Low-molecular-weight Polyolefins

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Polyolefin is the collective term for simple olefin based polymers, including polyethylene and polypropylene, which are used in films, containers, etc., that are essential in daily life. Polyolefins that are used as plastic in general include those with high molecular weights ranging from tens of thousands to hundreds of thousands. Meanwhile, low-molecular-weight polyolefins, with molecular weights less than tens of thousands, are types of wax, and show physical and chemical properties that are different from those of high-molecular-weight polymers. This article introduces features and examples of the application of our low-molecular-weight polyethylene 'SANWAX' Series and the low-molecular-weight polypropylene 'VISCOL' Series.

What is a wax?

While hair wax and car wax are the most familiar waxes to us, wax is a collective term for wax-like substances, and there are various different types. Its definition is "a substance [1] that is solid or semisolid at ordinary temperature with melting point at 40°C or higher, and [2] which melts without decomposing and has low viscosity when heated." The origin of the word wax is said to be "weax," which is Anglo-Saxon for beeswax, and its history goes back to 4000 B.C. Natural types of matter that had similar properties to beeswax were later found one after another, and paraffin wax and microcrystalline wax, which were purified from crude oil, and waxes synthesized from ethylene and propylene (synthetic waxes) came to be manufactured and distributed in the 20th century[1].

Waxes are made from various raw materials, and can be roughly classified into natural waxes, semisynthetic waxes, and synthetic waxes **(Table 1)**.

Natural waxes include beeswax and carnauba wax, which are derived from biological sources, and montan wax, paraffin wax and microcrystalline wax, which are derived from fossils (brown coal, crude oil). Since they are derived from natural sources, they have a wide range of compositional distributions, including molecular weight distribution, and require purification. Semisynthetic waxes are produced through synthesis while using natural substances as the raw materials. For example, amide wax is manufactured by a condensation reaction between fatty acid and amine. Synthetic waxes include polyethylene and polypropylene waxes, and they are manufactured by synthesis of petroleum raw materials (ethylene, propylene, and other monomers) or decomposition of polymers to reduce their molecular weight.

Applications of waxes are diverse, and they are used as raw materials or additives to many industrial products and daily commodities such as cosmetic products, printing inks, chemical paper, tires, flooring, and adhesives.

Synthetic waxes, in particular, possess physical properties that are easy to control, such as melt viscosity, since it is relatively easy to control their composition, even though they have similar properties to natural waxes. Since they can meet diverse needs, they are used quite often as industrial raw materials for paints, inks, adhesives, etc., for which application is actively developed.

Synthetic waxes can be classified into polymerization types and thermal decomposition types based on the manufacturing method. Polymerization types include single polymerization product of ethylene monomer and modified low-molecular-weight polyethylene prepared by copolymerization of ethylene and other polar monomers. Thermal decomposition types are the low-molecular-weight

Table 1 Classification of waxes

Natural wax				Semisynthetic wax	Synthetic wax
Derived from biological sources		Derived from fossils			
Animals	Plants	Brown coal	Crude oil		
Beeswax	Carnauba wax	Montan wax	Paraffin wax, microcrystalline wax	Amide wax	Low-molecular-weight polyethylene Low-molecular-weight polypropylene

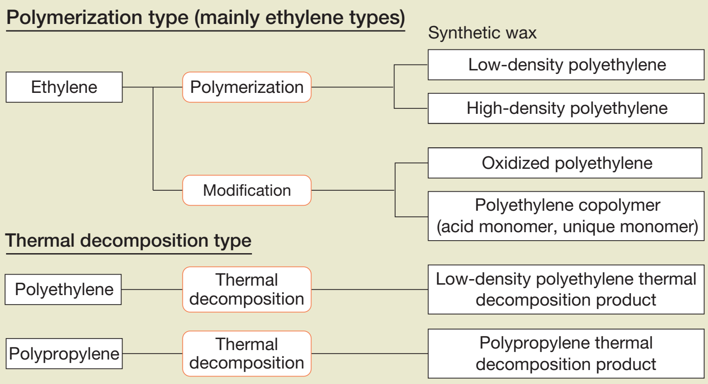


Fig. 1 Classification of synthetic waxes by method of manufacture

products of the decomposition of high-molecular-weight polyethylene resin or polypropylene resin with radicals **(Fig. 1)**.

'SANWAX' and 'VISCOL' Series

Our company manufactures and distributes the low-molecular-weight polyethylene 'SANWAX' Series, which was the first industrialized synthetic wax in Japan, and the low-molecular-weight polypropylene 'VISCOL' Series, which was developed by applying our technology **(Tables 2 and 3)**[1]. Both series have long-running products that are a half a century old since manufacture and release and that are still being utilized for their features. Please see the reference for the history of development and stories of the hardships the developers experienced at the time[2].

