Development of Covering Film for High-Performance Horticulture

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Japanese agriculture developed with the first consideration that regards on taste and convenience of consumers and met variety of their appetite. On the other hand, for the agricultural technology that has supported mass consumption, there are many problems at a point of "food safety" and "environmental conservation".

Therefore new technology development for food safety assuming low resources / energy consumption is demanded recently.

In this paper, we review technical thought of the covering film for high-performance horticulture, and give an outline of our action plan that survey the future market and agriculture.

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Introduction

Along with greatly shaking up the confidence in producers and distributors, the problems, such as BSE and avian influenza, which are threatening the safety of agricultural products occurring one after another, have suddenly increased our the awareness of "food safety" as consumers. On the other hand, even though Japanese agriculture is facing internal and external problems such as the depression of prices that accompanies the expansion in importation of agricultural products and the aging and lack of successors in the farming population, farmers on the leading edge of technology are thinking of the commercial value of "food safety" and are aiming at advanced protected horticulture technology that provides "reassurance," "stability" and "inexpensiveness."

In 1981, Sumitomo Chemical put Cleantate on the market. This brought about a technical revolution in the main market for agricultural polyvinyl chloride polyvinyl films (polyvinyl chloride films for agricultural use) due to polyolefin-based materials and has contributed to the development of protected horticultural technology.[1] In addition, since combining Cleantate operations with Sanzenkako Co., Ltd. in 2002, we always have been the market leader in agricultural polyolefin films (agricultural PO) as the top maker, and we currently have the top share in the agricultural PO polyolefin films market.

While the market share for agricultural PO polyolefin films is gradually expanding with its characteristics of being "strong in the wind, light and easy on the environment," its completeness in terms of the quality of heat retention (IR absorbency), clouding (fogging) resistance and the like is insufficient for complete replacement of agricultural vinyl chloride films. However, a heat retention (IR absorbency) equivalent to agricultural vinyl chloride film was proven for Cleantate DX, which Sumitomo Chemical marketed in 1995, and taking the opportunity of various companies marketing agricultural PO polyolefin films to which coating anti-clouding (anti-fogging) agents had been applied to suddenly increase the duration of resistance to clouding (fogging) starting in 1997, agricultural PO polyolefin films went from simply being recognized as a complementary material to agricultural vinyl chloride film to being acknowledged as a labor saving, durable material that reduces replacement operations and costs. Dissemination centered on large-scale protected horticulture operators and associated industries accelerated. In addition, the reduction of labor and reduction of resources consumed (reduced waste) conforms plans in agricultural policies and environmental protection policies supporting improvement of the competitiveness of domestic agriculture. With this operating environment as the background and as a result of progress in competitive development of agricultural PO polyolefin films, the quality has improved and recognition has increased year by year while the competition in the market has become fierce. At present, with the various makers of agricultural polyvinyl chloride films having added agricultural PO polyolefin films to their own company line-ups, the competitive materials on the market are no longer agricultural polyvinyl chloride films. The progress in agricultural PO polyolefin films has pretty much created a new market, and along with the developments in protected horticultural technology, it can be said to have started out on its own path of growth.

Based on its own polymer structure control technology and forming and processing technology, Sumitomo Chemical has combined additive mixing technology, and further, application technology and the like in carrying out development of agricultural PO polyolefin films, and it has accumulated a large amount of elemental technology. With the development of applied anti-clouding (anti-fogging) agents recently, new functions have been discovered through the establishment of surface modification technology,[5)–7)] and there are expectations for this to develop as a technology for creating high value. At present, we are working on creating a concept for the next generation of protected horticulture technology that further hybridizes this surface modification technology.

In addition to adding improvements in competitiveness as a business, the mission of Japanese agriculture in the future is to assure the safety of food. Through developments in protected horticulture and to make a contribution to Japanese agriculture, Sumitomo Chemical is not only providing materials for protected horticulture, but also considers the development of systems that support advanced protected horticulture technology to be important. The fact that there is a trend toward a strong hold on the area under protected horticulture while there is a reduction in the number of people becoming farmers shows that farmers involved in protected horticulture are moving toward larger scale operations, and here we can find the potential for farm managers responsible for the next generation. The authors are moving ahead with development where Cleantate provides them with this kind of value and aims at giving them something to dream about. .

Along with giving an overview of the technical concept of Cleantate, we would like to touch upon the development of future technology aimed at achieving these dreams in agriculture and market strategies.

