

Highlighting the Use of Brush Plating for Plating on Titanium, Nickel Plating, Copper Plating and Metal Matrix Composite Materials

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ABSTRACT

Selective or brush plating is an application method for electrodeposition which can be used for coating an array of pure metals, alloys, and composite materials. The ‘brush’ in brush plating describes a porous, non-conductive, flexible material which wraps the anode to keep it separated from the part to be plated. The plating solution is applied by rubbing the anode, covered with the brush material and saturated by the plating solution, against the area to be plated. This is done in lieu of dipping the entire part in a large tank of plating solution. Brush plating has seen its most advantageous use in plating smaller areas of larger parts because the amount of masking used can be reduced, and smaller volumes of solution can be utilized compared to traditional tank plating methods. Brush plating is portable and repair plating can be performed in the field, sometimes without even disassembling equipment. Brush plating is currently used for numerous specialty applications in the fields of aerospace, oil and gas, marine environments, manufacturing, and many others.

The process of brush plating will be presented in terms common to all electroplating processes. The effects of parameters particular to brush plating shall be clarified in terms of their contributions to the molecular level and to the properties of the resulting deposit. Applying solution by brushing it onto a part allows for higher metal concentrations in the plating solution, higher current densities, and higher plating rates compared to other plating methods. The application method (brushing) promotes fast solution replenishment on the electrode surface and dissipation of species generated by side reactions at the work surface. The type of brush material used on the anode will affect the type of surface finish or even the structure of the deposited material.

The paper will include a summary of a brush plating process for depositing nickel pre-plate on titanium with strong adhesion, highlighting advancements made to the plating process for a classic sulfamate nickel plating solution formulation, the application of copper onto threaded connections and evaluating differences in solution composition focusing on particle loading.

Key words: brush electroplating, nickel plating, corrosion, wear resistance, chrome alternatives, plating on titanium

INTRODUCTION

Electroplating is a commonly used technique in a variety of industries for applying metallic coatings to a surface to enhance corrosion resistance, hardness and wear characteristics, for appearances, anti-galling, conductivity, radiation shielding, or a variety of other deposit characteristics. Typical electroplating occurs when the part to be plated is submerged in a tank of plating solution with an anode and electrical current is applied between the two. Using this method, any part of the work piece which does not require plating must be physically masked off with a non-electrically conductive material such as tape in order to keep the plating material from adhering where it is not wanted.

Brush plating is also a technique for plating metals onto various substrates. A schematic for brush plating is shown below in Figure 1. In lieu of submerging the part/substrate (I) in plating solution via a large tank, the area to be plated is rubbed with the anode (II) which is wrapped in a plating solution soaked, non-electrically conductive, absorbent cover material (III). The solution can be delivered by flowing the solution (IV) through the anode or just by dipping the wrapped anode in plating solution and bringing it to the surface to be plated. Similar to traditional tank plating, masking (V) must still be applied around the surface to be plated in order to protect the rest of the work piece. However, because only a small amount of plating solution is applied to the area to be plated, a much smaller area can be masked just around the area to be plated instead of the whole work piece outside of the area to be plated.

Just like tank plating, an electrical current (VI) must still be applied in order to deposit the metal to the surface of the part. In brush plating, the anode is moved around the plating as current is flowing and solution is being applied. The movement of the anode and the brushing action of the wrap material disrupts the diffusion layer near the plating surface ensuring replenishment of the ions to be plated. Combining that effect with the higher metal concentrations of brush plating solutions means that brush plating deposits (VII) are typically applied at higher current densities and rates than other methods of electroplating.

The applications for brush plating now stretch across many areas of industry from oil and gas, to aerospace, to nuclear power generation, to general industry. Brush plating is commonly used for repairs made to damaged coatings and damaged parts, plating small areas of much larger parts, and where portability is essential. In many applications, brush plating has been used to repair parts without the larger piece of equipment needing to be disassembled. Brush plating has been around for more than 50 years and development is always moving forward. Here, a selection of research applications has been reviewed to highlight the advances currently being done to improve brush plating technology.

