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The Adhesion of Protective Organic Coatings to Novel REACH Compliant Packaging Steel Substrates

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Introduction

The challenge of this project is to evaluate and optimise the performance of novel chrome (III) based substrates, Trivalent Chromium Coated Technology (TCCT®) as a replacement for the commercially mature, chrome (VI) based substrate Electrolytic Chromium Coated Steel (ECCS®). This will be investigated for both organically coated, and uncoated substrate materials.

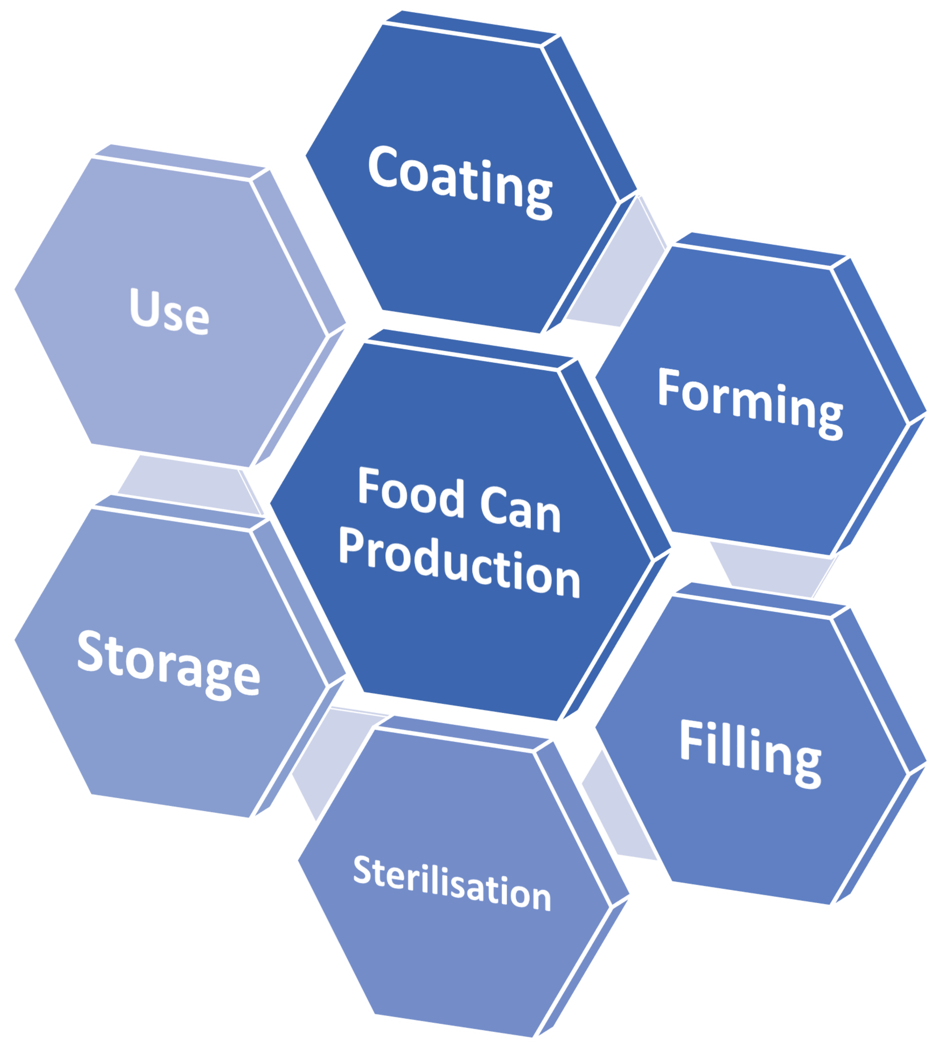
Packaging Steel Substrates

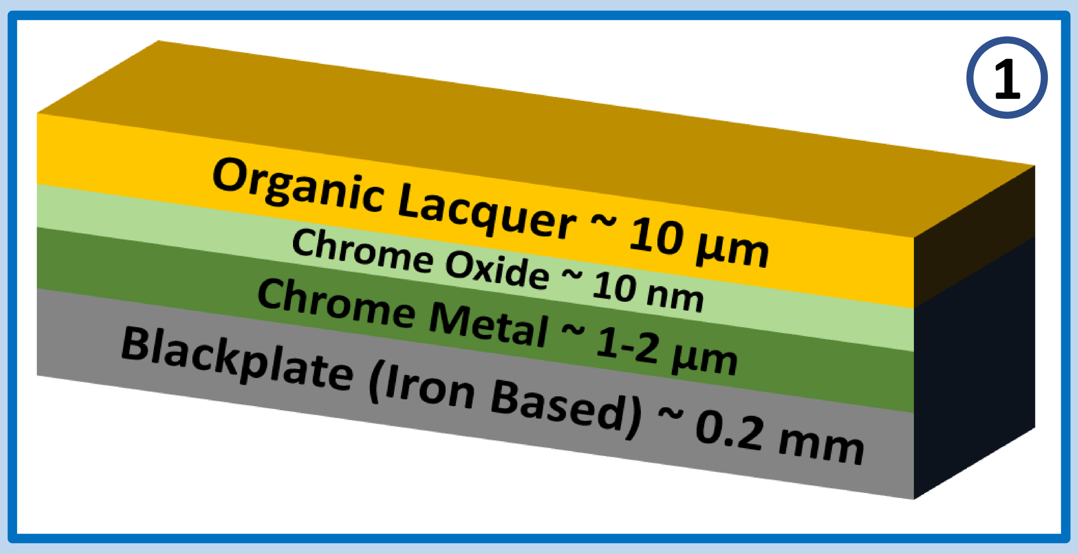
Cr (VI) Based ECCS® → **Cr (III) Based TCCT®**