Technical Concept of Cleantate

1. Increased Strength and Reduced Weight

The thickness for agricultural PO polyolefin films is set so that it is suitable for the part where it is applied. Representative thicknesses for parts where it is applied are shown in **Fig. 1**. For use with the inner tunnel and curtain where there is frequent opening and closing and light weight is important, so thinner products of 0.05 – 0.075 mm are used. On the other hand, with the outer sheet covering film, where importance is placed on heat retention (IR absorbency) and strength, products with a thickness of 0.1 mm or greater are used, and particularly in durable applications when the material is to be left up continuously for three years or more, thick products of 0.15 mm are used. However, there is the demerit of increased weight with the 0.15 mm thickness in deploying the outer film, which is accompanied by work in high places, and there has been a strong demand for reducing the weight.

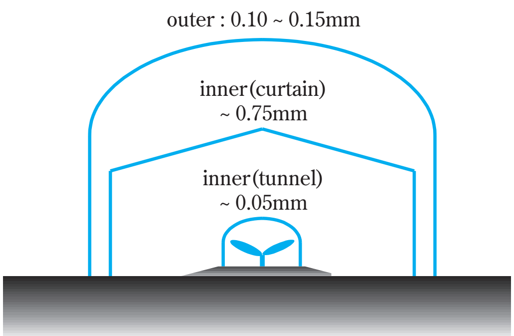


Fig. 1 Cross section of greenhouse

Conventional agricultural PO polyolefin films uses an ethylene-vinyl acetate copolymer resin (EVA), so the strength is recognized as being roughly satisfactory, since it already outstrips agriculture in terms of shock resistance strength and tear strength. However, the advent of metallocene based linier low density polyethylene (m-LLDPE) products utterly transformed this recognition. Among these, “Iku-iku,” (Mitsuishi Agri Co., Ltd., at that time) which is an all-metallocene agricultural PO polyolefin films, attracted a high level of attention along with the word “metallocene” as a film that could made thinner (reduced weight) with overwhelming strength as the background. On this occasion, the various agricultural PO polyolefin films companies entered into a competition on improving strength all at once, and progress was made in raising the level of agricultural PO polyolefin films strength through conversion to-metallocene.

The authors thought that it was important to maintain flexibility in the improvement of strength, and when designing the new Cleantate, the deployment properties were considered, and along with maintaining flexibility equal to that of EVA, we planned to achieve strength equivalent to that manifested in a 0.15 mm thick current product with a thickness of 13 mm for a 13% weight reduction.

Along with manifesting a tensile strength equal to conventional products even with the thickness reduced by 13% and with flexibility equivalent to EVA by using a metallocene based polyolefin plastomer in the new Cleantate, a resin composition that achieved punch shock (impact) strength of twice that of the conventional product was designed (**Fig. 2**, **Fig. 3**).

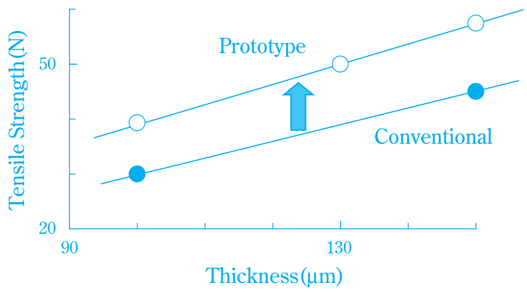


Fig. 2 Tensile strength vs. film thickness

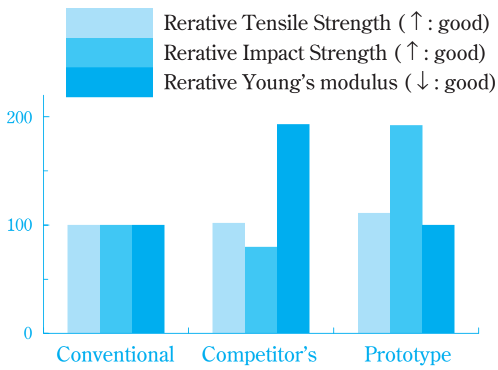


Fig. 3 Bench mark of mechanical properties

2. Heat Retention and Reduced Weight

What is called heat retention (IR absorbency) here indicates absorption by the film of the radiant ray energy radiated from the ground at night and the property of being able to re-radiate it within the greenhouse, and this normally expressed by the absorption ratio for the radiant ray energy. Naturally, it is necessary to raise the level of radiant ray absorption when reducing weight (making the film thinner), but additionally, in the design of the new Cleantate, it was necessary to supplement radiant ray absorption, which was lost in substitution for EVA lower that that for EVA, even more.

