High temperature baking-resistant Cr-free passivation coating for aluminised steel

Inorganic CrIII passivation or organic Cr-free passivation/TOC are commonly applied on aluminised steel coils to further enhance corrosion resistance. However, the poor machinability of inorganic CrIII passivation and poor baking resistance of organic Cr-free passivation/TOC coating limit their application. Henkel has, therefore, developed a new inorganic Cr-fee passivation coating, BONDERITE M-PA 1344, based on sol-gel chemistry, providing both outstanding high temperature baking resistance as well as good corrosion resistance and machinability.

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Aluminised steel coil is steel coil which is hot dipped in aluminium, 90%/silicon, 10% alloy. Aluminised steel has good heat resistance and heat reflection and so is widely used in applications such as automotive muffler, heat exchangers in residential furnaces, commercial rooftop air conditioning units, fireplaces, kitchen ranges, water heaters, barbecue burners, ovens, baking pans, and so on.

Only South Korean and Japanese steel mills produced aluminised steel coil in Asia before around 2015, with Chinese steel companies starting to develop and produce it in recent years.

The aluminised alloy layer can provide better corrosion protection than a Zn galvanised layer, however, pinhole defects often appear on the surface and result in poor corrosion protection of the Fe substrate. Additionally, if the Al/Si alloy layer is too thick it can decrease the stamping/bending properties of the steel sheets.

To enhance the corrosion resistance of aluminised steel sheets inorganic CrIII passivation and organic Cr-free passivation/TOC are normally applied, however, the poor machinability of inorganic CrIII passivation and the poor baking resistance of organic Cr-free passivation/TOC coating limit their applicability in some situations.

BONDERITE M-PA 1344

To overcome these disadvantages Henkel has developed a new inorganic Cr-fee passivation coating, BONDERITE M-PA 1344, based on sol-gel chemistry.

The sol-gel process helps provide an intact protection film on the metal substrate which provides excellent both high temperature baking resistance and corrosion protection. This process is essentially based on the hydrolysis and condensation reactions of alkoxysilanes (such as teramethoxysilane TMOS), metal alkoxides

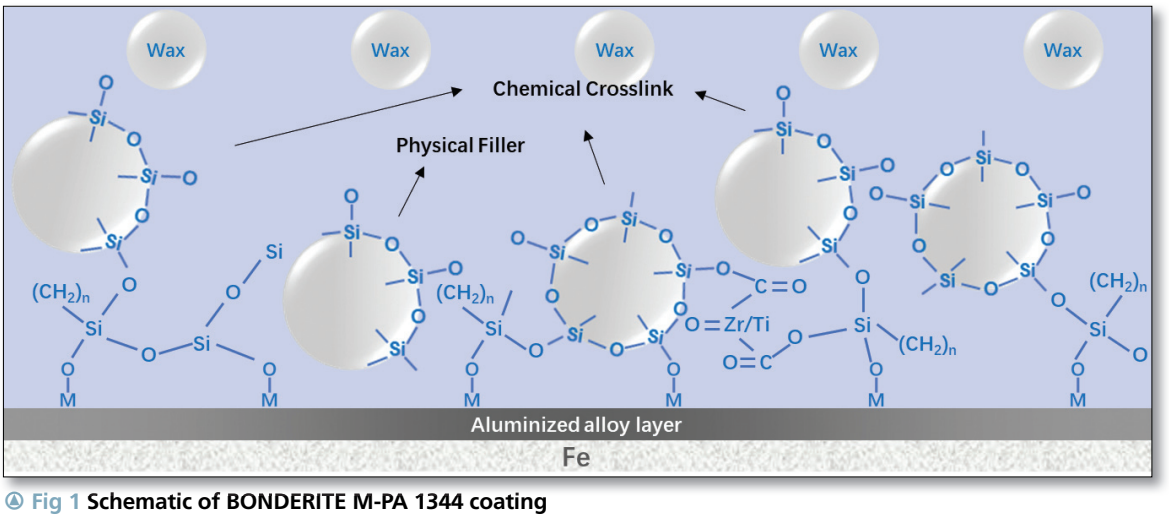

Fig 1 **Schematic of BONDERITE M-PA 1344 coating**

NSST	Corrosion Area (%)
48H	0
72H	0
96H	0
120H	1

Fig 2 **Neutral salt spray test (NSST) results, with three panel tests shown after 120H**

(M(OR)n), alkoxides of titanium, and zirconium, and organo-silanes.

COATING PREPARATION AND PERFORMANCE

In order to get a passivation film with good properties, we recommend a coating weight of BONDERITE M-PA 1344 in the range of 0.2-0.6g/m^2. If the coating weight is too high, the inorganic film may perform better as regards corrosion resistance and alkaline resistance, but it may not dry sufficiently easily and may crack due to inner stress of the film. On the other hand, if the coating weight is lower than 0.2g/m^2, the film may not perform well in corrosion resistance, although it could have good baking or stacking resistance. Thus, the coating weight should be well controlled during application of this passivation product to the metal substrate.

Figure 1 shows a schematic of BONDERITE M-PA 1344 coating. The main binders of inorganic passivation are alkoxysilanes, silica and silicate, which can form a dense protective film thanks to the dehydration-condensation reaction in the silanol. Meanwhile, the dehydration-condensation reaction between the silanol and the hydroxyl groups on the surface of metal improve the adhesion between passivation film and substrate. Furthermore, zirconium- and titanium-based complexing agents and corrosion inhibitor were selected to further improve the crosslinking density of the film. In addition, de-foaming agents, levelling agents and wax additives were introduced to prepare a defect-free, anti-friction film.

A whole range of tests have been perforemed to demonstrate the effectiveness of BONDERITE M-PA 1344 coating.

