obtained the prospect of making new thermal insulating boards No. 3 of XPS fit for practical use by uniting the thermal conductivity to the flame retardation.

At this point, the Kaneka Co. developed the new thermal insulating board No. 3 of XPS which did not use fluorocarbons at all for the first time in the world.

In addition, basic manufacturing technologies were established by making good use of the technologies for metal mold design and processing of extrusion foam. As a result, we acquired the manufacturing technology that was able to cope with various requirements like width, the thickness, strength, and the surface layer, and we succeeded in making a new thermal insulating board No. 3 of XPS fit for practical use. In fiscal year 2001, Kaneka began sales of the new thermal insulating board No. 3 of XPS obtained by this technology.

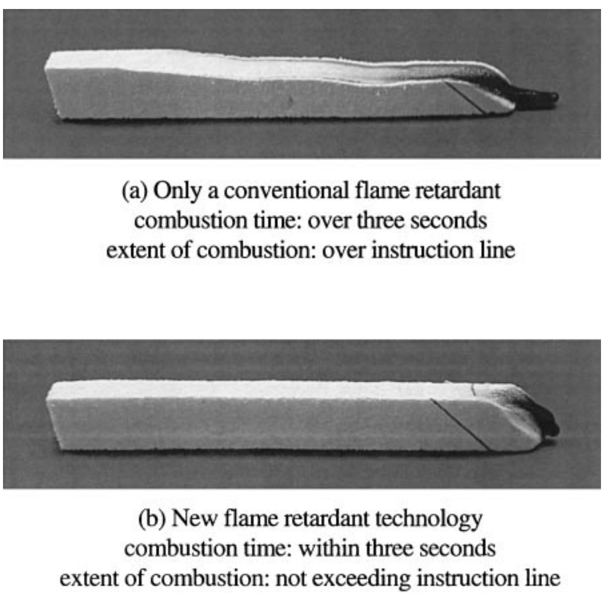

Fig. 3. Samples after combustion examination when isobutane is used as blowing agent.

4. Feature of the New Thermal Insulating Board No. 3 of XPS

As mentioned above, we succeeded in securing high performance of thermal insulation and flame retardation, which were the problems for use of isobutane, and commercialized the new thermal insulating board No. 3 of XPS that did not use fluorocarbons at all. The new thermal insulating board No. 3 of XPS satisfies all characteristics required with JIS A9511 like thermal conductivity, flame retardation, compressive strength, and flexural strength, as well as the XPS which uses HCFC-142b conventionally. The properties of the new thermal insulating board No. 3 of XPS are shown in Table 4.[8]

As a foam which has high performance of thermal insulation like the thermal insulating board No. 3 of XPS of this technology, the foam which used thermosetting resins such as urethane resins and phenolic resins with a difficult material recycling is known. However, the foam that used the polystyrene with an easy material recycling does not have any example besides this technology. That is, the thermal insulating board No. 3 of XPS of this technology is an excellent foam in environmental adaptability compared with other materials used for architectural applications.

Table 4. Various Physical Properties of New XPS3 "Kanelite super-E III" Which Uses Isobutane

Thermal conductivity W/m K	Compressive strength N/cm^2	Flexural strength N/cm^2	Combustibility	Amount of water absorption $g/100\ cm^2$	Potential of water vapor permeability $ng/m^2\ s\ Pa$
0.028 or less	20 or more	25 or more	3 second or less, not exceeding the combustion limit line	0.01	145 or less

5. Results of the New Thermal Insulating Board No. 3 of XPS

The high environmental adaptability of the new XPS developed by this technology is admitted. The major house manufacturer in Japan has adopted this as the thermal insulator for detached houses and for constructions. Moreover, the new XPS acquired the Eco Mark of Japan, and it was admitted as a product for green purchase.

The sales performance of the new thermal insulating board No. 3 of XPS obtained by this technology is as follows. About 23% of thermal insulating board No. 3 of XPS of Kaneka was converted to the new XPS in fiscal year 2001, and 50% or more was converted in fiscal year 2002. The whole quantity is scheduled to be converted to the new thermal insulating board No. 3 of XPS in fiscal year 2004, and Kaneka plans to abolish the use of HCFC-142b. As a result, the amount of use of HCFC-142b can be reduced approximately 1700 tons/year.

6. Contribution to the Global Environment Protection

6-1) Ozonosphere Protection. It is possible to contribute to the ozonosphere protection greatly by converting from HCFC-142b to isobutane that causes no ozone destruction. Reducing approximately 1700 tons of the amount of use of HCFC-142b as mentioned above, when converted from ozone depletion potential (0.065) of HCFC-142b into CFC-11, corresponds to the reduction of approximately 110 ODP tons.

6-2) Global Warming Prevention. It is possible to contribute to the global warming prevention greatly by converting from HCFC-142b to isobutane with extremely low greenhouse effect. Reducing approximately 1700 tons of the amount of use of HCFC-142b as mentioned above, the conversion from global warming coefficient (2000) of HCFC-142b into carbon dioxide corresponds to the reduction in approximately 3400000 CO_2 tons. This value corresponds to approximately 0.3% of 1200000000 tons, the total carbon dioxide emissions in Japan in fiscal year 1990 as mentioned above. It is understood that the effect is very large because the reduction target value in COP3 of Japan is 6%. (However, HCFC is not included in the benchmark year and the reduction item of COP3.)