Since the radiant ray spectrum radiated from the earth has a distribution with a peak in the vicinity of a wavelength of 10 μm, and it is appropriate to mix in inorganic compounds having a characteristic absorption in this band of wavelengths when designing the heat retention of agricultural PO polyolefin films .[9), 10)] However, when the heat retaining (IR absorbency) agent is dispersed in the resin, it must have an index of refraction aligned with that of the resin, have a microdispersion in the resin and the like. From these points of view, Mg-ALAl based complex hydroxides (so-called hydrotalcite compounds), Li-ALAl based complex hydroxides and the like are often used as heat retaining agents with superior cost-performance.

These complex hydroxides contain metal ions such as Mg, Mn, Fe, Co, Ni, Cu, Zn, Al, Cr, and Li and are layered complex hydroxides with alternating layers of a crystalline host having a positive charge and a guest layer made up of anions, water or the like with a negative charge, with the complex hydroxide as a whole being neutral in terms of charge. Moreover, the IR absorption characteristics, index of refraction, basicity, pore shape and the like change according to the composition of metal elements forming the host layers, and the IR absorption characteristics, index of refraction, anion exchange characteristics and the like vary according to the type and composition of the anions making up the guest layers.

In particular, the thickness of the guest layer is determined by the diameter of the anions introduced, and the absorption and desorption characteristics of the polar substances appear at a level that depends on that thickness, making for specific functions as halogen scavengers and acid trapping agents.[11)] At present, progress is being made in the development of various complex hydroxides that are given various function by making these adjustments.[12), 13)]

In addition, progress is being made in technical development for combined effects by combining inorganic compounds, including the attaining of radiant ray absorption that could not be achieved with a single compound through the joint use of inorganic compounds with different IR absorption characteristics.

The radiant ray absorption was maximized through the combination of the IR absorption characteristics of inorganic compounds in the design of the new Cleantate. Specifically, the design was done so that radiant ray absorption of the same level as conventional products with a thickness of 0.15 mm was obtained with a thickness of 0.13 mm, and along with improving the mechanical strength as mentioned earlier, a design with a 13% weight reduction was completed (**Fig. 4**, **Fig. 5**).

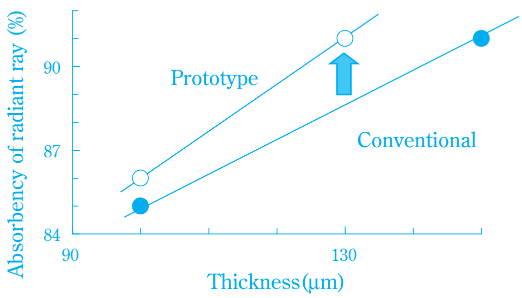


Fig. 4 Absorbency of radiant ray vs. film thickness

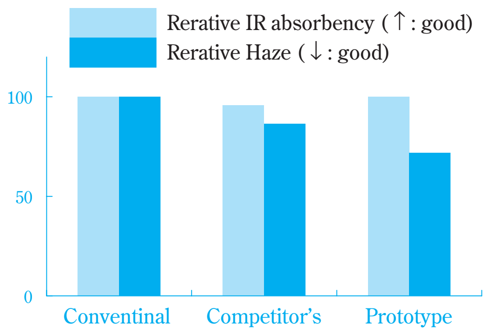


Fig. 5 Bench mark of optical properties

3. Light Transmittance (Transparency)

Fundamentally, cultivating plants that are grown outside in greenhouses requires maintaining the outside light environment. On the other hand, in order to decipher the effects of light in the ultraviolet range on plants and insects as well as the activities of microorganisms in the soil, activities are often carried out by controlling the light environment so that it is aggressively different from the outside in terms of the wavelength band. In addition, since it is necessary to inhibit the dissipation of radiant ray energy in the infrared range at night as was mentioned earlier, control that makes for a lack of transparency in this range is used. That is, the reason that importance is placed on a light environment that is similar to the outside is that the visible range affects photosynthesis and the ground temperature increase in greenhouses. Concerning this point, it can be said that protected horticulture in Japan, which has developed based on agricultural polyvinyl chloride film, has placed importance on visible light. In addition, the remarkable PET films, fluorocarbon resin films and the like have received high evaluations because of their superiority in direct transmission of visible light along with durability.

In order to construct a major position for Cleantate as a protected horticultural covering film, improvements in direct transmission of visible light, in other words, transparency, are necessary. At present, when we have come to establishing quality that surpasses others in strength, heat retention (IR absorbency), and further, clouding (fogging) resistance, Cleantate faces a fundamental question as a covering film for protected horticulture.

The transparency of polyolefin films is controlled by the dispersion action (refraction of incident visible light, degree of reflection) on visible light caused by higher order structures such as lamellae and spherocrystals.

