

Development of a UV-Curable Insulating Coating Agent ARONIX UVX-5800

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1. Introduction

As the mounting density on circuit boards increases due to miniaturization, weight reduction, and sophistication of electronic devices, the distance between conductors (electrode spacing) is becoming smaller¹⁾. This makes it easier for insulation defects to occur due to factors such as moisture and dust. Therefore, insulating coating agents such as acrylic resin and silicone resin are applied on the circuit board to improve insulation reliability.

For example, in the case of large-screen flat-panel TVs, insulating coating agents are used at the interface between the Flat Panel Display (FPD) panel and the Flexible Printed Circuit (FPC) (Figure 1)²⁾.

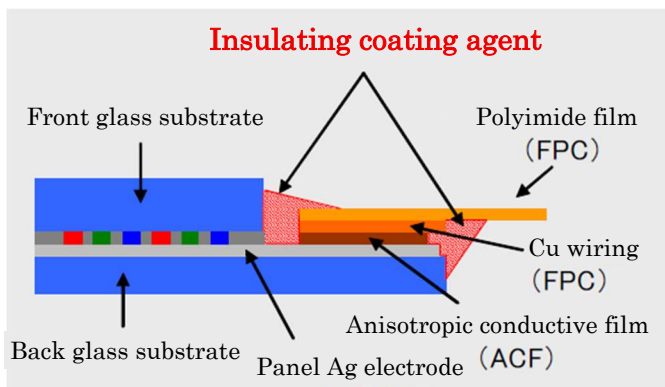


Figure 1: How insulating coating agent is used (example)

There are trends toward narrower pitches between panel electrodes and higher voltages in flat panel TVs²⁾, which are becoming increasingly higher in definition, and ion migration (hereafter “migration,” a phenomenon in which electrode metal migrates and precipitates inside or on the surface of insulating materials when voltage is applied to the system where electrodes and insulating materials are in contact^{3),4)} is more likely to occur. Therefore, insulating coating agents are required to mitigate this phenomenon.

In the case of the above coating agents, not only insulation reliability but also adhesion to the substrate (glass or polyimide film) is essential. In some cases, the ability to visually observe the electrodes through the coating agent was also an important requirement so that they could observe the state of migration.

Since conventional insulating coating agents could not satisfy the above characteristics, we developed this product.

This article introduces the mechanism of migration in systems using silver electrodes, which are generally known to be prone to migration, and summarizes the characteristics of the UV-curable insulating coating agent ARONIX UVX-5800 that we have developed.

2. Mechanism of migration

As shown in Figure 2, migration can be divided into three phenomena: dissolution of silver metal, migration of silver ions, and precipitation as silver metal,^{3),5)}

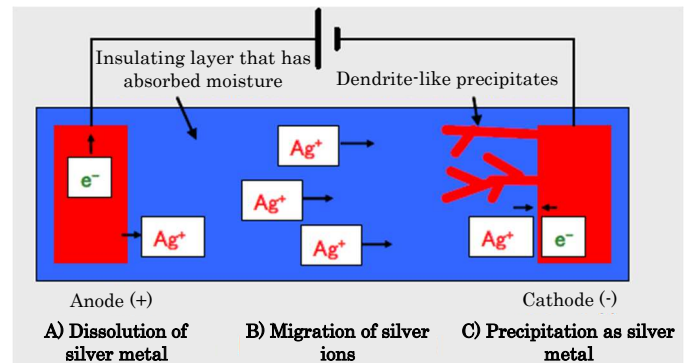


Figure 2: Mechanism of migration

A) Dissolution of silver metal

When DC voltage is applied between the electrodes and the insulating layer between the electrodes has absorbed moisture, an oxidation reaction (anodic reaction) that releases electrons occurs at the anode interface. In other words, an ionization-dissolution reaction is thought to occur through self-oxidation of the silver metal.



Despite its high standard electrode potential of 0.799 V (vs. SHE) and its known reluctance to form cations, as indicated by its position in the ionization series, silver is regarded as a metal prone to migration.