The 'SANWAX' and 'VISCOL' Series are thermal decomposition types, and have characteristics of [1] high softening points and high crystallinity compared to natural waxes, [2] excellent compatibility with polyolefin resins, [3] a wide range of molecular weight distribution due to being thermal decomposition types, and [4] relatively high compatibility with non-polyolefin resins **(Fig. 2, Table 4)**. Furthermore, the industrial processes of thermal decomposition are suited to small-quantity production compared to the industrial processes of the polymerization types, and can be minutely adjusted to meet various different needs.

Application examples of 'SANWAX' and 'VISCOL' Series

1. Pigment dispersing agent for plastic

While there is an extremely

Table 2 Typical properties of low-molecular-weight polyethylene 'SANWAX' Series

Product name	SANWAX 161-P	SANWAX 131-P	SANWAX 151-P	SANWAX 171-P
Appearance	White powder	White powder	White powder	White powder
Color number	30	30	30	30
Softening point (°C)	111	108	107	107
Penetration	2	3.5	4	4.5
Melt viscosity (mPa·s)	4,200	1,000	290	180
Weight average molecular weight	30,000	20,000	12,500	9,500

Color number: Hazen method, melting point: DSC method,
melt viscosity: measured with a BL type viscometer at 140°C
Molecular weight: High-temperature GPC method

Table 3 Typical properties of low-molecular-weight polypropylene 'VISCOL' Series

Product name	VISCOL 330-P	VISCOL 440-P	VISCOL 550-P	VISCOL 660-P
Appearance	White powder	White powder	White powder	White powder
Color number	200	200	200	1 (Gardner)
Softening point (°C)	153	153	152	145
Penetration	1 or lower	1 or lower	1 or lower	1.5
Melt viscosity (mPa·s)	4,000	1,800	200	70
Weight average molecular weight	40,000	30,000	15,000	8,000

Color number: Hazen method, melting point: DSC method,
melt viscosity: measured with a BL type viscometer at 160°C
Molecular weight: High-temperature GPC method

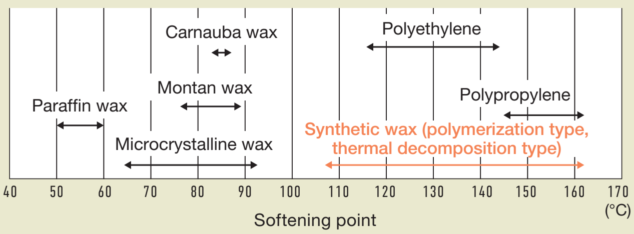


Fig. 2 Characteristics of synthetic waxes

Table 4 Structural characteristics of polymerization type and thermal decomposition type synthetic waxes

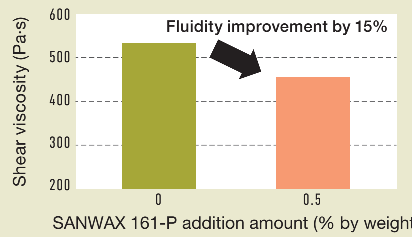
Manufacture method	Thermal decomposition type (method by our company)	Polymerization type (high pressure)	Polymerization type (low pressure)
Molecular weight distribution (Mw/Mn)	Wide (3 to 5)	Narrow (around 2)	Narrow (around 2)
Three-dimensional structure	Long-chain branching contained	Short-chain branching contained (normal methyl group)	Long-chain branching contained

large number of colorful plastic products that we see on a daily basis, the number of resin types that are used as the raw materials is actually small, and they mainly consist of polyethylene, polypropylene, ABS, etc.

When coloring plastic with pigments, etc., the dispersion of the pigment has a large effect on the quality of the molded product. However, simply putting pigments and resin together does not mix them well, but tends to generate uneven coloring[3]. Thus, the general method is to first prepare a master batch in which the pigments are dispersed at a high concentration, and add this to the resin as the coloring agent to mechanically knead by heating and melting (melting and kneading).

Use of the 'SANWAX' and 'VISCOL' Series can [1] prepare a high-concentration master batch with excellent pigment dispersion, as they have lower melt viscosity than the resins to be kneaded with and relatively high compatibility with pigments and resins. They also [2] have little effect on the mechanical properties of the resin as they have adequate molecular weights, and [3] excel in compatibility with the resin to be kneaded with. [4] Being nonpolar, they do not inhibit the color development of pigments and show stability in coloring. Thanks to such features, they are well-suited as pigment dispersing agents for plastic.

Photo 1 Colorfully colored plastic



Shear viscosity was measured (temperature: 240°C, shear rate: 608/sec) after kneading polybutylene terephthalate (PBT) resin and SANWAX 161-P (0.5% by weight), which were dried in advance at 130°C for 3 hours, in a twin screw extruder (temperature: 250°C).