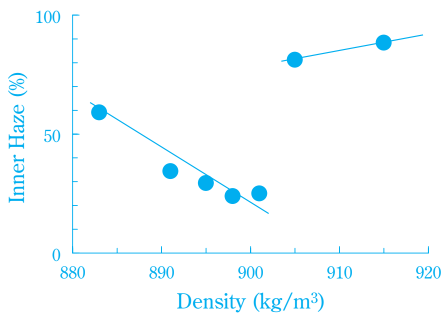
In addition, it is controlled by the molecular structures of higher order polymers (molecular weight and distribution, amount of branching, comonomer composition and distribution, etc.) and the forming and processing conditions (processing temperature, cooling temperature, degree of orientation, etc.). Here, we thought of the visible light scattering in agricultural PO polyolefin by dividing it into the scattering occurring within the film and the scattering occurring on the surface of the film.

(1) Improvement of transparency by controlling internal scattering

In the internal scattering in Cleantate the crystalline part (spherocrystals) of the polyolefin used behave as scatterers and the inorganic compounds used as a heat retaining (IR absorbency) agents behave as scatterers. While the scattering due to the polyolefin spherocrystals essentially cannot be ignored, the scattering due to inorganic compounds in Cleantate is large, and controlling this was the problem in improving the transparency.

When inorganic compound particles behave as scatterers, there is scattering due to particles equivalent to the visible light wavelengths (Mie scattering), and scattering due to refractive index mismatches. Both types of scattering are important control factors in the design of Cleantate, and optimization has been done for each of them. For Mie scattering, the primary particle diameter and distribution of the inorganic compound are controlled, and it is inhibited by optimizing the surface processing agents and processing methods. Moreover, since the index of refraction is determined by the chemical composition of the inorganic compounds, optimization is carried out with the addition of the IR absorption characteristics mentioned.

In designing Cleantate, there was improvement in scattering with inorganic compounds having smaller particle diameters (sharp scattering particle diameter distribution) and with combinations where refractive indices were matched to the polyolefin resin, and the visible light scattering due to inorganic compound particle diameter was controlled (**Fig. 6**).[15]



specimen : 1mm thickness, press molded
composition : m-LLDPE/inorganic compound = 84/16 (wt%)

Fig. 6 Optimization of resin density for transparency

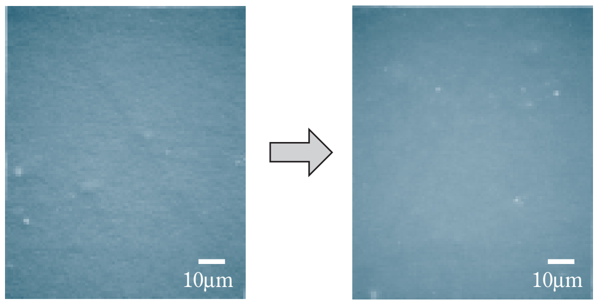
(2) Improvement of transparency by controlling external scattering

<Control of higher order polymer structures and inhibiting external scattering>

Since the polyolefin spherocrystals, which were one of the causes of internal scattering from periodic roughness in the surface of the film, the effects of external scattering are even greater. In addition, the development of spherocrystals is largely controlled by the forming and processing methods, particularly the cooling method and surface smoothing methods. Since almost all agricultural PO polyolefin is films formed by air-cooled inflation molding processing, it is impossible to obtain a mirror surface adherence effect using sudden cooling effects or cooled chilled rolling, and it is difficult to control the deterioration of surface smoothness due to the development of spherocrystals. In particular, the development of spherocrystals is prominent on the inside surface of the inflation tube where the cooling effect is poor, and there is a tendency for the surface smoothing to deteriorate and the external scattering to be amplified.[16]

Since development of spherocrystals is controlled in the design of the new Cleantate, the formation of surface roughness is alleviated by controlling the crystallization of the polyolefin resin inside the inflation tube and on the outside along with using a polyolefin with a specific density in the skin layer (**Fig. 7**).

We presume that this is due to the effects of using the characteristics of the inflation tube outer skin layer, which is relatively rapidly cooled and hardened and constraining the inflation tube inner skin layer to inhibit the development of spherocrystals.



