

Development of the All-Surface Plated Smart Handle Through In-Vapor Deposition Technology

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ABSTRACT

There are such outside door handles called smart handles which have a transmitting antenna, a lock/unlock sensor, and a sensor detection circuit, with which operation of door lock is possible just by "touching" the electrostatic-capacitance type sensor of the handles. As the design of the outside handles, body color painting and Cr plating are adopted. However, if plating is applied over the entire surface of a smart handle, electromagnetic waves transmitted from the antenna will be blocked since plating material is electrically conductive. In addition to this, touching a part other than the sensor may change the electrostatic-capacitance of the sensor, which results in unwanted functioning of the lock/unlock sensor. Because of this, only part of the handle, which does not hinder the transmission of electromagnetic waves and does not cause unwanted functioning, is covered by plating, that is called, "Partially plated specifications" (Figure 1).

However, there is a strong demand for plating of the entire surface in Asia and North America, and we are receiving such requests from our customers.

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COATING COMPATIBLE WITH PLATING OF ENTIRE SURFACE

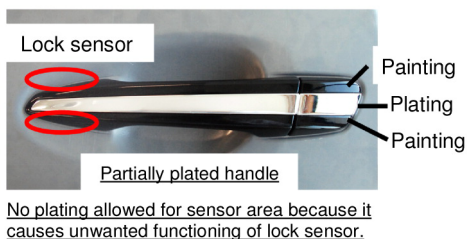
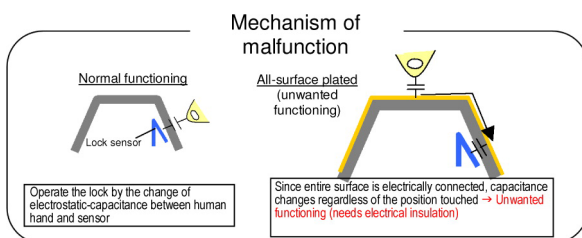


Figure 1. Mechanism of unwanted functioning

Conditions of "coating" for avoiding the malfunctions of the smart handle with plating of entire surface are as follows:

1. Design property equivalent to Cr plating
2. Insulation so that it does not hinder the transmission of electromagnetic waves from the antenna and does not cause unwanted functioning of the sensor.

Metal plating has to be employed to attain (1) the plating design property in the first place, but the continuous metal film is electrically conductive, therefore, it cannot obtain (2) enough insulation. However, we focused on the fact that all we need is an insulated coating, and decided to divide the metal coating with minute and independent blocks so that the insulation can be achieved structurally. We investigated the metal film with the island structure of In (indium) by a vacuum vapor deposition method (referred to as "vapor deposition" hereinafter). It is well known that In forms an island structure when forming a film deposited by vapor deposition. Each of these islands reflects light so that (1) the plating design property can be obtained, and because islands are independent with each other, (2) insulation can also be achieved (Figure 2).

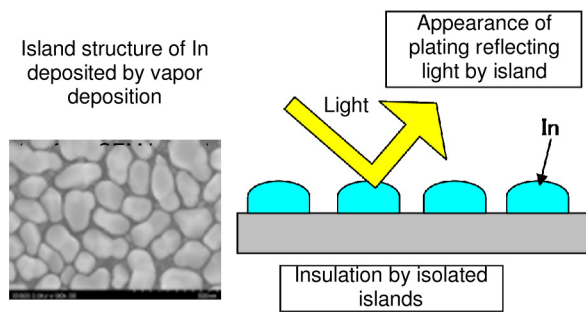


Figure 2. Coexistence of plating design property and insulation

QUALITY TARGET

The quality target is a design property equivalent to Cr plating and antenna/sensor functions equivalent to painted smart handles. Regarding exterior standards, we set the quality target required by customers through discussions. (Table 1)

