

# Chemical Treatments for Metal Surface Finishing: Techniques and Applications

Raoul Nanssou\*

Department of Science and Technology, Parthenope University of Napoli, 80133 Napoli NA, Italy

## Introduction

The surface finishing of metals plays a pivotal role in enhancing the functional and aesthetic properties of metal products. Chemical treatments for metal surface finishing are critical in various industries, including automotive, aerospace, electronics, construction, and manufacturing. These treatments improve metal surfaces by providing protection against corrosion, wear, and fatigue while also enhancing visual appeal through processes like polishing and coating. The increasing demand for durable, high-performance metal products has led to the development of a wide range of chemical treatments designed to modify the surface characteristics of metals.

Chemical surface treatments are essential because they can alter metal properties such as hardness, corrosion resistance, electrical conductivity, and appearance, without altering the bulk properties of the material. Common chemical treatments include electroplating, anodizing, passivation, phosphating, and surface coatings. The ability to tailor these treatments for specific applications has become a key aspect of modern manufacturing processes, where both functionality and aesthetics are paramount [1]. This research article aims to explore the various chemical treatments used in metal surface finishing, discussing their techniques, applications, and the impact these treatments have on metal performance and longevity.

## Description

Chemical treatments for metal surfaces can be broadly classified into processes that involve coating, modification of surface properties, and the creation of protective layers. These techniques are chosen based on the type of metal being treated, the desired outcome, and the specific industrial application. Electroplating is one of the most common chemical treatments for metal finishing. It involves depositing a thin layer of metal onto a substrate by applying an electric current in an electrolyte solution containing the metal ions. The electroplating process is widely used to enhance the surface properties of metals such as steel, aluminum, and copper.

Electroplating is used to improve corrosion resistance, wear resistance, and appearance. For example, chrome plating is often used on car parts, machinery, and tools to increase durability and provide a shiny finish. Gold and silver plating are used in electronics, jewelry, and medical devices for their corrosion resistance and aesthetic qualities. The metal substrate is immersed in an electrolyte bath that contains dissolved metal ions. When an electric current is applied, metal ions are reduced and plated onto the surface of the substrate. The thickness, smoothness, and uniformity of the coating can

be controlled by adjusting parameters such as current density, temperature, and plating time [2].

Anodizing is an electrochemical process that converts the metal surface, usually aluminum, into a durable, corrosion-resistant oxide layer. This treatment not only improves the metal's resistance to corrosion but also enhances its appearance by adding a controlled color through dyeing. Anodizing is commonly used in the aerospace, automotive, and architectural industries. It is particularly popular for aluminum parts and products, such as automotive trim, building facades, and aircraft components. The metal is immersed in an acidic electrolyte solution (such as sulfuric acid), and an electrical current is passed through the solution. This process thickens the natural oxide layer on the surface of the metal. The thickness of the oxide layer can be controlled to enhance durability, while dyes can be used to add color to the surface.

Passivation is a chemical treatment primarily used to improve the corrosion resistance of stainless steel and other metals. The process involves treating the metal surface with an acid solution, such as nitric acid, to remove free iron and other contaminants, which allows the formation of a protective oxide layer. Passivation is widely used in the food processing, pharmaceutical, and medical device industries, where stainless steel components must be resistant to corrosion and contamination. In passivation, metals such as stainless steel are treated with a mild acid solution that removes surface contaminants and promotes the formation of a chromium oxide layer on the surface. This oxide layer helps protect the metal from rust and corrosion.

Phosphating is a chemical treatment process used to apply a phosphate coating onto the surface of metals, particularly steel and iron [3]. The phosphate coating acts as a protective layer, enhancing the metal's resistance to corrosion and providing a good base for further coatings like paint or oil. Phosphating is used in automotive, machinery, and metalworking industries to improve corrosion resistance and promote adhesion of coatings, such as paints or lubricants. The metal surface is immersed in an acidic solution containing phosphoric acid and other chemicals, which forms a phosphate coating on the surface. The coating improves adhesion for subsequent treatments and provides resistance against corrosion. Various coating techniques are used in metal finishing to enhance surface properties such as hardness, wear resistance, and appearance. Powder coating is a dry finishing process that involves applying a fine powder onto the surface of the metal, which is then cured by heat to form a hard, durable coating. It is widely used for outdoor metal products such as appliances, automotive parts, and furniture.