↘ **Lacquering** ↙

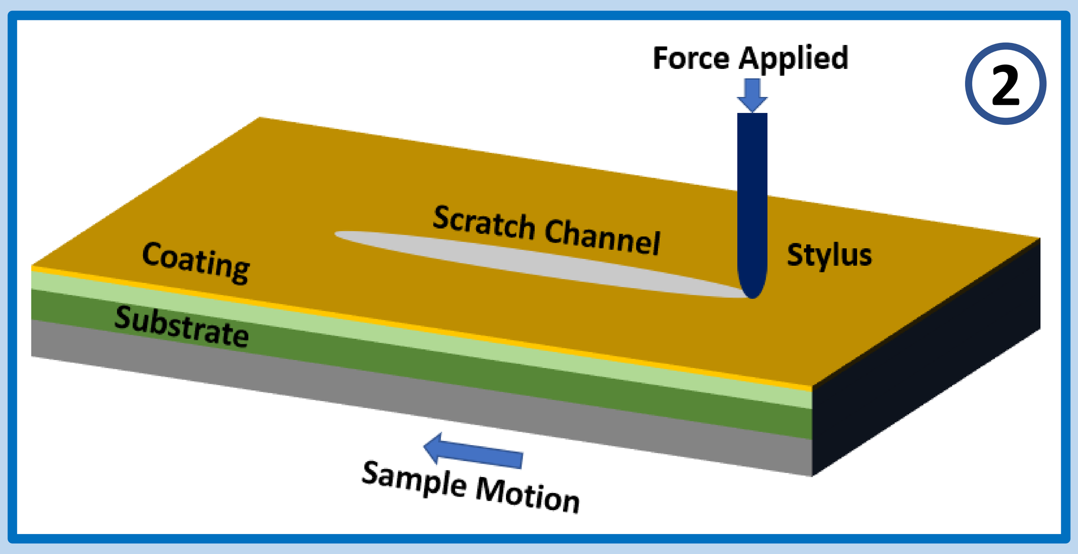
Sterilisation Simulation

Adhesion of Lacquer

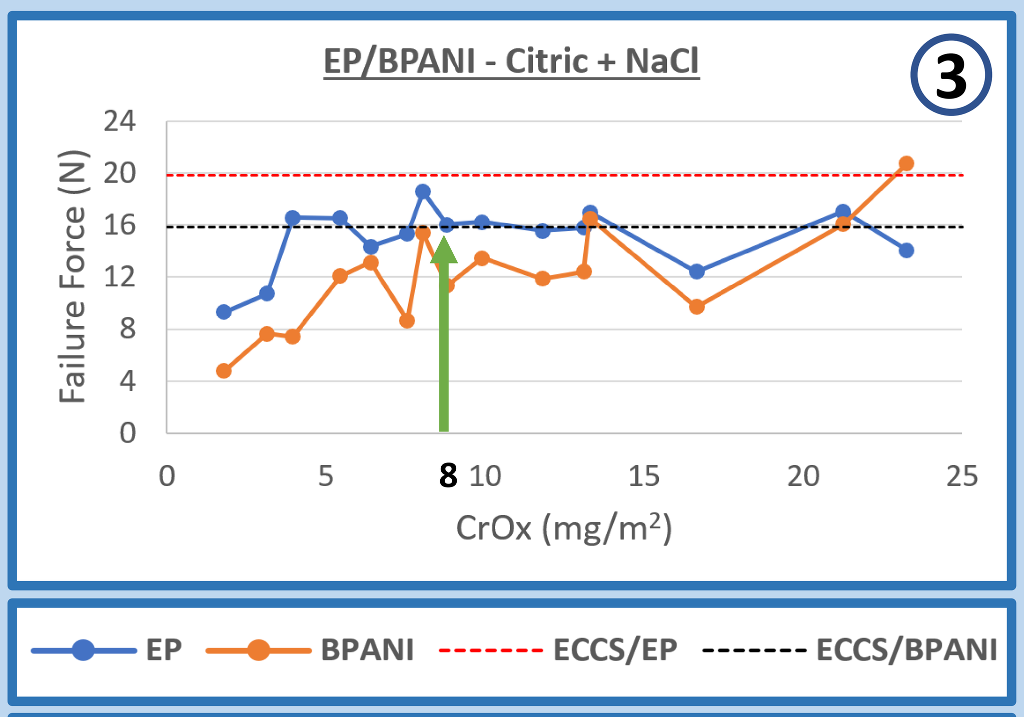


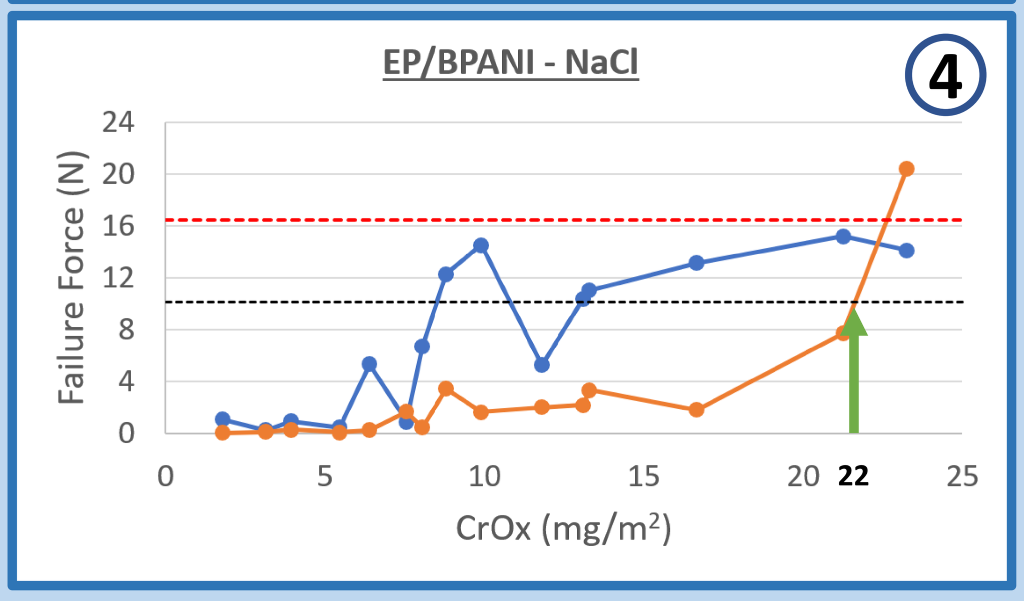


Sterilisation in Autoclave for 90 minutes @121 °C



Figures 1 and 2 – Layered cross section of the substrate materials, both TCCT and ECCS and a schematic of the scratch testing technique used to quantify the adhesion failure force of the lacquer.





Figures 3 and 4 – Failure force of Epoxyphenolic and bisphenol-A non-intent (BPANI) lacquers with respect to chrome oxide coating weight in citric acid + NaCl and NaCl solution.

