Information on the Cuptronic CBM Process

A sustainable adhesion promotion technology substituting CrVI etching in plating-on-plastic processes

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1 CUPTRONIC CBM PROCESS DESCRIPTION

1.1 Introduction

The current process for Chrome plating of certain plastics consists of:

1. Preparing the surface (pre-treatment/etching)
2. Adhesion of metal (electroless and galvanic)

Chromic acid (CrVI) has long been deemed essential for step 1. The surface has been etched to create a topographic surface that will allow for palladium adsorption. Cuptronic CBM (Covalent Bonded Metallisation) process provides a sustainable alternative that can substitute the use of CrVI in the chrome plating process.

The Cuptronic CBM process is a revolutionary new way of attaching metals like copper, nickel, silver and gold to a variety of surfaces, primarily plastic.

Specifically, the Cuptronic CBM process is designed to replace the conventional method of using chromic acid etching to create a structured surface, which promotes mechanical adhesion of metal to non-metallic surfaces and enables a complete replacement of CrVI in electroplating.

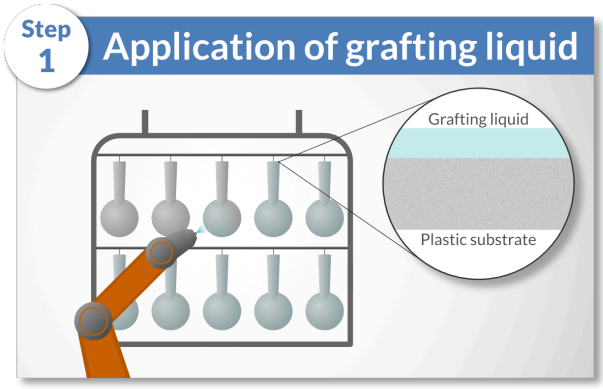
Electroplating based on the use of CrVI is currently facing several challenges due to various EU regulatory requirements. Firstly, CrVI is included in Annex XIV of REACH, meaning its use is only allowed if authorization is granted. Secondly, the Carcinogens and Mutagens Directive (2004/37/EC) requires each Member State to ensure the safety of workers by making it mandatory for employers to either replace CrVI or to reduce exposure to it by complying with occupational exposure limits (OELs) for CrVI. These limits are becoming increasingly strict.

The Cuptronic CBM process is the most promising replacement for traditional CrVI etching. The most important reasons why are listed below:

- Adhesion performance
- Wider choice of plastics
- Production costs
- Health and environmental benefits

1.2 How the Cuptronic CBM process works

The Cuptronic CBM process is an adhesion promotion technology based on a chemical molecular surface alteration method, which primes a non-metallic surface for electroless plating. Instead of using etching, the Cuptronic CBM process chemically creates customized polymers, which grafts from the substrate surface. These polymer structures create the texture to which the metal layer can adhere to. In practice, it is a three-step process, as depicted in the following sections.



In order to prepare the parts, the CBM grafting chemistry is applied as a liquid to the appropriate areas of the substrate surface. This liquid can be applied to the surface in a variety of ways, depending on what is optimal for each specific plating process:

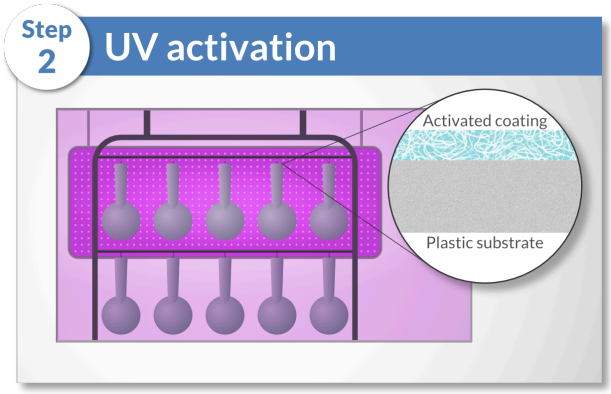
Spray coating

Pad printing

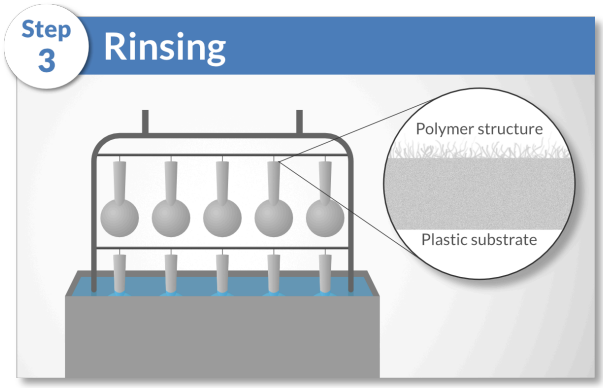
Roller coating

Dip coating

Curtain coating



The light instantly triggers the graft polymerization from the surface. This is normally achieved by UV light exposure, which can be produced either by flood light, or, in cases where selective metallization is needed, by UV laser. An alternative activation process is to use surface heat instead (from for example the injection molding). The polymers created in the polymerization step are designed to attract and capture palladium ions, which after reduction, are needed as a catalyst to deposit metals using conventional electroless metal chemistry.