Table1. List of quality targets

Evaluation item			Target
Design	Appearance		Equivalent to Cr plating $78.75 \leq L \leq 84.01$ $-1.0 \leq b \leq 2.5$
	Skin(flatness)		Body color Equivalent to painted products
Transmission of electromagnetic wave Sensor performance	Electrical insulation		More than or equal to $10^6(\Omega/\square)$
	Transmission of electromagnetic wave		Equivalent to painted products
	Electrostatic-capacitance sensor		No unwanted functioning
Exterior standards	Corrosion resistance	Salt spray test	No corrosion for 720h
		CCT	No corrosion for 120 cycles
	Weatherability	Accelerated weathering test(Xe500MJ+heat and humidity cycle(5cycle)+250MJ)	$\Delta E \leq 3$ No peeling(secondary adhesion)
		Outdoor weathering test(Place:Okinawa, Arizona)	1.5years $\Delta E \leq 3$
	Scratch resistance	Scratch resistance test	No change by visual inspection
	Adhesion property,water resistance,chemical		Within standard values

STRUCTURE OF COATING

Because the In island-structure metal film deposited by vapor deposition is a thin film with thickness of an order of several tens of nm, protection of the metal thin film is necessary to obtain the endurance required by

automobile exterior standards for outside door handles. We, therefore, investigated the three layered structure of undercoating/In film/top coating. Technical issues are as follows (Figure 3).

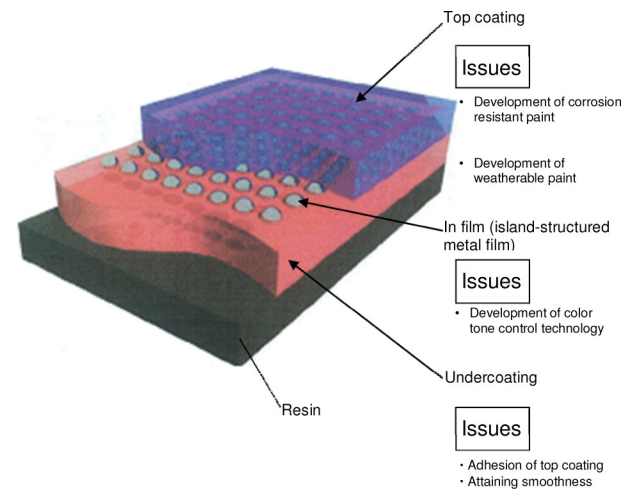


Figure 3. Coating structure and technical issues

ISSUES OF PAINTS AND COUNTERMEASURES

In this paper, countermeasures against the issues of top coating mentioned above i.e., improvement of corrosion resistance, weatherability and scratch resistance will be discussed as an example of the development of paints.

Regarding the corrosion resistance, if metal film is continuous, for example, permeation of water through a scratch causes corrosion of a part of the metal film which can spread laterally. In this regard, an island-structured In metal film can have a higher corrosion resistance because it has islands that are independent of each other preventing the lateral spread (to the neighboring islands) of corrosion even if corrosion of a certain island takes place, provided the adhesiveness of the top coating and undercoating at the gaps of islands is good enough (Figure 4). To obtain good adhesiveness of the top coating and undercoating to improve corrosion resistance, we made use of the hydrogen bond in this study, which takes place between the curing agent of the top coating and the uncured part of the undercoating during the cure of the top coating. The existing curing agent of the top coating has a high probability of reaction with a monomer which exists abundantly in the top coating, resulting in only a small portion of the curing agent reacting with the uncured part of undercoating. We, therefore, slightly reduced the reactivity in the top coating (retarding the reaction) so that less curing agent is consumed by the reaction in the top coating, thereby promoting the hydrogen bond between the undercoating and the top coating. To realize this, the reaction rate of the hydroxyl group (-OH) in the top coating with isocyanate (-NCO) in the curing agent was reduced by changing the position of the hydroxyl group of the monomer component of the top coating to form a higher steric hindrance of the carbon chain (from primary to secondary) (Figure 5). Further more, the volume of the hydroxyl group(-OH) within undercoating was larger than