Table 1: Standard electrode potentials in aqueous solution E⁰ (V)/25°C⁶⁾

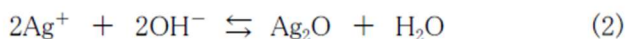
	Standard electrode potential E ⁰ (V)
Fe ²⁺ + 2e ⁻ = Fe	-0.44
Ni ²⁺ + 2e ⁻ = Ni	-0.257
2H ⁺ + 2e ⁻ = H ₂	0.000
Cu ²⁺ + 2e ⁻ = Cu	+0.340
Ag ⁺ + e ⁻ = Ag	+0.799
Au ⁺ + e ⁻ = Au	+1.83
Ag ⁺ + e ⁻ = Ag	+0.799
AgCl + e ⁻ = Ag + Cl ⁻	+0.222
AgBr + e ⁻ = Ag + Br ⁻	+0.071

One reason for this is the presence of halide ions. Silver metal is more easily dissolved when in the presence of halide ions, because the halide formation reaction, which has a lower electrode potential, occurs preferentially in equilibrium (Table 1).

B) Migration of silver ions

Silver ions (Ag⁺) that have dissolved out from the anode react with hydroxide ions (OH⁻) to form silver oxide (Ag₂O), which disperses in colloidal form. On the other hand, silver oxide colloids form silver ions again by hydration reaction.

That is, silver that dissolved at the anode exists as silver oxide and silver ions in the insulating layer that has absorbed moisture.



Silver ions move between electrodes by electrophoresis or diffusion driven by concentration gradients, while silver oxide moves between electrodes by diffusion alone.

In migration, electrophoresis is said to have a greater influence than diffusion³⁾.

C) Precipitation as silver metal

Silver ions that migrate between the electrodes and reach the cathode receive electrons from the cathode and precipitate as silver metal.

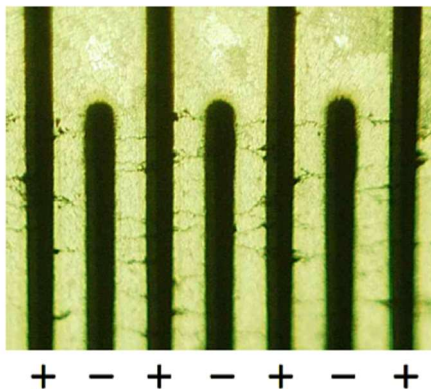
Silver ions that reach the cathode interface sequentially receive electrons and precipitate as silver metal, causing the precipitate to grow.

Because silver ion concentration increases with distance from the cathode interface, the tip of any protrusion that has begun to form is exposed to a higher silver ion concentration than the flat cathode interface. More frequent contact with silver ions causes the precipitate to grow in a branch-like shape.

Once the branches grow to a certain extent, silver ions that have entered the gaps between them deposit from the interior, forming additional sub-branches. As this process repeats itself, dendrite-like precipitates with multiple branches grow from the cathode toward the anode.

When this reaches the anode, a short circuit occurs.

Photo 1 shows an example of dendrite-like precipitates.



Cathode tip after insulation reliability test
Photo 1: An example of dendrite-like precipitates (transmitted light method)

As ways to control migration by improving the insulating coating agents, the following three points are considered particularly important.

1) Reduction in water absorption and moisture permeability:

To prevent dissolution of the silver electrode and migration of silver ions.

2) Reduction in halide ion concentration:

To prevent dissolution of the silver electrode.

3) Improvement in adhesion to the substrate:

To leave no gap at the interface between the substrate and the coating agent.

3. Characteristics of ARONIX UVX-5800

3.1 General characteristics

ARONIX UVX-5800 is a UV-curable insulating coating agent that combines moisture-proof performance and adhesion to polyimide, two properties that have been difficult to achieve simultaneously in the past. Table 2 shows the general characteristics of UVX-5800 and its cured product.

Photo 2 shows an image of UVX-5800 coated on a glass substrate with silver electrodes (comb-shaped, L/S = 50 μm/50 μm) (coating agent thickness = 2 mm).

Through the use of high-purity raw materials and specialty acrylates, UVX-5800 contains very few ionic impurities, and its cured product shows lower moisture permeability than ordinary acrylic polymers.

In addition, we used an existing adhesive with high adhesion to glass and polyimide as a comparable example.