After the CBM reaction, the grafted polymers are encased in a now solid layer of grafted and bulk polymers. This provides some protection for the grafted polymers. However, before the conventional electroplating process can be started, the remains of the bulk polymers need to be removed. This is done by simply washing in cold water.

1.3 The role of CBM in a full plating process

The Cuptronic CBM process is designed to be a part of a complete plating process. As can be seen in the following diagram, in an ordinary plating process, the CBM process replaces the step where the plastic substrate is typically etched using CrVI.

The Cuptronic CBM process is incorporated in an ordinary plating process

The CBM process may be applied directly after injection molding, just before plating, or anywhere from the injection molding facility to the plating facility. The treated parts may also be stored for plating later.

The use of CrVI in conventional plating processes has been motivated by its vital role in pre-treatment (etching). Etching is a pre-requisite for adequate adhesion between plastic substrate and the deposited metal layers. Until now, alternative approaches to traditional etching have not provided the required results according to the information provided in numerous assessments of alternatives (AoA) carried out by the applicants of a CrVI REACH authorization. As such, all applicants for authorization have highlighted the importance of continued use of CrVI. However, with this technology, this argument is no longer valid, as demonstrated above.

1.4 Health and safety benefits

Etching is the heavy-duty step in the chrome plating process. The most important health and safety benefit of introducing the Cuptronic CBM process is that no SVHCs such as CrVI need to be used anymore while delivering the same or higher quality of surface to the second step in the process (metallization). The use of CBM enables a completely CrVI free plating when CRIII is used in the final galvanic plating. Thus, the overall health and safety risk is clearly lower.

The Cuptronic CBM process is carried out in a grey room atmosphere with an air cleaning ventilation system. Due to the closed system there is no worker exposure during the operating process and standard procedures are in place for maintenance to ensure workers are not exposed to risks from chemical substances.

With the use of CrVI comes a number of obligatory measures to protect the health of workers. These measures are costly and can be avoided when using the Cuptronic CBM process. Indeed, occupational workplace exposure to CrVI is heavily regulated in most European countries (most notably via Occupational Exposure Limits) and rules are expected to get stricter in the future.

1.5 Environmental benefits

The overriding environmental benefit of the CBM process is the complete removal of SVHCs and hence CrVI in the pre-treatment phase. Depending on the process configuration, there may also be benefits related to the energy consumption. This would apply in scenarios where e.g. the energy used in the UV radiation step is substantially lower than the energy used for heating the etching baths in a conventional etching step. There are also plans to replace UV in the process with heat which would further reduce energy consumption, especially if the heat to activate the CBM chemistry can be obtained from the injection molding process.

The biggest difference when comparing environmental impacts relates to the waste water part of CrVI which is very different for the Cuptronic CBM process. The Cuptronic CBM process also rinses, however, the rinse water contains no hazardous chemicals and only small quantities of the used chemical mixture. As such, it requires no complex water treatment procedures.

Air emissions are also very limited due to a closed and controlled application environment where emissions can be effectively managed and reduced.

1.6 Implementation benefits

The Cuptronic CBM process only replaces the etching step, which means that the rest of any current electroplating process and equipment can be kept as is. Indeed, the Cuptronic CBM process can be implemented in-line into an existing process operation. It can also be implemented in parallel to current production, since it can be separated in both time and location.

The Cuptronic CBM process is not sensitive to injection molding parameters, which means molding parameters may be optimized with the regards to the parts quality instead of the plating properties. Multi-component parts, i.e. using more than one type of plastic, can easily be injection molded for selective plating by doping the plastic not to be plated. I.e. one could use the same plastic to make a 2K part by simply adding a doping agent into the plastic that should not be plated.

1.7 Plastics selection benefits

The reality for the vast majority of plating-on-plastic processes today is that the choice of plastic material is restricted to only what is known as “plating grade” plastics, which means a very limited number of plastics that are tailored for plating.

By contrast, the Cuptronic CBM process uses a completely different method to promote adhesion. Thus, it works very well on a wide variety of plastics, which are not possible, or very difficult, to plate today, e.g. PP, PA-12, COC, ASA or PEEK. This is a truly ground breaking change, which liberates both designers and production engineers from previously non-negotiable restrictions. Since a much wider range of plastics can be used, the choice can be driven by *desired properties* of the plastic itself, rather than mainly by its plateability which allows for sustainability properties of the plastic (i.e. recyclability) to be taken into account.

