

SILSBOND hybrid pretreatment technology: Cr-free, phosphate-free, VOC/HAP-free metal pretreatment for improved paint adhesion and corrosion resistance

11/24/2025

Contents

1. General description	1
2. SILSBOND hybrid pretreatment technology	3
2.1. Mechanism.....	4
2.2. Products and Lab accelerated corrosion test results	5

1. General description

Prior to painting, metal parts are often treated with aqueous metal pretreatment solutions for improved paint adhesion. The painted metal parts would thus have greatly enhanced corrosion resistance and prolonged service life. Metal pretreatments are popularly used in industries such as automotive, aerospace, heavy metal equipment, agriculture and other general industries where high performance of the painted metal parts is required. Based on their chemistries, the major commercial pretreatments can be divided into the following groups:

- 1) Hexavalent chromium (Cr6) pretreatment (chromating). This acidic pretreatment solution reacts with a metal surface to form a typical 1- μ m thick film (or conversion coating). This thin film can provide metals with both excellent paint adhesion and bare corrosion protection in the unpainted state. In addition, a diluted Cr6 pretreatment solution can also be used as a sealer (or “post rinse”) to enhance performance of other pretreatments products. For example, zinc phosphate pretreatment is sometimes followed by a Cr6 post rinse to achieve its best performance. However, Cr6 ion is identified as cancer-causing agent and thus the Cr6 pretreatment needs to be replaced.

- 2) Zinc phosphate pretreatment (Zinc phosphating): This pretreatment solution deposits a 1-5 μm thick, adhering layer of zinc phosphate crystals on metal to improve paint adhesion and corrosion resistance for metal components. However, discharge of zinc phosphate waste solutions into surface waters like ponds, lakes and rivers, can cause severe “eutrophication” that is detrimental to aquatic ecosystems. In addition, a slurry of metal phosphate particles (“sludge”) is inevitably generated in the zinc phosphate pretreatment bath during processing of metal parts. Zinc phosphate sludge removal is costly due to increasingly strict environmental regulations.
- 3) Nano-ceramic pretreatments. This term is often used to refer to zirconium oxide and/or titanium oxide pretreatments which can deposit a nano-scale thin film on metal parts to enhance paint adhesion. Other merits of these pretreatments are environmental friendliness, ease of operation and close to sludge-free operation. However, these pretreatment solutions contain a high amount of F ions which leads to two undesirable issues: 1) short bath life due to the contamination of excessive amount of dissolved metal ions and 2) pretreated carbon steel parts are sensitive to “flash rust” (loose yellowish iron oxide powder) that is detrimental to paint adhesion of the steel parts.
- 4) Organic-inorganic hybrid pretreatments (“SILSBOND”). Like nano-ceramic pretreatments, SILSBOND can deposit a nano-structured thin film on metal parts for improved paint adhesion and SILSBOND is also environmentally safe, convenient and ambient operation with no substantial sludge formation. The big advantages of SILSBOND over nano-ceramic pretreatments are:
- SILSBOND only contains a trace amount of F ions and therefore it has longer service life (or bath life) and SILSBOND treated carbon steel parts are no longer sensitive to “flash rust”.
 - Like Cr6 pretreatment, SILBSOND can also be used as a sealer/post rinse to enhance other performance of pretreatments. For example, zirconium oxide pretreatment followed by a SILSBOND sealer/post rinse has been in use in general industries.

In 2021, **SILSBOND 01** product was approved for military use with the surface cleaning method(s) and on the substrate class(es) (Al and carbon steel) listed below.

Specification	Manufacturer Designation	Manufacturer Name/Address	Cage Code	Qualification Number	Surface Cleaning Method(s)	Type	Substrate Class(es)
TT-C-490	Silsbond 01	Same as above	343Y2	PT#00020	I, II	IV	A,C



(a)

(b)

Figure 1. (a) SILSBOND pretreated Cold Rolled Steel (CRS) parts entering powder coating booth; (b) powder coated steel parts being inspected for the surface quality

2. SILSBOND hybrid pretreatment technology

In 2009, Ecosil initiated the development of SILSBOND pretreatment technology with financial support through the National Science Foundation (NSF) Small Business Innovative Research program (SBIR) Phase I, II and IIB (IIP-1152518) grants. SILSBOND pretreatment products, such as SILSBOND 01, became commercial in 2011 and since then are being used in various manufacturing industries as either a pretreatment or a sealer.

