

Cobalt/Chromium Carbide Composite Coatings Applied by Brush Plating for Use as an Alternative to Hard Chrome

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ABSTRACT

Due to increased concern for both environmental and worker safety from governments around the world, many significant industrial chemicals are being phased out of production processes. One example is the use of hexavalent chromium compounds for the electrodeposition of hard chrome. Electrodeposited chrome is typically used for improved hardness, lubricity, wear resistance, and corrosion resistance. This work will support the use of a metal matrix composite composed of cobalt and chromium carbide particles as an alternative for chrome coatings deposited from hexavalent chromium compounds.

Metal matrix composite (MMC) coatings consist of two phases co-deposited during plating: a continuous metal phase such as cobalt and small (<100 μm) particles of another chemical species distributed throughout. The physical qualities of the composite (such as hardness) are strongly dependent on the ratio and distribution of the two constituent phases. The composition of the plating solution and the parameters used during plating both play important roles in the composition and quality of the final deposit.

While most research has focused on applying metal matrix composites by tank electroplating methods, this presentation will focus on applying the coating via brush plating. Brush plating is a portable electrodeposition technique where solution is applied to the part by a plating solution saturated sleeve on the anode when contact is made to a localized area. Brush plating operations typically use less masking when plating small areas of a larger part. Less solution is needed because the part does not need to be immersed. And the brushing action allows for faster solution replenishment at the electrode surface.

This paper will show examples of a matrix material of cobalt co-deposited with either 1 μm or 6 μm chromium carbide particles. It will be described how the concentration of the particles in solution determines the range of particle incorporation; as well as develop an understanding of how tailoring the plating parameters to the system of particle and matrix is vital to creating a deposit for specific deposit characteristics.

Key words: chrome alternative, brush electroplating, metal matrix composites, wear resistance, high temperature oxidation

INTRODUCTION

In the war on corrosion and wear, maintenance repair engineers will be hard pressed to find a plating material as strong as chrome. It has high hardness, high lubricity, low wear resistance, and maintains some of its hardness even after being exposed to high temperatures. However, there's increasing pressure to find an alternative to this material due to the worker safety and environmental issues it presents. Regularly, hard chrome is electroplated where it is needed using a plating solution containing chromium trioxide. Chromium trioxide is registered with both REACH⁽¹⁾ and the EPA⁽²⁾ as carcinogenic, mutagenic, and teratogenic. It is also incredibly hazardous environmentally due to its highly oxidizing nature. Thus, it is important to evaluate both alternative materials and alternative methods for applying coatings which can achieve similar properties to what hard chrome is able to achieve.

Cobalt/chromium carbide metal matrix composites (Co/Cr₃C₂ MMCs) have previously been considered as a candidate to replace hard chrome in some applications. These coatings can be applied in a number of different ways such as cold spray and tank plating. Co/Cr₃C₂ MMCs have been shown to be resistant to high temperature oxidation treatments (< 800 °C). Depending on the parameters used during plating and post plating treatments, the deposit can also offer high hardness and wear resistance. Serving as a potential replacement to some applications of hard chrome, this material actually becomes more wear resistant after a lower temperature heat treatment (400 °C for 1 hour) and remains stable when held at temperatures in excess of 800 °C. These properties could allow it to function as a repair coating in some of the areas chrome is currently used in nuclear power generation such as coatings on gears and cylinders.

Unlike traditional hard chrome electroplating, there is no hexavalent soluble chromium in the plating solution for brush electroplating Co/Cr₃C₂ MMCs. Microscopic solid chromium carbide particles are suspended in the plating solution and remain uncharged. Chromium in this form does not exhibit the same safety hazards as hexavalent chromium because the species remains non-ionic. In brush electroplating, the plating solution is delivered directly through the anode to the work surface instead of needing to immerse the entire part in plating solution. The brush plating technique is more portable than traditional tank plating and requires smaller volumes of solutions since the part does not need to be completely immersed in solution. This means that often repairs can be made at the job site instead of parts being transported to a plating shop.

This study has been performed in order to optimize the plating parameters for this cobalt/chromium carbide matrix composite deposit in order to attain properties which best correlate to hard chrome. The first hypothesis to be tested was that increasing the amount of chromium carbide particles in the solution would increase the amount of particles incorporated into the deposit. It was expected that since chromium carbide has properties closer to that of chrome, the more particles that could be incorporated in the deposit, the closer those properties would come to chrome.