Fig. 3 Formability (fluidity)

Table 5 Effects of 'SANWAX' addition on mechanical properties

Test item	No addition	SANWAX 161-P (addition of 0.5% by weight)
Shear viscosity (Pa·s)	533	458
Tensile strength (MPa)	54.7	54.1
Bending strength (MPa)	81.8	80.1

Measured according to tensile test: ASTM D638, and bending test: ASTM D790 after kneading in a similar fashion to Fig. 3 and molding in an injection molding machine (nozzle temperature: 250°C, die temperature: 50°C).

2. Machinability improver for plastic

Molded products of polyethylene, polypropylene, vinyl chloride (PVC), ABS, polybutylene terephthalate, etc., are normally manufactured by melting and kneading the resin as powder or pellets with additives such as stabilizers and fillers, extruding the mixture into the die and then cooling. The formability may deteriorate, e.g., if the fluidity is reduced because of frictional resistance between the melted resin and metal or the high melt viscosity of the resin during the melting and kneading process. There are issues such as a decrease in molding cycle (decrease in productivity) and failure to produce molding products with complex shapes if we try to improve the formability by adjustment of the die temperature or injection molding pressure.

Since 'SANWAX' and 'VISCOL' are low in viscosity, the addition of these during the molding process can improve the fluidity of the resin as they enter the interface between die and resin or the gaps in polymeric chains. As they deliver effects with the addition of a small quantity, they improve formability without reducing the mechanical properties of the resin **(Fig. 3, Table 5)**. Besides the performance described above, they are also used to improve the mold release characteristic of the molded products or add a lubricating property to PVC by utilizing their low polarity.

In recent years, manufacturers of transport machines, mainly in the automotive field, are showing the trend of replacing metallic components with resin components. Also, engineering plastics, which excel in heat resistance, mechanical strength, etc., are being used. In order to further improve the mechanical properties of engineering plastic, which by nature has poor fluidity and formability in the melted state, in more and more cases, composite materials are being applied with fillers that have high aspect ratios such as glass fiber and carbon fiber. While needs are currently growing for high- concentration filling with these fillers, high filling with the filler material increases the overall viscosity of the composite material, and may cause productivity decrease or appearance defects.

'SANWAX' and 'VISCOL' are also effective in engineering plastic filled with high-concentration fillers, and can improve

Photo 2 In molded plastic products

Photo 3 As matting agent/water resistance-imparting agent in gravure ink raw materials for food packaging films and molded components

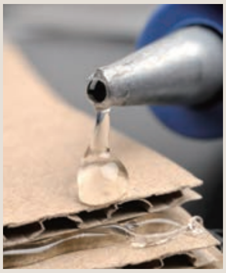


Photo 4 In hot melt adhesives

productivity without reducing the mechanical properties of the composite material by improving fluidity with the addition of a small quantity.

3. Modifier for paints and printing inks

The design properties have large effects not only on the functions but also on the manner of consumption in the field of paints and printing inks. A matted appearance with delustering is often demanded. Luster is determined by surface evenness, and becomes matted once a certain level of unevenness is present.

When 'SANWAX' and 'VISCOL' polyolefin waxes are used in paints, the wax particles form unevenness on the surface of the coating film and diffuse the light to give the delustering effect. They also provide a uniform delustering effect when combined with delustering agents such as silica by preventing the precipitation of the agents and keeping them on the surface. In addition, improvement in coating film durability can be expected, as polyolefin waxes are hydrophobic, and the wax components oriented on the surface waterproof the paint surface, adding mold prevention and antifouling.

Paints and inks normally have poor sealing properties with nonpolar molded products, sheets, films, etc., typical of which is the OPP film. However, 'SANWAX' and 'VISCOL' have high affinities to such nonpolar materials and can add a favorable sealing property to such films and sheets by using them as components of paint or ink.

4. Additive for hot melt adhesives

Although hot melt adhesives are environment-friendly adhesives which can reduce volatile organic compounds as they do not contain solvents, they have the disadvantage of decreasing in adhesive strength when the environmental temperature (ambient temperature) increases after adhesion, as they have low melting points and are thermoplastic. 'SANWAX' and 'VISCOL' have higher melting points than hot melt adhesives and thus can mitigate the effects of adhesive strength deterioration under high temperatures when used as additives. Since they are also low in viscosity, they can be used to easily adjust the viscosity of the adhesive, making them easy to handle like other normal adhesives.

Future prospects

Even though low-molecular-weight polyolefins are already used in diverse applications, we believe that they still have enough potential for further application developments. In the recent years, resin replacement of metallic components is being advanced mainly in the automotive industry, and their importance as molding aids to improve the production speed, yield, and formability of molded products has also increased. We will continue to devote our efforts to providing and developing products that meet such needs.

Reference

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