SILSBOND hybrid pretreatment products are aqueous solutions, consisting of specially hydrolyzed silane molecules, zirconium/titanium fluoric acids and other additives. These solutions are Cr-free, phosphate-free and VOC/HAP-free and can be used without pH adjustment. They have a broad pH range, from 3.0 to 9.0. SILSBOND waste solutions can be discharged directly into sewage systems. Many years of industrial use has proven that

SILSBOND products have much longer bath life as compared to nano-ceramic pretreatments. Figure 2 schematically compares the SILSBOND pretreatment with zinc phosphate pretreatment in a coating system. Figure 3 compares the SILSBOND process and Zinc phosphating process. Clearly, SILSBOND is a much thinner film and its processing time and steps are much shorter than zinc phosphating.

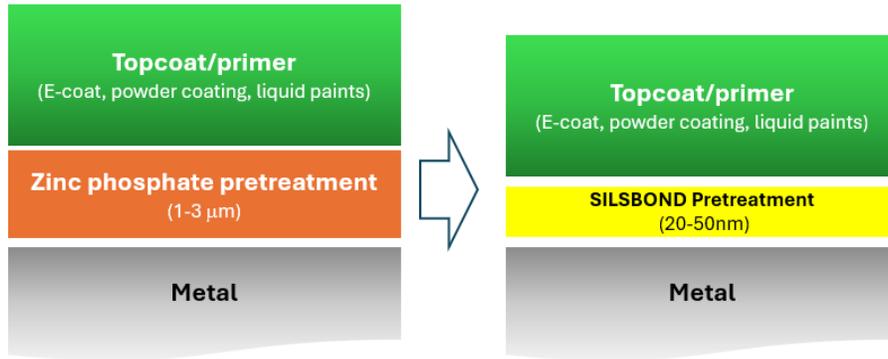


Figure 2. Comparison of SILSBOND with zinc phosphate pretreatment in a coating system

SILSBOND pretreatment production line (5 steps, bath temp: ambient)



SILSBOND sealer production line (6 steps, bath temp: ambient)



■ - Inorganic pretreatment

Zinc phosphate pretreatment production line (10+ steps, bath temp: ~55°C/130°F)



■ - Degrease □ - Rinse ■ - Activate ■ - Zn phosphate pretreatment ■ - Post rinse

Figure 3. Process comparison: SILSBOND vs. zinc phosphate pretreatment

2.1. Mechanism

When a metal surface is contacted with a slightly acidic SILSBOND 01 solution by immersion or spraying, the metal oxide layer is removed and a nano-structured film is formed rapidly. Figure 4 shows SEM images of polished steel surfaces with different

pretreatments. Figure 4(a) shows the polished only steel surface and Figure 4(b) shows the regularly shaped zinc phosphate crystal formed on the surface after zinc phosphate pretreatment. The SILSBOND treated steel surface in Figure 4(c) exhibits a uniform distribution of nanoparticles (zirconium oxide) sealed by an invisible organo-siloxane layer.