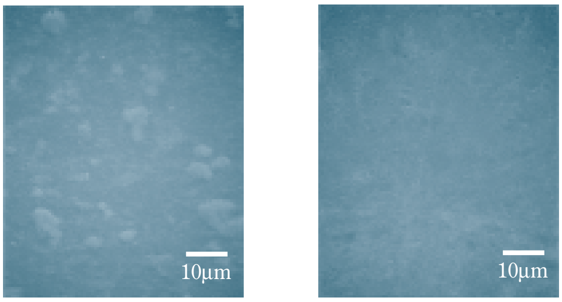
a) Outer Haze : 2.6
Uncontrolled

b) Outer Haze : 1.1
Controlled

Fig. 7 Surface structuer by SEM

<Control the shape of the application of the anti-clouding (anti-fogging) film and inhibiting external scattering>

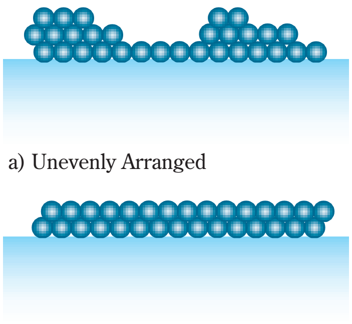
The application of an anti-clouding (anti-fogging) film to Cleantate manifests its function through the two mechanisms of making the surface hydrophilic due to the inorganic compounds and creation of a micro-roughness on the surface. In general, it is not easy to form a robust coating film with an inorganic substance on the surface of a soft polyethylene film, and frequently binder components such as resins are necessary. Conversely, the an anti-clouding (anti-fogging) film application for Cleantate is a microparticle thin film formed using the self-assembly self-organize function that inorganic microparticles have, and we can assume that the microparticles are strongly bonded to microparticles and microparticles to the polyolefin film surface by the liquid crosslinking force and intermolecular force. Moreover, the microparticle film is formed using a wet application process that makes use of an inorganic colloidal liquid, and the film thickness is controlled by the concentration of the colloidal liquid and the adjustment of the coating solution film layer thickness. Scattering inhibition technology is incorporated at the same time by controlling the shape of the particulate thin film in the anti-clouding (anti-fogging) film formed using the properties of these colloidal particles (**Fig. 8**, **Fig. 9**).[17]



a) Outer Haze : 6.1
Conventional coating process

b) Outer Haze : 3.8
Development coating process

Fig. 8 Coated surface structuer by SEM



a) Unevenly Arranged

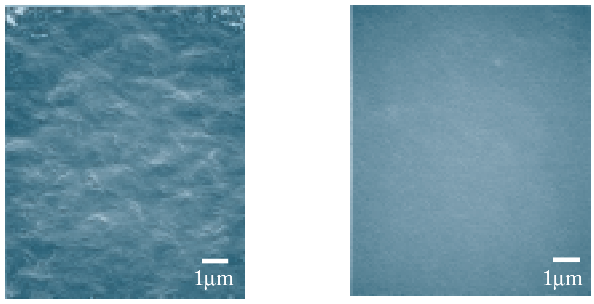
b) Uniformly Arranged

Fig. 9 Cross section model of arranged particles

The characteristics of the substrate, such as surface smoothness and flexibility, the characteristics of the colloidal solution, such as colloidal concentration, the surface charge of the colloidal particles, the pH, viscosity of the dispersion medium, the surface tension and viscoelasticity of the liquid and the coating liquid film thickness greatly contribute to the controllability of the shape (regularity, smoothness) of the microparticle film. Therefore, it is necessary to optimize all of these to improve the transparency of the anti-clouding (anti-fogging) film. The colloidal particles in the liquid are repulsed by the surface charges and form a stable dispersion. However, with a reduction in the dispersion medium on the surface of the substrate, a lateral capillary force (meniscus force) is generated, and with this as the driving force, the particles begin to collect.[18), 19)] This lateral capillary force operates effectively when the distance between particles is small, and that force is broken if a fixed inter-particle distance is exceeded or the frictional force between the particles and the substrate surface becomes too strong.[20)] In addition, the regularity of the arrangement is affected according to the dispersion medium because the speed of particle movement varies with drying. Furthermore, the colloid is stabilized by optimizing the surface charges on the colloidal particles and the pH, and aggregation or the forming of a gel can be controlled.

In the design of the new Cleantate, a smooth anti-clouding (anti-fogging) film application is formed on the surface by forming a coating with a colloidal liquid compatible with the properties of the polyethylene film substrate in an optimal film thickness, and the external scattering caused by the surface roughness of the polyethylene film is controlled (**Fig. 10**).

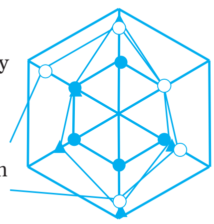
By combining the above technologies, the new Cleantate, which achieves a quality that is top in its



a) Substrate surface

b) Coated surface

Fig. 10 Coated surface structuer by SEM



● : Conventional Cleantate
▲ : Highest point of competitor's in each property
○ : Cleantate Extra

Fig. 11 General quality of Cleantate Extra class in the market, has all the properties of strength, heat retention (IR absorbency) and transparency, was marketed in 2003 as Cleantate EX (Extra), and it is currently growing steadily as the main pillar of earnings for agricultural material operations at Sanzenkako (**Fig. 11**).