Table 2: General characteristics of ARONIX UVX-5800 and its cured product

		UVX-5800	Comparison example
Solution viscosity/25°C (mPa·s)		3,000-6,000	3,000-6,000
Cured product Tg (°C) ^{a)}		24	15
Water absorption of cured product (%) ^{b)}		1.8	3.6
Moisture permeability of cured product (g/m ² ·24 h) ^{c)}		13.5	27.0
Ionic impurities concentration (ppm)	Chloride ions ^{d)}	1.8	2.0
	Sodium and sodium ions ^{e)}	0.5	0.5

• UV curing conditions: Metal halide lamp; irradiation light intensity = 0.2 W/cm² (UV-A); irradiation energy = 1 J/cm² (UV-A)

a) Temperature at tanδ maximum, measured at a frequency of 1 Hz

b) Immersion conditions: 24 hours at 40°C

c) Evaluation method: In accordance with JIS Z 0208 (40°C, 90% RH, film thickness = 2 mm)

d) Evaluation method: Ion chromatography

e) Evaluation method: ICP mass spectrometry

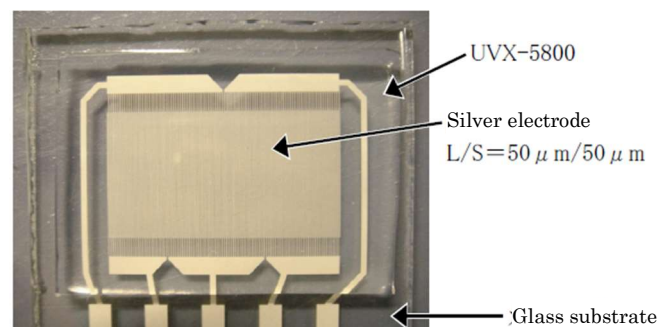


Photo 2: UVX-5800 coated on a glass substrate with comb-shaped silver electrodes

3.2 Adhesion to the substrate

3.2.1 Adhesion to polyimide

Figure 3 shows the 180° peeling strength of the cured product formed by injecting UVX-5800 between polyimide (Kapton 100H: Du Pont-Toray) and adhesion-modified PET (A4300: TOYOBO Co., Ltd.) so that the thickness of the coating agent was 2 mm and UV-curing it through A4300, and that of the cured product to which thermal shock (liquid bath: -40°C ↔ +85°C; immersion time = 30 minutes each; number of cycles = 20) was applied.

The 180° peeling strength of UVX-5800 before and after the thermal shock test was quite high at 9.0 N/cm and 14.6 N/cm (both peeled off from the interface between the coating agent and polyimide), and the peeling strength did not decrease after thermal shock. The increase in peeling strength after the thermal shock test is presumed to result from internal stress (generated by curing shrinkage) being relaxed under the heat of the test.

UVX-5800 is expected to be suitable for precision equipment such as cell phones and digital cameras that use FPCs.

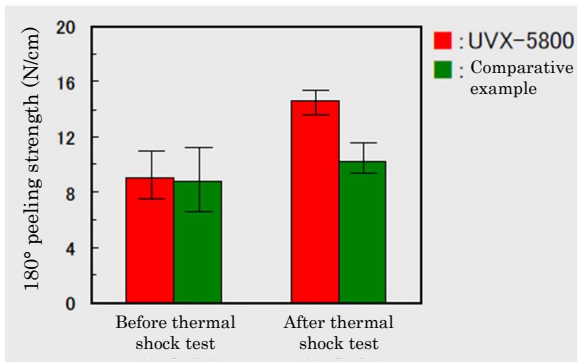


Figure 3: Adhesion to polyimide

3.2.2 Adhesion to glass

Figure 4 shows the tensile bond strength of two cured products: one formed by injecting UVX-5800 between two glass substrates, resulting in a coating agent thickness of 2 mm, and UV-curing it, and a second to which thermal shock was applied.

The tensile bond strength of UVX-5800 before and after the thermal shock test was very high at 279 N/cm² and 293 N/cm² (in both cases, failure occurred at the interface between the coating agent and glass), and peeling strength did not decrease even after thermal shock is applied. UVX-5800 is therefore expected to find use in applications involving glass substrates, such as displays.

