IMPROVING OF COVERING POWER OF TITANIUM WHITE COVER COAT BY CONTROLLING BUBBLE STRUCTURE

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Improving of Covering Power of Titanium White Cover Coat by Controlling Bubble Structure

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Abstract Titanium white cover coat is required to produce stable white color development without a lack of hiding substrate and with less coating thickness. The basic mechanism of titanium cover coat is to disperse crystals of titanium dioxide well in glass structure so as to promote a good white color development. Therefore, it significantly affects the covering power of titanium cover coat whether a sufficient number of the crystals are dispersed or not in the glass structure. Chemical compositions of the cover coat frit, milling formula and firing conditions are key to a good color development, and another factor critical to covering power is bubble structure in enamel layer or a number and size of bubbles. Bubbles in enamel layer generate diffused reflection which may supplement covering power of titanium dioxide. The amount of soluble salts in enamel, clay content and firing conditions affect the final bubble structure.

Key words covering power, cover coat, titanium dioxide, clay, bubble structure

Introduction

In general, enamelware of sheet steel is coated and fired with ground coat and cover coat and is widely used for electric appliances, cookware, architectural panels, etc. Cover coat has various colors: white, ivory, yellow, green, red, blue and so on, and the most popular color is white. Titanium white cover coat sometimes causes defects about covering power. For instance, too thin coating cannot hide the dark color of ground coat enough so that the dark color is seen through cover coat after firing. This defect is caused by a) inadequate amount of titanium dioxide in frit composition, b) improper milling formula or c) wrong firing conditions. These factors may produce insufficient bubble structure in enamel layer. It is estimated that an amount and size of bubbles in enamel layer affect covering power of the cover coat. How bubble structure affects the covering power was studied.

Test conditions

a) Milling Fomula

Titanium cover coat frit (TMW-130 from TOMATEC)		100	(wt%)
Mill additions:	Clay	6	
	KCl	0.1	
Water		50	

b) Fineness of grinding: Residue 2 – 4grams/50ml/200mesh sieve
Ground by ball mill (2/1000 model from MMS)
c) Firing conditions: at 830 degrees C. for 3 minutes
d) Sheet steel: 150x100x0.8mm (JEF-CPE1D1 from JFE Steel)
e) Spray gun (W-200G from Anest Iwata)
f) Furnace by electric oven
g) Colorimeter (SME-100 from Sanko Electronic Laboratory)
h) Grinder (METASERV2000 from Buehler)
i) Optical metallograph (BX51M from Olympus)

The cover coat enamel slip prepared as above was applied on fired ground coat and fired for observations of properties to be discussed below.

Result and discussion

Three kinds of clay were used for the enamel slip to check variation of bubble structure, and the slips were coated in different thickness. Figure 1 shows the variation of L-values.

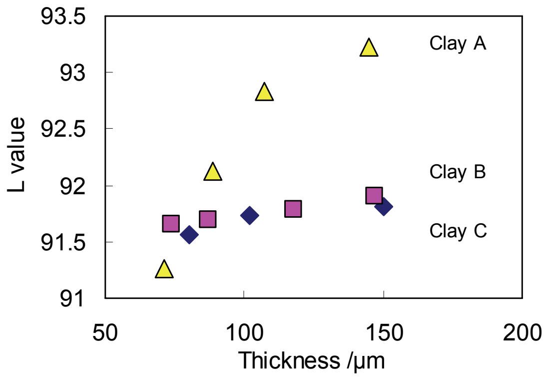
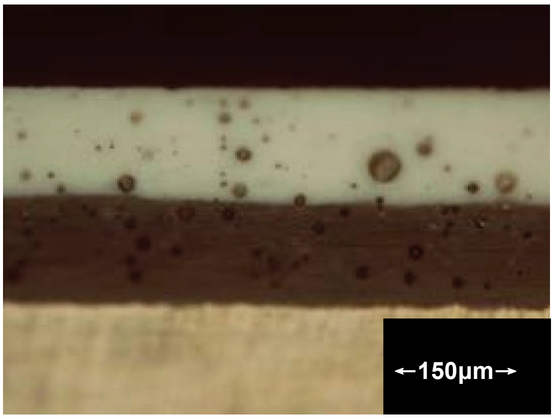
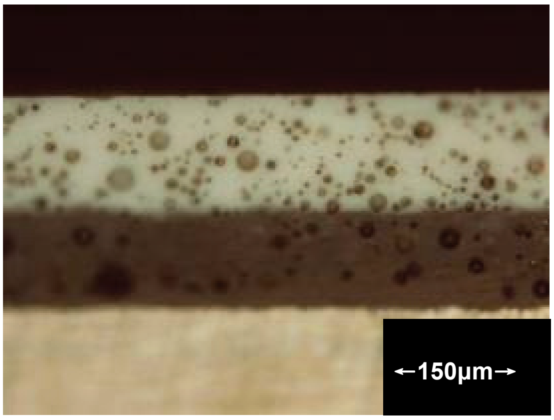