Future Market Strategy and New Product Development

1. Market Strategy

The reason that PET films, fluorocarbon resin films and the like have received high evaluations from the market is their maintaining superior transparency over a long period of time and their ability to resist soiling. Therefore, their value has been confirmed, even though they are high cost films. While the initial transparency of agricultural polyvinyl is by no means inferior to these films, the light transmittance is greatly reduced by soiling within several months. Therefore, it must be changed every season and high-cost films are not taken on. With the goal of confirming the value of soiling resistance and grasping the actual conditions for customers that can take on high-cost films, the authors carried out an analysis of the Ministry of Agriculture, Forestry and Fisheries statistical data.[21]

Fig. 12 shows the distribution of production, that is, annual earnings, for farmers viewed by product. What should be surprising is that we found that more than half of Japanese farmers (excluding livestock farmers) have annual earnings of 1,000,000 yen or less.

These make up the majority of farming households, and it can be said that most of these follow the pattern of being rice farmers that are type 2 part-time farmers. On the other hand, there is a completely different pattern in the earnings distribution of farmers producing flowers and ornamental plants and vegetables in greenhouses. While the farming households producing flowers, ornamental plants and greenhouse vegetables do not come to 10% of the whole, the proportion of high earnings farming households, which have annual earnings that exceed 10,000,000 yen, exceeds 40%. This is obvious proof that their earning power exceeds the group and is superior. Both of these are producers of crops that place importance on the strength of light, and we determined them to be farmers with proficient investment capabilities.

The authors focused on this point, and we carried out a joint investigation of market strategies and new development strategies with Sanzenkako. As a result, we came to the conclusion that we can obtain support from these advanced farmers from the higher order standpoints of high level control of cultivation management, economic rationality in agricultural management, and further, lower waste for used plastic if we improved the light transmittance by preventing soiling and could replace PET films and fluorocarbon resin films what have become popular as high additive value products up to this point. At present we are moving forward with the project of developing a high-performance protected horticultural covering film with a soiling prevention function as a product value, making an entry into the high additive value product market, having set the goal of establishing a revenue base for Cleantate operations.

2. Development Concept

A large number of substances that cause soiling are scattered freely in the outside environment, and they give rise to soiling through a variety of mechanisms. Specifically, there are attraction and adherence of dust due to surface charges, adherence and dissolution of oil mists, smoke and the like, and propagation of molds that use plastic as a source of nutrients (**Fig. 13**).

As a result of detailed analysis of the surface of the film 30 days months after actual deployment, if was

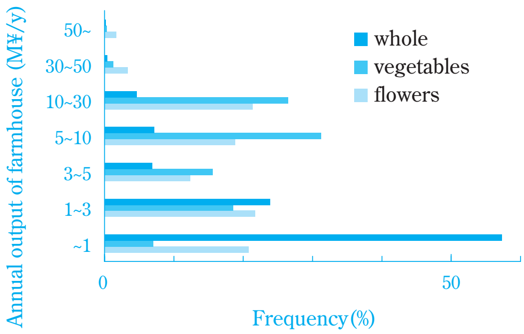


Fig. 12 Frequency distribution of output on each product

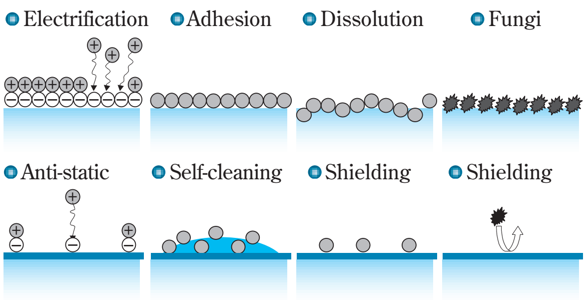


Fig. 13 Prevention model against dirty particles

determined that most of the substances causing soiling were soot (benzopyrene), nitrogen oxide, sulfur oxide, and other smoke components.

Thus, the authors assumed that it would be possible to prevent this kind of soiling using properties for the prevention of the charges manifested using an inorganic hydrophilic coating and self-cleaning properties, and we began working on developing an agricultural PO polyolefin film with a soiling prevention function contributed by an inorganic hydrophilic coating.

First of all, the authors proposed a process concept for forming an anti-clouding (anti-fogging) coating film and a soiling prevention coating film on both surfaces of a multilayered film, in an application of the existing Cleantate production process.

In this process, the multilayer cylindrical tubular film obtained from the inflation molding process was used without alteration.

