

ATO anti- static coating inks and coated films

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ABSTRACT

Recently, the anti- static property is required to plastics. We manufacture various anti-static coating inks consisting of fine Sb doped tin oxide (ATO) particles.

This paper deals with the properties of some anti- static coat on plastic films with high hardness and high transparency.

1. Introduction

Plastics are workable, lightweight, and rust-preventive and have other ideal properties. They also have a few drawbacks, such as collecting static electricity, dust and dirt, and being scratched easily. Hard coating performance is often required of acrylic and other transparent plastics as a scratched surface has a direct impact on the commercial value. In addition, there is a new, growing need for anti-static performance to prevent adhesion of dust on products in which light reflection is critical.

Our company manufactures and markets various transparent anti-static paints for plastics, based on proprietary ultrafine particle dispersion technology. Among them are the thermosetting anti-static lacquer paints and hard-coating UV setting paints. Both produce anti-static performance when applied on the substrate and only require minimum coating cost.

These anti-static, transparent paints for plastics are introduced below.

2. Hard Coating and Anti-static Performances

Hard coat can be produced by direct coating, transfer of hardened film, lamination, and other methods. The direct coating methods generally include vacuum processes (vacuum metallizing, sputtering), thermosetting processes (silicone, melamine, urethane, and other liquids), and UV or electron radiation curing processes (polyester acrylate, urethane acrylate, epoxy acrylate, and other multi-func-

tional acrylate coating liquids). Today, UV setting processes are most commonly used because of their high productivity, surface hardening, and durability qualities.

Anti-static mechanisms may be roughly divided into two types; the ion conduction type in which an electric current is produced by the molecules, ionized by airborne moisture, as they travel inside or the surface of a substance, and the electron conduction type in which electrically-conductive oxides play the role. The ion conduction type is susceptible to the moisture and other environmental conditions and thus lacks stability in providing anti-static performance. In contrast, the electron conduction type is virtually non-susceptible to environments and thus provides stable performance.

The electrically-conductive oxides generate an electric current by the movement of the electrons or electron holes created by crystal defects. The electric passage is formed by contact between the electrically-conductive oxides, which include tin oxides, antimony doped tin oxides (ATO), zinc oxides, antimony oxides, indium tin oxides (ITO), etc. Among them, ATO is commonly used for anti-static purposes.

The UV setting paints manufactured by our company are single-package type paints that provide both hard coating and anti-static performances.

3. UV Setting Paints

3.1 Main Features and Properties

Our company's proprietary ultrafine particles are dispersed in the UV setting paints to produce high transparency and low haze levels. The same ultrafine particles are already used in the anti-static coat for CRT surfaces where

high transparency and low haze levels are critical.

Table 1 shows different types of anti-static UV setting paints and their typical properties. Their surface resistivities range from 10^7 to $10^{10}/\square$ at 22°C and 50%RH. The main agents are ketone for R-307 through R-310, and ketone/alcohol for R-408 and R-410. Best protection can be provided by R-408 and R-410 for polycarbonate (PC) that are easily damaged by organic solvents.

Table 1 Anti-static UV setting paints and their typical properties (PET 50μm, film thickness 1μm)

	R-307	R-308	R-309	R-310	R-408	R-410
Surface resistivity (Ω/\square)	5×10^7	3×10^8	4×10^8	5×10^{10}	3×10^7	5×10^{10}
Total light transmission (%)	88.9	87.4	89.0	90.0	87.4	90.0
Haze (%)	0.7	0.7	0.7	0.7	0.7	0.7
Pencil hardness	F~H	H~2H	H~2H	H~3H	H~2H	H~3H
Dispersant		Ketone			Ketone/alcohol	

Fig. 1 shows time change (liquid) of surface resistivities of R-308 and R-310. The surface resistivity change after 60 days at room temperature is only minimal for both R-308 and R-310, indicating that they are in stable conditions.

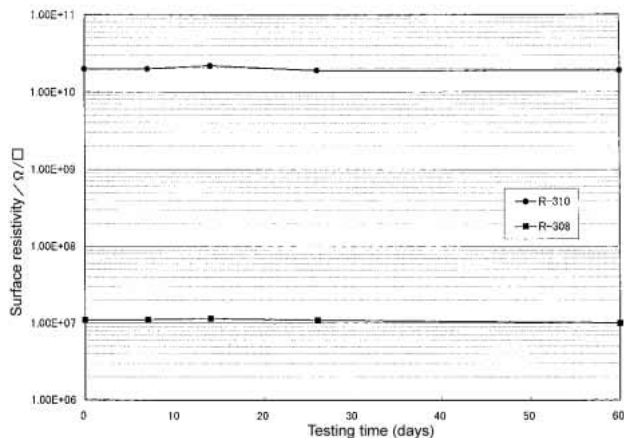


Fig. 1 Time change of surface resistivity of R-308 and R-310 (PET 50μm, film thickness 1μm)

The paint properties are given below.