In addition, with the best use of features such as the high performance of thermal insulation, the new XPS contributes to the emission reduction in the heat-trapping gases such as carbon dioxide substantially through the energy saving in houses. That is, when fluorocarbons are used, the emission effect of the fluorocarbons greatly exceeds the energy-saving effect to the carbon dioxide emissions, and the XPS using fluorocarbons comes to give the influence of the minus rather for global environment. However, when isobutane is used, carbon dioxide emissions will be substantially reduced because its greenhouse effect is very small.

6-3) Relations to Recovery and Destruction of Fluorocarbons. So-called "Fluorocarbons Recovery and Destruction Law" was enacted in 2001, and recovery and treatment were obligated for the fluorocarbons that have already been used for the refrigerators and other machines in Japan. In relation to this law, the discussion includes about the fluorocarbons used for the thermal insulator of the building now. However, it is very difficult to find the means to recover fluorocarbons from the foam used for an architectural purpose. On the other hand, there is no problem of the recovery and destruction when this technology is applied, and the brake can be put on the accumulation of fluorocarbons in the global environment.

7. Conclusion

We worked on the development of the new XPS which had high performance of thermal insulation, and which did not use any fluorocarbons, the causative agents to global environmental concerns. Concretely, we tried to achieve high performance of thermal insulation and the flame retardation in XPS when we used isobutane, a green gas, as the blowing agent. As a result, the target was achieved by a novel cell structure, "Complex cell structure", and its control technology, and a new technology of flame retardation; thus the desirable product was able to be developed for the first time in the world.

This technology is now able to contribute greatly to the emission reduction in fluorocarbons that are the causative agents of ozone layer depletion and global warming, and it is possible to contribute to the carbon dioxide emissions reduction substantially as a thermal insulator through the energy saving of the house building. That is, it is possible to contribute greatly to the global environment protection, and it is an extremely excellent technology with high prospects.

Kaneka Corporation has been proceeding with several developments of new technology for contributing to the global environmental protection, and produced the award-winning technology. It is a great honor for us to be awarded the 51st CSJ Award for Technical Development. We wish to express our gratitude to related all persons deeply.

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Youichi Ohara was born in Yashiro, Hyogo, Japan in 1962. He graduated from Department of Industrial Chemistry, Faculty of Engineering, Kobe University in 1985, and received his Master's degree in 1987 from the same University. He joined Central Research Laboratories of Kaneka Corporation in 1987. In 2002–2003, he was a senior researcher of Polymer Designing & Processing Research Laboratories, Polymer Designing Materials R&D Center. Since May 2003, he has been a senior researcher of Polymer Designing & Processing Research Laboratories, Polymer Designing & Processing Product Development Center of Corporate R&D Division. Research Experience: high performance polymer and polymer alloy, flame retardant technology of engineering plastics, extruded polystyrene foam.

Kenkichi Tanaka was born in Yamaguchi prefecture Japan. He graduated from the Department of Chemical Engineering, Faculty of Engineering, Kyusyu University, and received a Master's degree from the same University, and then joined the department of expanded resin of Kaneka Corporation in 1979. From April 2000 to April 2003, he was a senior researcher of R&D group, Building & Construction Materials Division. Since May 2003, he has been a manager of Building & Construction Materials Research Group, Polymer Designing & Processing Product Development Center. Research Experience: expanded polyethylene foam, extruded magnet roller, extruded polystyrene foam (board, sheet).

Takahiro Hayashi was born in Osaka Prefecture Japan in 1962. He graduated from the Department of Mechanical Engineering, College of Engineering, Osaka Prefecture University, in 1985. He joined Kaneka Corporation in April 1985. From 1999 until 2003, he was a researcher of R&D group, Building & Construction Materials Division. Since May 2003, he has been a researcher of Building & Construction Materials Research Group, Polymer Designing & Processing Product Development Center of Corporate R&D Division. Research Experience: research on extruded polystyrene foam, processing technology development of extruded polystyrene foam.

Haruo Tomita was born in Nara prefecture Japan in 1951. He graduated from the Department of Synthetic Chemistry, Faculty of Engineering, Kyoto University in 1974, and received his Master's degree in 1976, and his Doctoral degree in 1981 from the same University. He joined Central Research Laboratories of Kaneka Corporation in April 1981. From April 2000 until March 2003, he was a manager of R&D group, Building & Construction Materials Division. Since April 2003, he has been a manager of R&D group, Kanekalon Division. Research Experience: epoxy resin, high performance polymer and polymer alloy, extruded polystyrene foam and polyolefin foam, synthetic fiber.

Shigeru Motani was born in Mie prefecture Japan in 1950. He graduated from the Department of Applied Chemistry, Osaka Technical Institute in 1975. He joined Osaka Factory of Kaneka Corporation in March 1969. From April 1984 until March 1994, he was a researcher of Plastic Processing (Foaming) Laboratory. From March 1994 until March 1998, he was a manager of KANE-LITE-FOAM Manufacturing Division, Osaka Factory. Since March 1998, he has been a manager of Technical & Market Development group, Building & Construction Materials Division. Research Experience: extruded plastics foam and polystyrene polyolefin.