Example 1: Color and production

Toilet flush buttons, which are made in both chromeplated and plain white versions. With the Cuptronic CBM technology, the white plastic could be used for both the white parts *and* the parts to be chrome plated. In this case, the main benefit would be avoiding the switch from one plastic to another in the injection molding machine and not having to stock both types of plastics.

Example 2: Weight and strength

Optical frames should be light but mechanically strong. With CBM, Polyamide-12 resin, which has these properties, can be used for metallized frames, even though it is not a plating grade plastic.

Example 3: Additives or fillers

The technology is not affected by the use of additives or fillers. So, whether additives are used or not, e.g. for cost savings or mechanical property, the plateability will not be impaired.

1.8 Cost benefits

The Cuptronic CBM process is cost competitive when looking at operational costs and when

considering the overall costs, it enables clear cost savings due to a higher yield, wider choice of plastics and less stringent measures to protect the environment and workers' health.

1.9 Substances used

The Cuptronic CBM process chemistry is customized for different applications, thus there are a large number of different potential compositions. The following types of substances are used in the Cuptronic CBM process.

- Monomers
- Solvents
- Photo activators
- Catalysts

None of the substances used in the Cuptronic CBM process are classified as carcinogenic, mutagenic, respiratory sensitizers or reproductive toxins and none of them are being suspected of having endocrine disruptive properties.

1.10 Applications

There are numerous potential industrial application areas where the Cuptronic CBM process could be used for substituting CrVI etching in plating on plastics. Those that currently have been identified as prime candidates are:

- Automotive (interior as well as exterior applications)
- Sanitary (e.g. flush buttons and shower heads)
- Decorative (e.g. perfume bottle caps)
- Household appliances (e.g. coffee makers)

Example 3: Additives or fillers

2 TECHNICAL FEASIBILITY

2.1 Key technical quality aspects

Cuptronic CBM process is tested and used and is found to be a technically feasible alternative to etching using CrVI in the chrome plating process. It is ready to access the market.

The main technical quality aspects that have been tested are those that are influenced by using the Cuptronic CBM process:

- Level of adhesion as measured in a standardized peel test
- Passing automotive/sanitary thermo cycle tests

Other commonly evaluated quality aspects, functional properties or aesthetical characteristics are assumed to be unaffected by the use of the Cuptronic CBM process. Compared to traditional CrVI etching there will be *no difference* regarding any of the following properties:

Health and environmental safety for finished articles	Sunlight resistance
Corrosion resistance	UV resistance
Chemical resistance	Aesthetics
Wear resistance	Reflection behavior
Abrasion resistance	Absorption capability
	Electrical conductivity of the surface

2.2 Test conducted

Internal Cuptronic Testing

After rigorous testing, Cuptronic adheres to several standards (ISO 2409, ASTM B571-97 and IPC 650) and fulfils the most important criteria, being adhesion strength. Adhesion requirements vary depending on applications and are typically between 10-50 N/cm. Adhesion performance of CBM is one of the key strengths of this technology where the results constantly exceed those arrived at when using CrVI and conventional etching.

Client Tests

The accumulated data from client industrial testing is abundant. However, this data cannot be shared due to NDA restrictions or, is not made available to Cuptronic. Four major European plating companies are in the process of testing a larger number of samples. These test runs are expected to be completed by early fall 2019. So far, the feedback indicates that the testing results are positive.

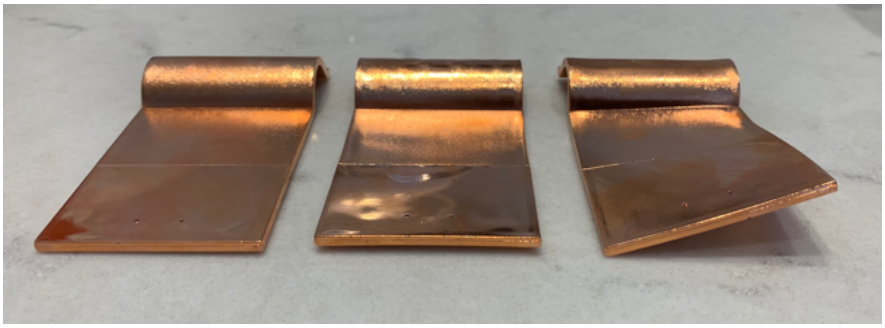
Test Methods

Every customer has their own testing methods, but they also adhere to their industry specific standards testing methods such as ISO 2409, ASTM B571-97 and IPC 650.