Fig. 1 L-values with different clay and coating thickness

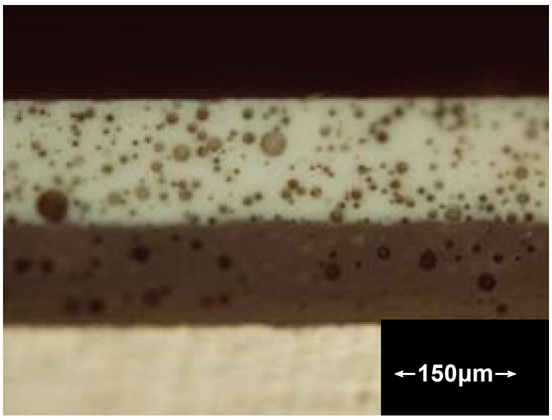
L-values changed from about 91 to 93.2 for Clay A, while from about 91.5 to 92 for Clay B and Clay C. The L-values of Clay A being affected by coating thickness changed more than those of Clay B and C. Picture 1, 2 and 3 show cross sections of fired enamels using each clay.



Pic.1 Cross section of the enamel using Clay A



Pic.2 Cross section of the enamel using Clay B



Pic.3 Cross section of the enamel using Clay C

Table 1 A number of bubbles in a specified area of enamel

Size of bubble /μm	Clay A	Clay B	Clay C
1-5	28	53	41
5-10	34	199	166
10-15	20	71	83
15-20	8	17	23
20-25	2	6	4
25-30	2	1	2
over 30	2	1	2
Total	86	348	321

For Clay C and B, their bubble structures are very similar as per the Table 1, and L-values after firing in different coating thickness changed similarly. On the other hand, the number of bubbles for Clay A were much fewer, approximately one-fourth of those of Clay B and C. It is estimated that a few bubbles in enamel layer more influence L-values by variation of coating thickness. This is schemed as below.