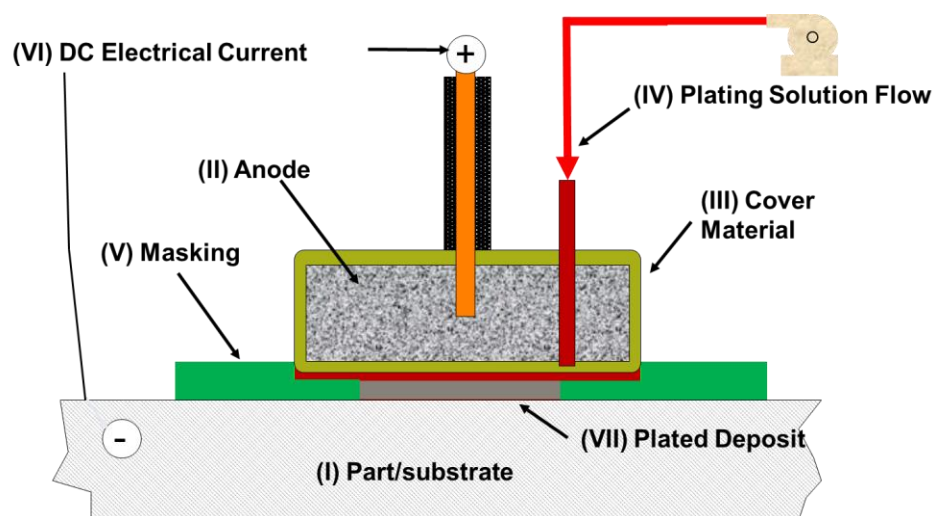


Figure 1: Schematic representation of a typical brush plating operation.

To date, few applications have been performed on nuclear systems but the potential is astounding. Nuclear plants continue to age and outlive what was their intended lifespan and to maintain safety and functionality repairs will be needed. Brush plating is a portable technique which can be brought to the part that needs to be repaired. The applications described below show work being done which could be useful in applications related to nuclear power generation. They show the ability of brush plating to apply deposits which resist wear in high temperature applications (metal matrix composites (MMCs)), the ability to apply deposits in hard to reach, non-line-of-sight areas (encapsulated plating), and to apply deposits on different metal substrates respectively (nickel plating onto titanium).

RESULTS AND DISCUSSION

Metal Matrix Composites (Cobalt/Chromium Carbide)

In electroplating, normally the plating solution is a single-phase aqueous solution containing among other ingredients, positively charged metal ions which are meant to be reduced on the electrode surface. In that case, electroplated deposits would be limited to metals and alloys whose metal ions can be dissolved in water and then reduced on the work piece. New plating solutions have been developed for the brush plating process which combine solid microscopic particles with the plating solution to allow for the deposition of new complex materials.

The plating solution for the cobalt/chromium carbide metal matrix composite (Co/Cr₂C₃ MMCs) was developed due to a need for alternative materials to replace electroplated hard chrome. The plating solution used to plate hard chrome contains chromic acid (H₂CrO₄) which is recognized by numerous national and international environmental and worker safety agencies as being carcinogenic, mutagenic, and teratogenic. While Co/Cr₂C₃ MMCs do still contain chromium, it is not in a form that is known to be toxic in the way chromic acid is. The purpose of the deposit is to provide a coating which compares to hard chrome in terms of its hardness and wear resistance at both room temperature and at high temperatures (~800 °C).

The developed plating solution can contain between 20 and 150 g/L of 1 to 6 µm diameter particles which are suspended in the solution through constant agitation. The concentration of particles in the solution is varied depending on the desired application and geometry of the surface to be plated on. As more particles are added to the solution, on average more particles will become incorporated into the deposit. This is shown in Figure 2. The expected effect on properties is that as more particles become incorporated into the deposit, the deposit will become more like the chromium carbide which is harder and more resistant to wear.

While higher concentrations of particles did lead to improved properties up to a point (between 60 to 100 g/L) the solution appeared to become over saturated by particles as the concentration stretched above 100 g/L. This led to very high incorporation of chromium in the deposit as measured by X-ray fluorescence (XRF). But the deposit was more likely to become crumbly to the touch and the average hardness of the deposit dropped when measured by Vickers indentation of part cross sections. An example of that type of deposit is shown below in Figure 3. It was found that when plating onto flat panels, deposits had the highest wear resistance when plated with 60 g/L of chromium carbide particles and also at a lower current density (0.465 A/cm² vs 1.085 A/cm²). Plating at a lower current density