EXPERIMENTAL PROCEDURE

Brush electroplating was performed mainly on masked off 5.1 cm x 5.1 cm areas of carbon steel panels (UNS G10080). All solutions, materials, equipment, and the process itself were developed by SIFCO Applied Surface Concepts[†]. The plating solution used to apply the deposit was a cobalt brush plating solution with microscopic chromium carbide particles added to it. The particles added were an average of 6 µm in diameter and solutions were plated at particle loading levels of 0, 20, 40, 60, 100, and 150 g/L. The particles were suspended through the plating solution using constant agitation in a custom made 26.5 L mixing vessel. The solution was pulled to the work surface through a peristaltic pump and applied directly to the work piece by the anode. The anode was a titanium mesh coated in an iridium based mixed metal oxide material. The plating conditions used are summarized below in Table 1. The apparatus used for brush plating is shown in Figure 1.

(1) Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) from European Chemicals Agency (ECHA), Telakkakatu 6, 00150 Helsinki, Finland

(2) U.S. Environmental Protection Agency (EPA), 1200 Pennsylvania Ave, NW, Washington, DC 20460
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[†] Trade name.
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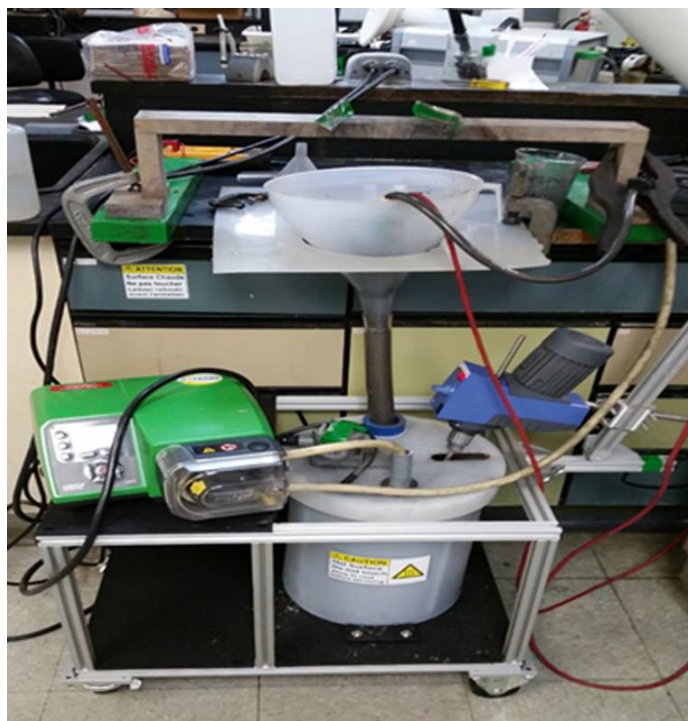


Figure 1: Brush plating setup for Co/Cr₃C₂ MMCs. Solution is stored and agitated in the vessel on the bottom, pumped to the plating surface on top via the peristaltic pump and drains down the funnel back to the storage vessel to be recirculated again. The rectifier which supplies power to the operation is not shown.

After masking off the area to be plated with non-conductive tape, a typical plating operation involves several preparation steps before the deposit itself is applied. Using solutions from (3) above sequentially the sample area is electrocleaned, etched, desmutted, and pre-plated with nickel before the final deposit is applied. Each preparatory step is performed using a separate anode made of graphite with an area of 5.1 cm x 7.6 cm and covered with a cotton jacket. Depending on the current density required, different rectifiers were used to supply the electrical current. All rectifiers used had a maximum voltage of 20 V but maximum amperage varied between 20 and 150 A.

Samples were analyzed for thickness and incorporation of chromium into the deposit by benchtop X-ray fluorescence (XRF). Chromium incorporation was reported as percent of the deposit relative to cobalt because carbon is not detectable by XRF. A number of samples under different conditions were

Table 1
Conditions used for electroplating Co/Cr₃C₂ MMCs

Parameter	Value
Plating temperature	125 °C
Wrap material	SiC infused abrasive
Anode material	Mixed metal oxide
Solution flow rate	1 L/min
Voltage	5-20 V
Current density	0.465 to 1.085 A/cm ²
Particle concentration	0 to 150 g/L
Anode to cathode ratio	55 and 100 %
Solution depletion	0 to 65 %