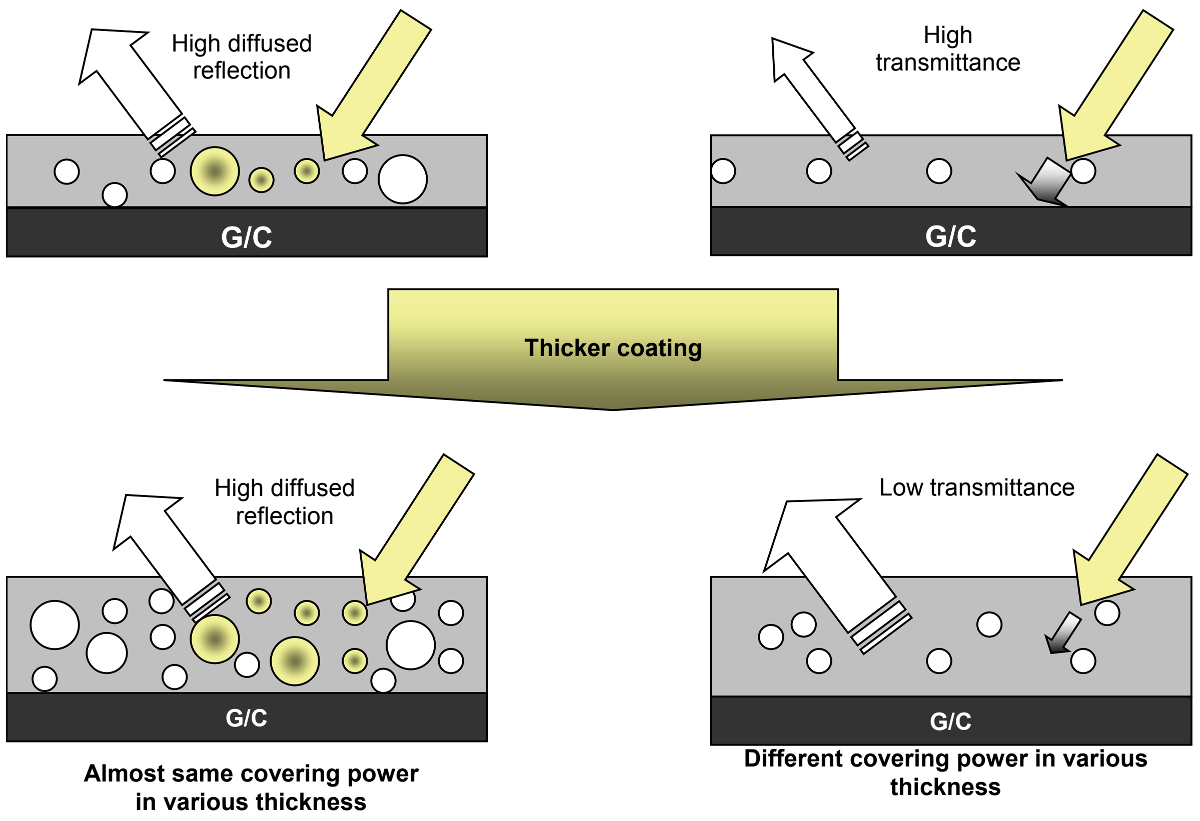
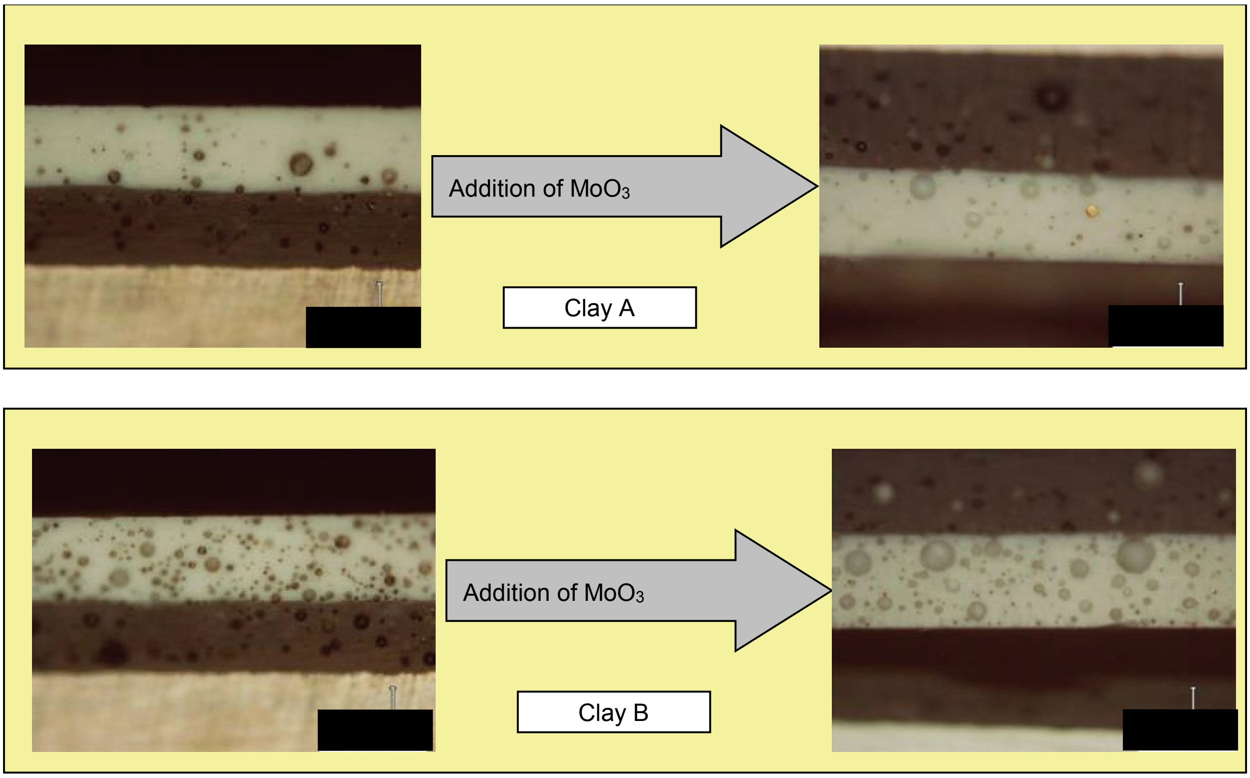