Lacquer Coating Adhesion

- The influence of chrome oxide on the adhesion of two different lacquers was investigated, when subjected to two different chemical solutions (Figures 2 and 3).
- Citric and NaCl simulant - TCCT® coated with epoxy lacquer is comparable with ECCS® at an 8 mg/m² coating weight of CrOx.
- BPANI coated TCCT® performs consistently poorer, requiring 22 mg/m² of CrOx to rival ECCS®.
- The degree of lacquer adhesion is influenced by the quantity of chrome oxide on the surface of the substrate [1].It has been shown that this chromium oxide layer is the source of hydroxyl ions which in turn bond with the ester groups of the polymer film [2].

Surface Analysis

- There is no correlation between surface roughness and chrome oxide level (Figures 5, 6 and 7). This is due to the chrome oxide coatings reaching a maximum thickness of ~30 nm.
- Time of flight secondary ion mass spectrometry (Tof-SIMS) allows surface chemistries to be visualised, allowing chromium/iron ratio's to be interpreted (Figure 8) and potential iron bearing defects located.
- X-ray photoelectron spectroscopy (XPS) has been used on the same sample set of TCCT® to lend insight into the number of bonding sites (hydroxyl ions) on the substrates surface for the organic lacquers to adhere with. (Figure 9) highlighting surface iron, and chemical inhomogeneities across the width of the substrate strip.

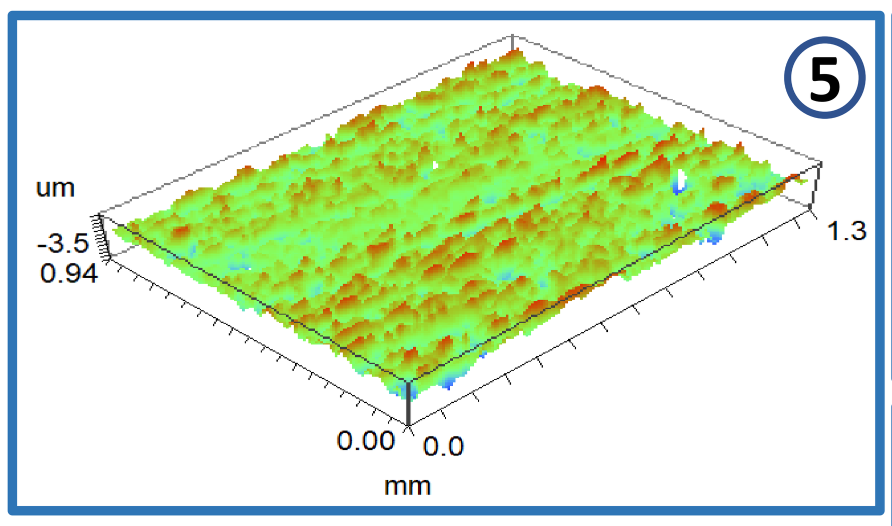
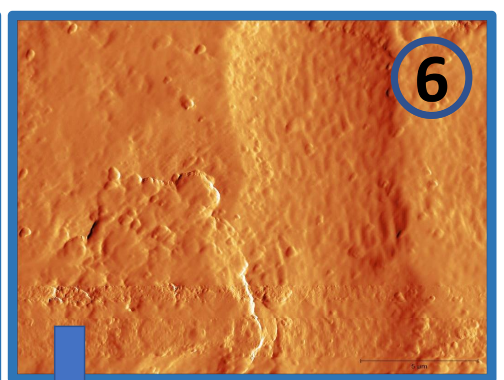
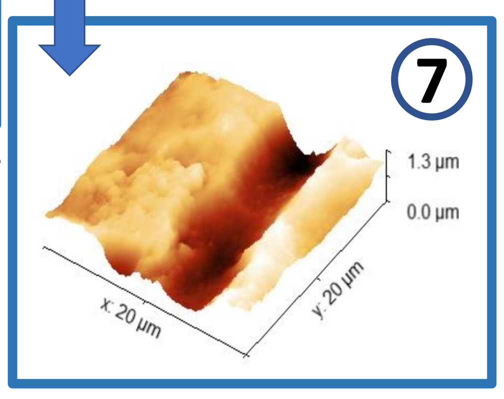
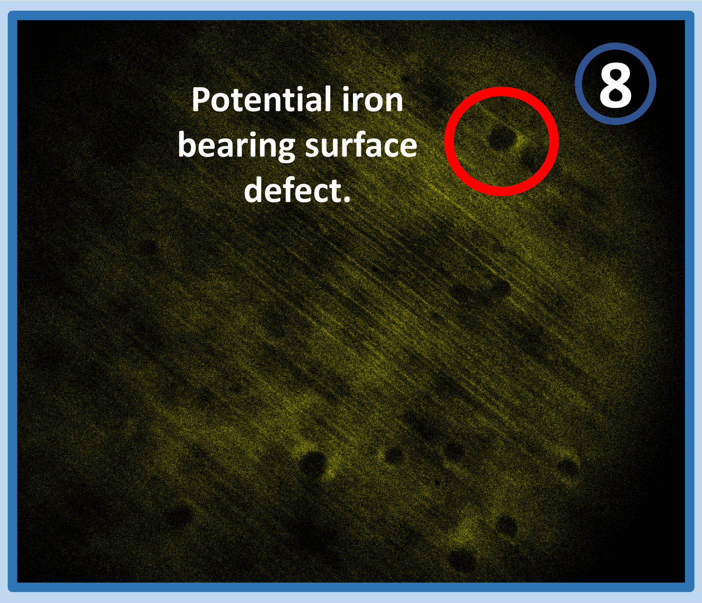