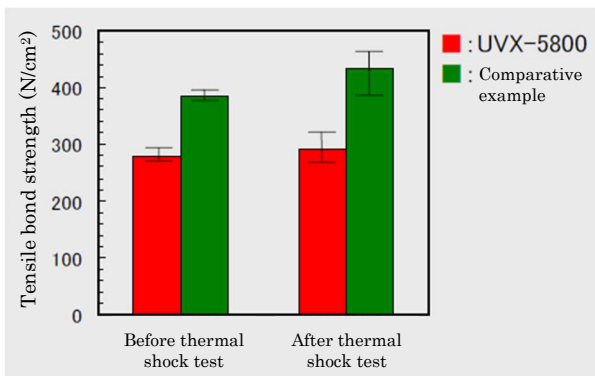


Figure 4: Adhesion to glass

3.3 Insulation reliability

Figure 5 shows the change in resistance over time, measured by applying a voltage of 80 V to the sample shown in **Photo 2** in an environment of 40°C and 80% RH; **Photo 3** shows the state of the silver electrode after this test.

UVX-5800 maintained favorable resistance after 1,000 hours (**Figure 5**). After the insulation reliability test, no dendrite-like precipitates or changes in electrode width were observed on the electrode substrate (**Photo 3**), indicating that UVX-5800 has high insulation reliability.

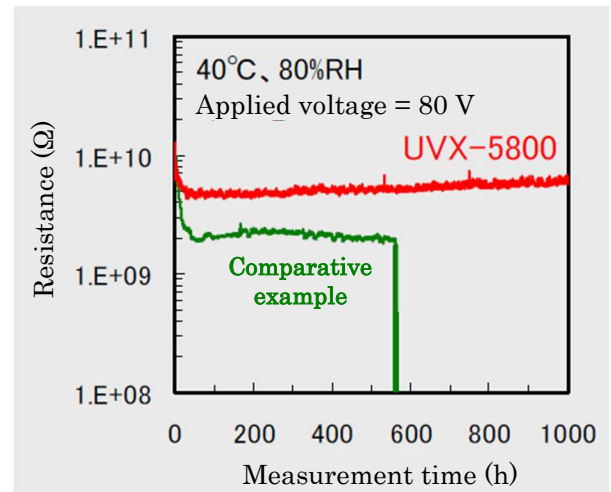
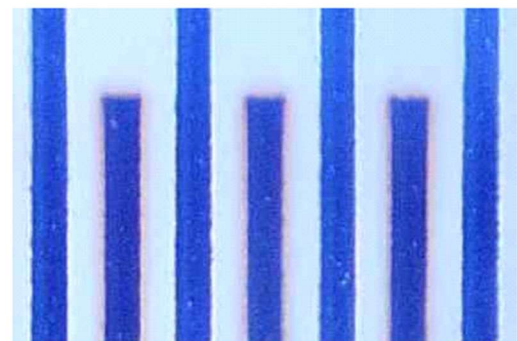
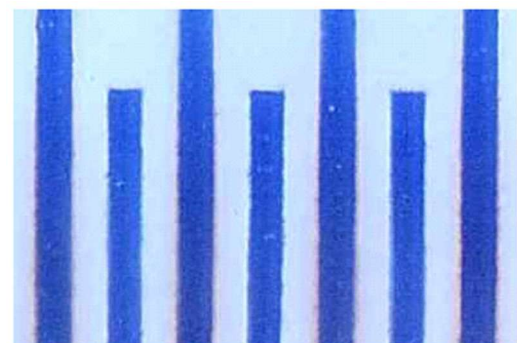


Figure 5: Insulation reliability test results



a) Anode tip after testing



b) Cathode tip after testing

Photo 3: Silver electrode after insulation reliability test (transmitted light method, L/S = 50 μm/50 μm)

4. Conclusion

The UVX-5800 we have developed shows good adhesion to polyimide and glass, and excellent insulation reliability, making it well-suited for insulating coatings on precision devices such as cell phones and digital cameras, as well as on displays.

#Characteristics:

- Low moisture permeability
- Low level of ionic impurities
- Favorable adhesion to polyimide and glass
- Excellent insulation reliability

5. Reference

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