Fig. 2 Behavior of light in enamel layer

When there are a small number of bubbles in enamel layer, light passes through cover coat layer and is not diffused in the layer. On the other hand, when there are a large number, light is so diffused to generate diffused reflection which helps cover coat stable in different coating thickness. Therefore, it is preferable for a proper amount of bubbles to exist in enamel layer.



Pic. 4 Cross section of bubble structure with addition of MoO_3

It was examined how the behavior of light in enamel layer is controlled by adjusting bubble structure as required. A certain amount of MoO_3 was added to the cover coat slip to see how bubble structure changes. For Clay B, the size of bubbles became larger and a number of bubbles decreased, while for Clay A, the size also became larger but a number increased. For Clay B, the surface tension of enamel was falling during firing when MoO_3 added as MoO_3 produced more bubbles, and the bubbles getting larger were united with each other and finally released to the air. For Clay A, however, there contains a fewer bubbles which did not grow enough to be united even if MoO_3 produced more bubbles. Figure 3 and 4 show L-values with or without the addition of MoO_3.

With the addition of MoO_3,inclination of the L-values tended to decrease for Clay A as a number of bubbles increased. On the contrary, inclination of the L-values tended to increase for Clay B as a number of bubbles in enamel layer decreased.

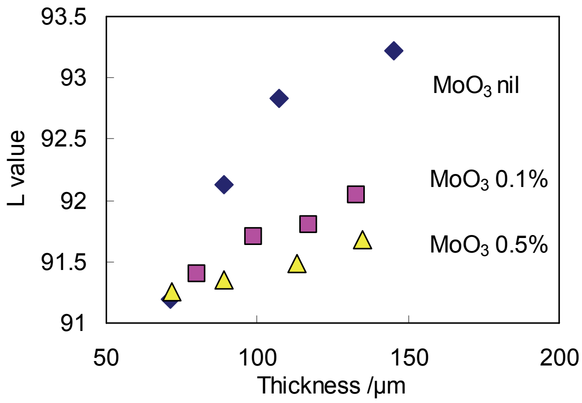


Fig. 3 Changes of L-values with and without MoO_3 (Clay-A)

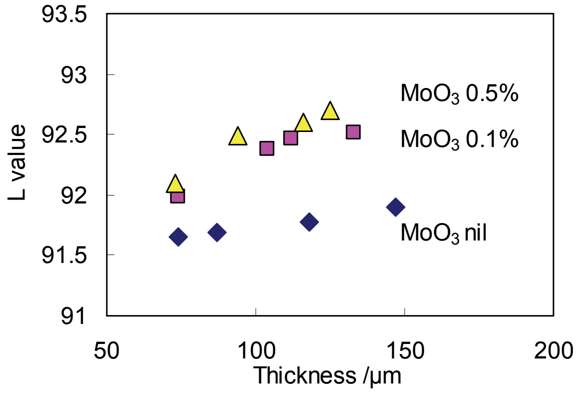


Fig. 4 Changes of L-values with and without MoO_3 (Clay-B)

Conclusions

It is found that the color stability to the thickness is changed by the bubble structure in enamel. For the bubble structure that a large amount of bubble exists in enamel, Incidence light causes diffused reflection by bubble, therefore much of the diffused light support to color stability in different thickness. The color stability to the thickness can be improved by controlling the bubble structure in enamel.

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