The main point is creating satisfactory flexibility, transparency and strength by optimizing the various layers of the resin that make up the multilayer cylindrical tubular film. By optimally layering a metallocene based polyolefin plastomer, the authors succeeded in industrializing this concept.[22), 23)]

3. Verification of Soiling Prevention Effect

The new agricultural PO polyolefin with the anti-clouding (anti-fogging) coating film and a soiling prevention coating film formed on both surfaces is presently being tested in actual atmospheric exposure tests in cooperation with Sanzenkako. **Fig. 14** shows the relative illumination retention changes over time. This so-called relative illumination is the proportion of the outside illumination inside the greenhouse for simultaneously measured outside illumination, and the retention is a comparison with the initial value. Moreover, the illumination in the greenhouse was measured just past the test film.

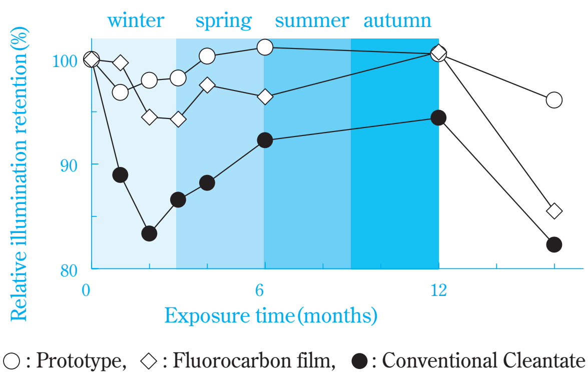


Fig. 14 Relative illumination retention vs. exposure time

Compared with the remarkable drop in relative illumination with conventional Cleantate, we find that the developed product roughly maintained the initial standard during one year of deployment and more. For comparison, this exceeds that of a fluorocarbon resin film. Since fluorocarbon resin films are recognized in the market as materials that can withstand 10 years of continuous deployment, we presume that the developed product soiling prevention function will withstand 10 years of use. In particular, we think that the fact that a high relative illumination can be maintained even in the winter, when the amount of light is small, makes for differentiation in the point of outside environment dependence versus typical photocatalytic titanium oxide based materials where the soiling prevention function is controlled by the outside ultraviolet light intensity.

In addition, the authors focused on the fact that only two months after deployment of conventional Cleantate, there was a sudden drop in relative illumination and carried out a detailed analysis of the soiling during this period. As a result, it was determined that the cause of the soiling was not soot (benzopyrene) and other smoke components, but rather sooty mold (Alternaria), black mold (Cladosporium) and other molds. On the other hand, these molds were not detected on the surface of the developed product where no drop in relative illumination was seen. These molds are known as ones that have plastic as a source of nutrients, and, and besides being the cause of the black moldy soiling typically seen in the living environment, there are cases where it is a problem in industry as a microbial disaster with growth on lenses and printed circuit board wiring substrates.

The authors thought that mold growth would be inhibited by an inorganic hydrophilic coating film, and sooty mold was extracted from the group of molds collected in an experimental environment and mold culture investigations were carried out on various film surfaces (**Fig. 15**). As a result, sooty mold did not grow on the inorganic hydrophilic coated surface of the developed product, and growth was confirmed on a polyethylene resin surface, polyvinyl chloride resin surface and fluorocarbon resin surface.

Since the inorganic hydrophilic coating film does not include bactericidal and other physiologically active substances, we assume that it have the effect of inhibiting the growth of mold by simply isolating it from the plastic that serves as a source of nutrients. We think that the fact that the growth of the mold is inhibited without annihilating it is an important property from the standpoint of protecting the ecological system and think that this point will serve to differentiate this from the conventional photocatalytic titanium oxide based materials. Since this coating film can be formed on a variety of material surfaces, we can naturally expect applications as a soiling prevention technology for carport roofs and outside wall siding materials, without its being limited to protected horticultural coating films.

fungi : Alternaria

	Prototype	Conventional	Fluorocarbon film
anti-fungi	–	+++	++
coating layer			
substrate			
coating layer			
anti-fungi	–	–	+

number of colonies : large +++ > ++ > + > – small

Fig. 15 Assay of anti-fungi property

Mold rapidly increases soiling during its active growth period. In addition, generation of smoke and the like can be thought of as varying with the seasons. If various free substances add their successive attacks of soiling in their peculiar seasons in the actual usage environment, it can be predicted that the main components of soiling will vary with the season. To probe the prevention functions for more soiling mechanisms, the authors are currently continuing observations in Aomori Prefecture, Chiba Prefecture and Kumamoto Prefecture with the cooperation of MGS, Sanzenkako and Sumika Agrotech Co.,Ltd., respectively.

In addition, with the understanding and cooperation of the national JA organization and production farmers, we are carrying out monitoring tests in actual cultivation environments.