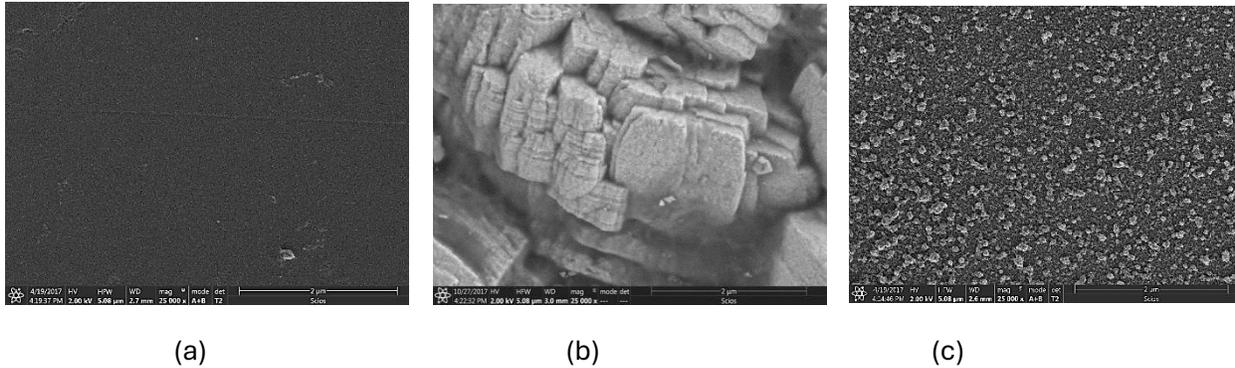


Figure 4. The SEM images of polished cold rolled steel (CRS) surfaces with different pretreatments: (a) no pretreatment, (b) zinc phosphate pretreatment and (c) SILSBOND 01 pretreatment

2.2. Products and Lab accelerated corrosion test results

- SILSBOND 01

- Features: natural pH 5.0 -6.0, complies with Military TT-C-490 spec, demonstrates superior Salt Spray Test (SST) performance compared to zinc phosphate pretreatment and enhances other pretreatments when used as a rinse free sealer
- Performance:



Figure 5. 1000-hr SST result for polyester (PET) powder coated cold rolled steel (CRS) test panels (creep <1.0mm)

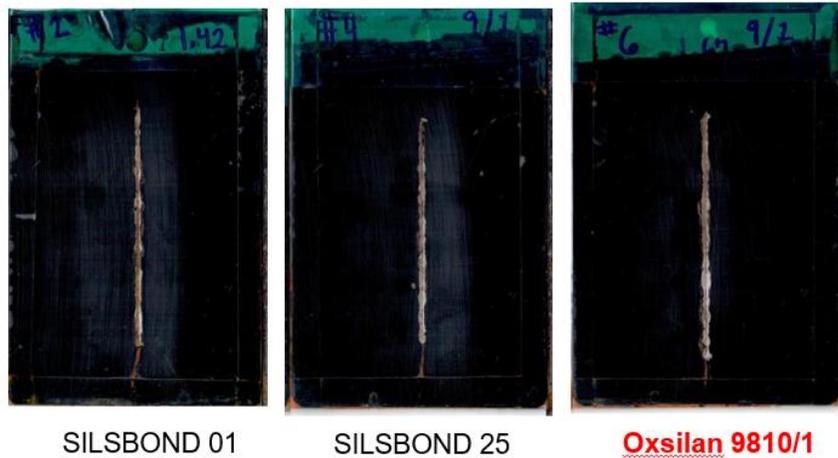


Figure 6. 500-hr SST result for epoxy e-coated CRS test panels (creep <1.0mm)

- **SILSBOND AM4**

- Features: natural pH 9.0-10.0; superior flash rust inhibiting, very good paint adhesion and corrosion protection
- Performance:

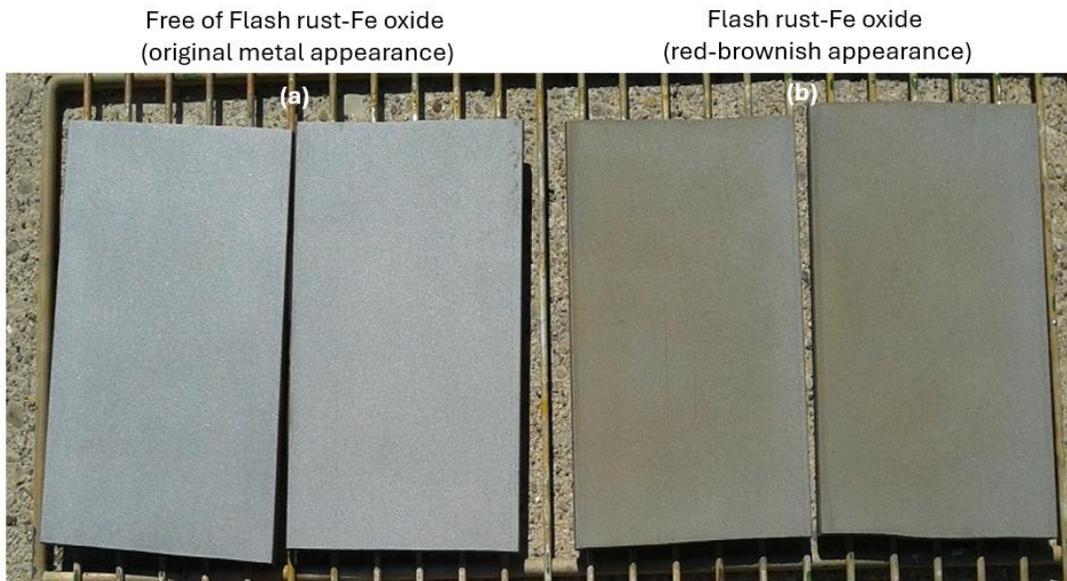


Figure 6. Abrasive-blasted A36 (Hot Rolled Steel, HRS) panels sprayed with different pretreatment solutions and dried in place; (a) SILSBOND AM-4 (no flash rust); (b) alkaline cleaned (yellow flash rust)

- **SILSBOND 03**

- Features: natural pH 3.0-5.0, excellent performance on Al
- Performance

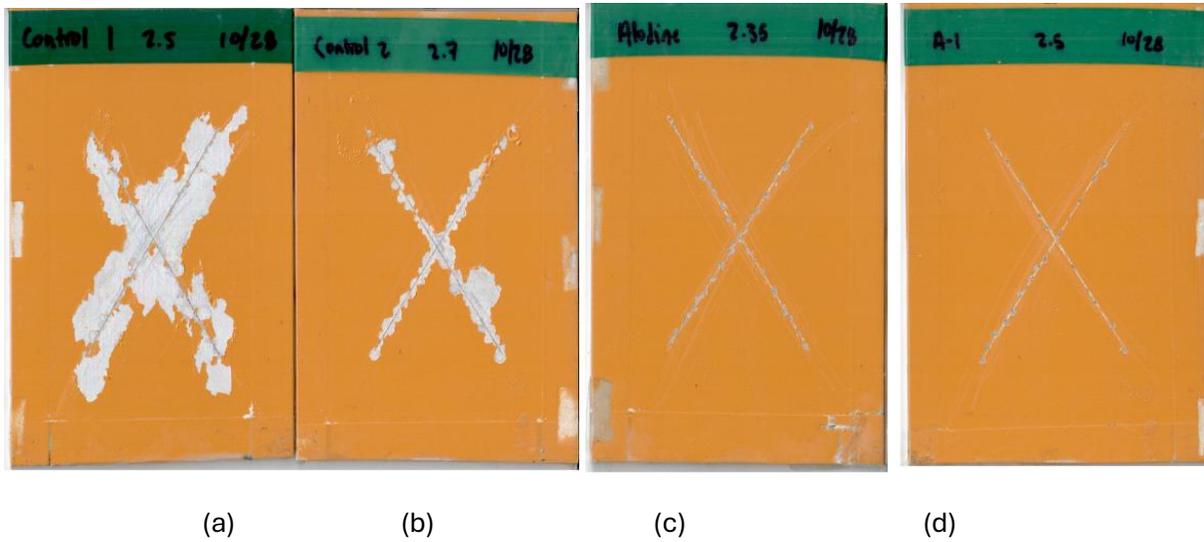


Figure 7. 240-hr CASS (Copper Accelerated Salt Spray Test) result for extruded Al 6061 (Caterpillar signature yellow PET powder coat); (a) Alkaline cleaned only, (b) Acid cleaned only, (c) Cr6 Chromated, (d) SILSBOND 03