2.3 Process benefits

In addition to eliminating CrVI, an additional advantage of the Cuptronic CBM process is that it allows for a wide variety of plastics to be used, not only expensive "plating grade" as today. Also, a wide range of polymer types, like PP, ASA, PET, PES, COC, PEEK etc. can be plated in the same line. This increases the choice for customers.

Another advantage of the Cuptronic CBM process is that is not affected by injection molding parameters. The molding does not need to be sub-optimized for plating. With the use of the Cuptronic CBM process, the injection molding step can instead be optimized for the best molding throughput and end results.



Same good adhesion using different injection molding parameters (Normal / no after pressure / short cooling down time)

2.4 Customer progress status

Cuptronic has initiated a dialog with a multitude of companies, representing both end-user manufacturers, sub-contractors and chemical suppliers, mainly from the European automotive and sanitary industries. In some cases, good progress is made and there is active collaboration to jointly move forward towards industrial scale implementation. The first industrial pilot line is expected to be up and running during the1st quarter of 2020 and the first full industrial scale production line should be operational by the end of 2020. In other cases, though, the sales process is unfortunately put on hold due to ongoing process for REACH authorization decisions for use of CrVI.

3 ECONOMIC FEASIBILITY

3.1 Cost comparison

Cuptronic CBM process is cost-comparable to current ways of etching and its introduction is pro-competitive for the industry, driving more competition, lower prices and more choice for customers.

The table below shows a breakdown of the costs for the Cuptronic CBM process compared to traditional CR(VI) etching.

Aspect	CBM compared to CR(VI) etching
Cost of chemicals	Same or higher
Personnel costs	Higher
Energy costs	Same
Working environment atmospheric control	Lower
Raw materials	Lower
Process modification costs	Yes, see below
Total production costs	Lower

There are many aspects to implementing the Cuptronic CBM process on an industrial scale, and a full detailed cost comparison depends on the overall facility layout based on which a comprehensive calculation can be made. A cost benefit will be expected but who will profit depends on the business model in question: it may be the injection molder, electroplater or the OEM.

Capital expenditure

A CBM production line has to be installed. It consists of a CBM chemical application unit, a UV light exposure unit. These two units should be in-line and automated. Any coating line supplier can supply such a CBM production line. An automated line at Cuptronics facilities able to apply the Cuptronic CBM process on 50,000 panels (45 x 60 cm), which equals 27,000 m^2, per month cost approximately EUR 400,000.

Material (plastic) costs

Only plating grade plastics can be used to metallize with the conventional CrVI etching process. The Cuptronic CBM process can use non-plating grade plastics which are 25 – 50% cheaper. Furthermore, one could use plastics that are not possible to metallize today, that are both cheaper and have better properties. In cases where the same type of part is made both in a plated and a non-plated version (e.g. toilet flush buttons, which should be either white or chrome plated), the benefits

of using the same plastic would outweigh the potentially slightly higher costs of using the same plastic for both.

Increased yield

As the Cuptronic CBM process is much less sensitive to temperature divergences in the molding process than the current injection mold/etching processes, the yield will increase. Today, injection molded parts have to be manufactured within an extremely small production parameter window to be able to be plated. The Cuptronic CBM process is not affected by injection molding parameters and injection molders can optimize their production, reaching significant cost benefits.

Cost for chemicals

High volumes: EUR 0.05 per m^2.

Personnel costs

Marginal increases in personnel costs, when the process has been automated.

Energy cost

Energy costs per treated m^2 are likely to be close to the conventional etching, though these costs are expected to decrease when shifting from UV to heat and particularly when it is possible to use the excess heat of injection molding.

Working environment/atmospheric control

- ATEX certified application unit

4 AVAILABILITY

4.1 Current Status

Cuptronic has a small-scale production site with a capacity of 50,000 PCB panels a month which has been operational since 2017. Cuptronic is in the process of building a mobile and automated production unit for a European Tier 1 supplier to the automotive industry including close co-operation for scaling up the process. There are also ongoing discussions with major sanitary companies.

The equipment needed for the Cuptronic CBM process is readily available as it is commonly used on an industrial scale in similar processes. The CBM chemical mixture can be produced and supplied in larger volumes without any difficulties. There are no indications suggesting there could be limits to availability of the CBM process.

The first full scale industrial production line is expected to be operational by end of 2020.

5 CONCLUSION

The Cuptronic CBM process is an innovative, commercially and technically viable adhesion promotion solution to improve plating of plastics enabling a full substitution of CrVI. The benefits for workers safety, the environment and companies involved in plating of plastics are clear. The business case is sound and after the initial investment in setting up a CBM process, overall costs will be lower than when using CrVI. CBM is easily integrated into an existing plating process, a fact which makes the costs of shifting much lower than when moving to a completely different plating technology where an existing electroplating facility would be of no use.