Appearance : Dark blue

Resin : UV setting resin

Specific gravity : 0.9~1.0

Viscosity : 1.6~3.2mPa.s

Main solvent : Ketone, ketone/alcohol

The film forming conditions are as follows:

Substrate : PMMA, PC, PET, etc.

Application method : Bar coat, reverse coat, flow coat, spin coat, etc.

Optimum thickness : 1~5μm

Drying method : Hot drying (50°C) 30sec~5min

Setting method : High-voltage mercury lamp (110W/cm) 20~30sec

3.2 Film Performance

The surface resistivity of the UV set film is hardly affected by humidity because electron conduction is caused by the filler. The surface resistivity is 10^7 to $10^{10}/\square$ and, when 10kV is applied by a static meter, the electric charge is discharged instantly. This proves high anti-static performance. The hard coat quality by pencil hardness was H~4H (4H with PMMA substrate), and anti-scuffing performance with steel wool was good.

Table 2 shows the temperature dependence of surface resistivity of R-308 coat (50%RH per JIS L1094) using a 50μm PET substrate.

Table 2 Temperature dependence of surface resistivity of R-308 coat (PET 50μm, film thickness 1μm).

Temperature (°C)	10	40
Surface resistivity (Ω/\square)	4.0×10^7	3.8×10^7

The surface resistivity was nearly identical between 10°C and 40°C.

Table 3 shows the results of heat resistance test of R-308 with 50μm thick PET (treating time: 2 hours; measuring environments: 22°C, 50%RH). The surface resistivity remained virtually unchanged after the treatment at -30°C or 150°C, proving good heat resistance.

Table 3 Results of heat resistance test of R-308 (PET 50μm, film thickness 1μm)

Temperature (°C)	-30		150
Surface resistivity (Ω/\square)	Before treatment	4.0×10^7	4.0×10^7
	After treatment	4.5×10^7	3.7×10^7

Table 4 shows the results of chemical resistance test of R-308 and R-310 (immersion time: 10 minutes; measuring environments: 22°C, 50%RH). The surface resistivity re-

Table 4 Results of chemical resistance test of R-308 and R-310 (PET 50μm, film thickness 1μm)

		Boiling water	Ethanol	Acetone	Toluene
R-308	Surface resistivity before test (Ω/\square)	1.5×10^8	1.7×10^8	1.8×10^8	2.4×10^8
	Surface resistivity after test (Ω/\square)	0.9×10^8	1.8×10^8	1.5×10^8	2.4×10^8
R-310	Surface resistivity before test (Ω/\square)	2.5×10^{10}	2.8×10^{10}	3.1×10^{10}	3.9×10^{10}
	Surface resistivity after test (Ω/\square)	2.9×10^{10}	2.8×10^{10}	3.1×10^{10}	3.7×10^{10}

mained virtually unchanged in boiling water, ethanol, acetone, or toluene, proving good chemical resistance.

Fig. 2 shows the results of weather resistance of R-308 and R-310 using a carbon arc type weatherability tester (JIS K5400). The films proved to be durable to the UV rays and the total transmission rate virtually remained unchanged after 600 hours on the fade-meter. The surface resistivity somewhat lowered but did not present any functional problem.

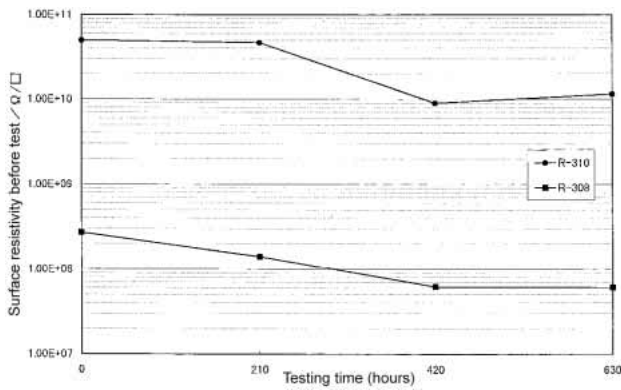


Fig. 2 Results of weather resistance test of R-308 and R-310 (PET 50μm, film thickness 1μm)