PVD is a process that involves the vaporization of metal in a vacuum to form a thin, metallic film on the surface of the substrate. This process is commonly used for creating decorative finishes on products like watches, jewelry, and cutting tools. Thermal spraying involves spraying molten or heated material onto a metal surface to create a coating. It is used to enhance properties like corrosion resistance, wear resistance, and thermal insulation. Chemical treatments have widespread applications across various industries, improving metal properties and ensuring that products meet the demands of modern manufacturing [4].

In the aerospace industry, metal surface finishing is critical to the performance, safety, and longevity of aircraft components. Techniques such as anodizing, electroplating, and passivation are used to enhance the corrosion resistance, wear resistance, and aesthetic appearance of parts like engine components, landing gear, and airframes. The ability to withstand extreme

\*Address for Correspondence: Raoul Nanssou, Department of Science and Technology, Parthenope University of Napoli, 80133 Napoli NA, Italy; E-mail: nanssou0077@gmail.com

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environmental conditions, such as high-altitude pressure and temperature fluctuations, is crucial, making chemical treatments indispensable. The automotive industry relies heavily on metal surface finishing for both functional and aesthetic purposes. Electroplating, phosphating, and powder coating are commonly used to enhance the durability, corrosion resistance, and appearance of automotive components such as chassis, wheels, and trim parts. These treatments also contribute to vehicle performance, with improvements in fuel efficiency and reduced maintenance needs due to corrosion resistance.

In electronics manufacturing, metal surface finishing is vital to ensuring the performance and reliability of electronic components. Gold and silver electroplating are used for connectors, circuit boards, and other components to ensure good electrical conductivity, corrosion resistance, and long-term performance. The miniaturization of electronics has increased the demand for precision in surface finishing, making chemical treatments more important than ever. In construction, especially in architectural applications, metal surface finishing enhances the aesthetic appeal and functional durability of materials like aluminum, steel, and copper. Techniques such as anodizing and powder coating are commonly used for architectural panels, window frames, and structural supports to improve both the visual appeal and resistance to corrosion.

Some chemical treatments, especially electroplating and anodizing, can generate hazardous waste and by-products that pose environmental risks. The industry is increasingly focused on adopting more eco-friendly chemicals and developing closed-loop systems to minimize waste and reduce the environmental footprint of chemical treatments. The application of certain chemical treatments can be expensive, particularly in highly specialized industries like aerospace and electronics. The cost-effectiveness and scalability of these treatments are critical factors in determining their use in large-scale manufacturing. Chemical treatments must be carefully controlled to avoid negatively affecting the underlying metal. Over-treatment or improper processing conditions can lead to surface defects, such as pitting, discoloration, or weakening of the substrate [5].

## Conclusion

Chemical treatments for metal surface finishing play an essential role in enhancing the durability, appearance, and performance of metal products across numerous industries. Techniques such as electroplating, anodizing, passivation, phosphating, and coating offer a wide range of benefits, including improved corrosion resistance, wear resistance, and the ability to impart specific aesthetic qualities. These treatments are crucial in industries like aerospace, automotive, electronics, and construction, where high-performance and long-lasting metal products are required.

However, challenges remain, particularly in terms of environmental impact, cost, and maintaining the integrity of metal surfaces. As the demand for high-performance materials grows, the development of more sustainable, efficient, and cost-effective chemical treatment processes will be essential

to meet industry needs. Continued research and innovation in chemical treatments for metal surface finishing are vital to advancing manufacturing practices and ensuring the longevity and reliability of metal products in an increasingly complex technological landscape.

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## Conflict of Interest

None.

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