Figure 5 (above) – 3D White light interferometry surface roughness plot of a novel chrome (III) coated substrate.





Figures 6 and 7 (right)– 2D and 3D atomic force microscopy plots (20 x 20 µm) of a novel chrome (III) coated substrate.



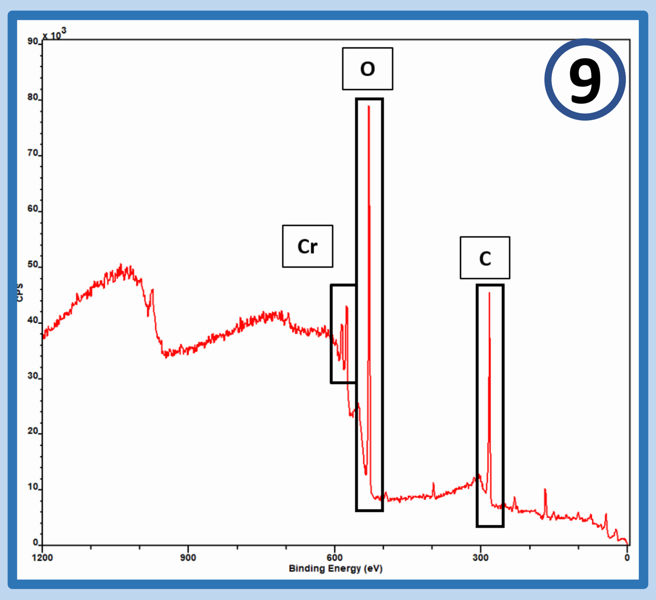


Figure 8 – Tof-SIMS chrome/iron plot where chrome is yellow and iron is black.

Figure 9 – XPS wide scan of the same substrate as figure 8 illustrating chemical composition.

Conclusions

- As chrome oxide levels on TCCT® increase, so does the failure force of both lacquers in both simulant solutions.
- Surface chemistry techniques, both qualitative (Tof-SIMS) and quantitative (XPS) are crucial in understanding how the surface of substrates vary and influence the adhesion of lacquers.
- **New Hypothesis: Exposed iron is key to adhesion properties and increasing CrOx leads to less defects witnessed and therefore less exposed iron.**

Future Work

- Electroplate this novel chrome (III) substrate in Swansea University and create our own samples with view to optimising the manufacturing process.
- Investigate new hypothesis.

[1] Edy J, McMurray H, Lammers K, de Vooys A. Kinetics of corrosion-driven cathodic disbondment on organic coated trivalent chromium metal-oxide-carbide coatings on steel. Corrosion Science. 2019;157:51-61.
[2] Beentjes P. Durability of polymer coated steel in diluted acetic acid environment. Delft, The Netherlands: The University of Technology Delft; 2004.

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M2A MATERIALS AND MANUFACTURING ACADEMY
YR ACADEMI DEUNYDDIAU A GWEITHGYNHYRCHU

UKRI Engineering and Physical Sciences Research Council

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