4. Thermodyring Anti-static Paints

4.1 Types and Properties

Table 5 shows the types of thermodyring anti-static paints and their properties. Roughly, there are five types; environment-friendly water-based type (C-331, C-332), solvent type with polyester resins (C-226), solvent type with vinyl chloride resins (C-210) and solvent type with cellulose resins (C-401). Although they do not give sufficient hardness required of hard coating, their film transparency is quite remarkable with the transmission rate of 98% or higher, haze value of 0.3% or lower, and the surface resistivity can be adjusted freely in the $10^9\sim 10^{11}/\square$ range. C-331, C-332, and C-401, in particular, can produce films in the low resistivity range of $10^6/\square$. Binders and resistivities can be selected according to the substrate type and application.

Table 5 Types of thermodyring anti-static paints and their properties

Product No.	C-201	C-226	C-331	C-332	C-9401
Conductive components			Conductive metal oxide		
Binder	Vinyl chloride	Polyester	Polyester	Polyester	Cellulose
Dispersant	Ketone	Ketone	Water	Water/alcohol	Ketone
Setting temperature			100°C		
Film properties			$10^9\sim 10^{11}(\Omega/\square)$		
Surface resistivity(Ω/□)					
Total transmission rate			98% min.		
Haze value			0.3% max.		

4.2 Water-based paints for plastics are environment-friendly and their demand is expected to grow.

Table 5 shows properties of C-331 and C-332 by the surface resistivity at 22°C and 50%RH. The surface resistivity can be adjusted freely in the $10^6\sim 10^{12}/\square$ range with good transparency and film adhesion.

Table 6 Surface resistivity of C-331 and C-332 (PET 50μm)

Type	Surface resistivity(Ω/□)	Total transmission rate (%)	Haze value (%)	Cross-cut (JIS K5400)
10^6	$4.7\sim 6.7 \times 10^6$	88.8	0.8	100/100
10^7	$2.7\sim 3.6 \times 10^7$	89.0	0.8	100/100
10^8	$1.1\sim 2.6 \times 10^8$	89.5	0.8	100/100
10^9	$1.3\sim 2.3 \times 10^9$	89.8	0.8	100/100
10^{10}	$1.0\sim 5.9 \times 10^{10}$	89.9	0.9	100/100
10^{12}	$1.3\sim 1.5 \times 10^{12}$	90.2	0.9	100/100

Note: Total transmission rate and haze value include those of the substrate (PET substrate: total transmission rate 90.4%, haze value 0.6%)

Table 7 shows the results of water resistance and alcohol resistance tests of C-331 and C-332 at 22°C and 50%RH. The film's water resistance is good after setting at 100°C for 10 minutes. The alcohol resistance is not sufficient after setting at 100°C for minutes, and heat treatment to 140°C or higher is necessary. Some data indicate a higher haze value under higher heat treatment temperature. This is because heat treatment was introduced immediately after the paint was applied. The haze value can be reduced to a practically acceptable level if preheated at 50°C.

Table 7 Results of water and alcohol resistance test of R-331 and R-332 (PET 50μm, film thickness 1μm)

Heat treating temperature(°C)	100	140	150
Surface resistivity (Ω/□)	$1.1\sim 2.6 \times 10^8$	$1.0\sim 1.8 \times 10^8$	$1.1\sim 2.3 \times 10^8$
Total transmission rate (%) Note1)	89.8	89.4	88.8
Haze value (%) Note 1)	0.8	1.8	4.3
Cross-cut (JIS K5400)	100/100	100/100	100/100
Surface resistivity after water resistance test (Ω/□) Note2)	2.6×10^8	1.9×10^8	2.1×10^8
Surface resistivity after alcohol resistance test (Ω/□) Note2)	2.0×10^9	3.7×10^8	4.3×10^8

5. Conclusions

A growing demand exists for anti-static films on plastics having higher transparency and anti-static performance. But it is not easy to meet both requirements using the existing techniques.

Our company succeeded in developing paints capable of producing highly transparent and anti-static films using the proprietary ultrafine particle manufacturing and dispersion techniques. The resulting products can be applied on various plastic substrates by means of dip, gravure, spin, and other coating methods. In short, they can produce high-performance, anti-static films easily as well as inexpensively.

This technology is expected to contribute to providing anti-static functions to the display protective plates, building materials for clean rooms, plastic lenses, etc.