120H neutral salt spray test (NSST) results under ASTM B117 conditions (35oC, 5% NaCl, pH 6.5-7.2) are shown in *Figure 2*. The table on the right shows the the corrosion area percentage on the aluminised substrate with 0.4g/m^2 passivation coating as a function of the salt spray time. No corrosion was observed up to 96h, and even after 120h NSST, only around 1% corrosion area was found, which indicates good anti-corrosion performance. This is due to the introduction of the nano-sized silica, which not only worked as a chemical cross-linker which can improve the crosslink of resultant film, but also worked as a physical filler which can seal any micro-hole in the film.

The most end applications of aluminised coil are in high temperature environments, like automotive muffler, ovens and baking pans. Hence, high temperature baking resistance is a key requirement for passivation on aluminised coil. BONDERITE M-PA 1344 shows excellent high temperature baking resistance and has been certificated by many key customers in China.

To evaluate the baking resistance of the film, we performed a number of tests in an aggressive testing environment. The coating was applied on aluminised substrate (coating weight is around 0.4g/m^2) and cured at PMT (peak metal temperature) 80°C. After seven days aging, the panels were baked at 250, 300 and 350°C separately for 6h. *Figure 3* shows that all the resultant colour variation ΔE before and after baking are less than 3. It is believed that due to its inorganic composition, this product provides superior high temperature baking resistant properties compared to competitor product, which would be obviously yellowed and degraded under these high temperatures, colour variation ΔE is 6.78 after baking at 250°C for 6h. The sample photos and exact data are shown in *Figure 3*.

The machinability of BONDERITE M-PA 1344 was evaluated by a friction coefficient tester ALTEK 9505. The original friction coefficient of aluminised steel is larger than 0.25. And the friction coefficient would be decreased ▷

Baking temperature and time	Competitor product 250°C 6h	Bonderite M-PA 1344 250°C 6h	Bonderite M-PA 1344 300°C 6h	Bonderite M-PA 1344 350°C 6h
△E	6.78	1.03/ 1.94	1.18/ 2.09	1.02/ 2.09
Sample photos				

Fig 3 **Baking resistance test results of BONDERITE M-PA 1344 film at different temperatures**

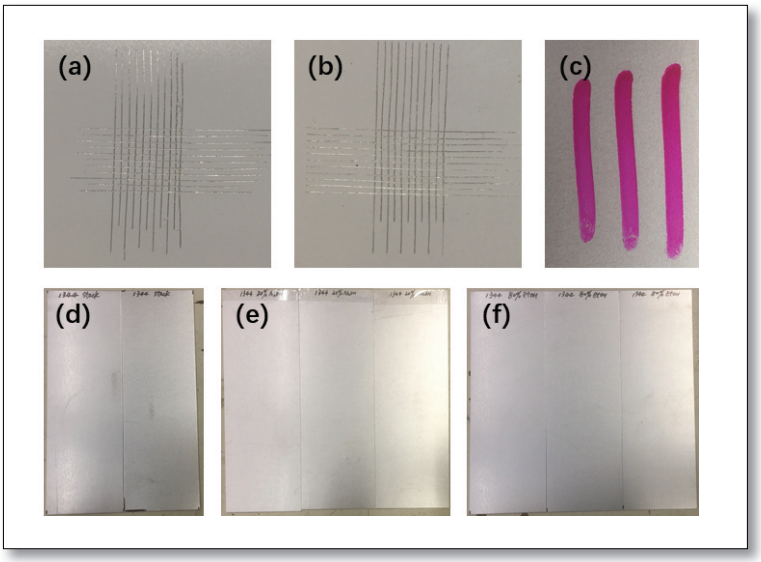

Fig 4 **BONDERITE M-PA 1344 panels after various tests and treatments**

into a range of 0.1-0.2 based on different substrate surface roughnesses. An additional benefit of Bonderite M-PA 1344 is that it is compatible with rust-preventative oil, thus a post-treatment spray with oil can further improve corrosion protection and machinability of the substrate.

We have also studied other properties of BONDERITE M-PA 1344 coating. The results of various tests are shown in *Figure 4*.

- 6a Paintability (liquid paint (Zhenghua Coating), DFT 40-60 µ, cross-hatch, 3M 600 tape peeling test, no coating peel-off)
- 6b Paintability (powder paint (Akzo Nobel EA05BH), DFT 40-60 µ, cross-hatch, use 3M 600 tape peeling test, no coating peel-off)
- 6c surface energy (38# dyne pen, no shrink of ink in 2 seconds)
- 6d Moisture resistance (120H stacking test, 49°C, RH98%)
- 6e Alkali resistance (dip coated panels into 20% NaOH, 25°C for 30s, and then test colour change ΔE)
- 6f Solvent resistance (rub test of coated panels with 80% EtOH for 20 times, and test the colour change ΔE)

The results demonstrated that this passivation coating performed well, not only in its high temperature baking resistance, but also in corrosion protection, moisture resistance, chemical resistance and good adhesion of top coatings.

Normally, the coating thickness of Cr-free siloxane/silicate passivation coating is monitored by XRF using the Si element line. However, as the Si element in Si/Al alloy layer strongly interferes with the results the alternative K element line is preferred. IR can also be used to monitor the passivation coating weight, but only without rust-prevention oil.

CONCLUSIONS

BONDERITE M-PA 1344 is a novel inorganic chrome-free passivation coating which provides a homogenous and dense film to protect aluminised steel sheet substrate from corrosion. This newly developed anti-corrosive coating shows outstanding high temperature baking resistance as well as good corrosion resistance and machinability. Additionally, it also provides good paintability and can be used with rust-preventative oil. MS

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