4. New Protected Horticulture Technology

We are at the point where the concept of combining a coating film (hardware) that can last for a long time without a reduction in the superior light transmittance due to soiling and a soiling prevention method (software) operating through a new function that inhibits the growth of mold gives us expectations as a new protected horticulture technology that supports safety, health and security We will introduce examples of development on the following two points.

(1) Comfortable cultivation space overflowing with light touched by the breeze

Most Japanese protected horticulture is composed of simple facilities covered in plastic films, and the atmosphere differs form European protected horticulture, which is centered on glass greenhouses. In addition, they are circular arcs or gables with approximately 4 – 6 m between the spans, and work using agricultural machinery in the greenhouse is difficult leaving out some exceptions. Therefore, we attempted to achieve a comfortable cultivation environment that improves the labor effectiveness within the greenhouse. Sanzenkako, in cooperation with universities, construction companied and architectural designers, is progressing with a development project for a new plant cultivation structure (Active-House) that helps to reduce the force of wind without cost increases due to the increased size of the greenhouse or its being accompanied by deterioration of the inside environment, such as a reduction in the amount of solar radiation. In this project, the design was done based on an aerodynamic analysis, and a facility with a landmark structure with a wing profile cross section has been proposed. This has the strength to withstand a maximum wind speed of 50 m/sec., and it attempts to provide a near futuristic agricultural environment that gives maximum consideration to natural illumination and workability. Currently, a new plant culturing structure that is a combination of this prototype facility and a covering film that gives a soiling prevention function has been set up at the Kanagawa Prefecture Kanagawa Agricultural Academy, and various tests

Fig. 16 Active-house (prototype) in Kanagawa agriculture academy

are progressing (**Fig. 16**).

(2) Environmental protective protected horticulture aimed at food safety

Currently, we are progressing in the development of a comprehensive crop protection system that brings in the concept of an ecological system that includes insect pests. This is something that tries to maintain a safe agricultural environmental system that eliminates insect pests by a reciprocal combination of (1) chemical elimination (highly selective agricultural chemicals), (2) elimination through field husbandry (variety improvement, cultivation management), (3) physical elimination (traps, screens) and (4) biological elimination (using natural enemies). In addition, the target is elimination of sooty mold and black mold that cause sooty mold diseases and leaf mold diseases. What was found this time is that mold growth inhibiting functions using isolation of the source of nutrients reduce specific types of mold and have little danger of disturbing the ecological system. The authors have applied this technology to micro physical elimination and have thought in terms of inhibiting the growth of mold on the surfaces of various types of plastic present in protected horticultural environments. For example, if the surface of a mulching film is improved with mold resistance, we expect that there will be an effect of preventing the movement of molds that inhabit the area around the roots of the crops from moving to the plants with the scattering of water drops. At present, we are moving ahead with evaluations of the effects on the inhibition of the growth of mold in actual cultivation using a prototype coated with a mold resisting film on the surface of an existing polyethylene mulching film.

5. Outlook for Overseas Operations

In China, which is pulling along the world economy as the world's factory at present, the demand for food is expected to increase explosively with the modernization of lifestyles. From this outlook, there is an urgent need to improve the producibility of agricultural products, and to do so, there must be revolutionary improvements in variety improvement for plants and protected horticulture There is already said to be an area of 1,600,000 ha in protected horticulture in China, and in the costal areas which are near the areas with large consumption, there are large-scale farm facilities being operated with the introduction of agricultural technology being pushed forward by Israel and the like. This is an extremely attractive as a market for coating films. However, if we attempt to enter this large-scale market with existing protected horticulture technology, there will be no avoiding the problem of disposing of the waste film. In addition, if protection technology is insufficient, there is a possibility of many problems, such as effects on environmental pollution and wild animals, arising. The authors think that we should introduce advanced protected horticultural technology into to this Chinese market, which is hiding explosive growth. The new protected horticulture concept (facilities, covering film, cultivation management method) introduced this time is one that aims at establishing both improvements in productivity and safety and health, and it is based on the concept of wanting to help growth predicated on coexistence with the Earth's environment through reduction of resources and low environmental impact.

Operational planning is still at the market survey stage, but when the plan becomes specific, we are thinking in terms of obtaining the confidence of everyone from producers to distributors to consumers domestically and overseas with the development based on the ideas described above.

Conclusion

There is an attempt now to give the Cleantate brand, which as been established as a protected horticulture cover film, rebirth as a total brand that provides "agricultural comfort" (easy agriculture with high earnings, metropolitan agriculture that is related to healing, emotional agriculture that touches life itself and the like). The authors want to continue to increase the brand strength of Cleantate and move forward with development aimed at realizing the agriculture of our dreams.

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