

A PROCESS FOR FORMING COATINGS ON METALLIC SURFACES

FIELD OF INVENTION

- 5 Embodiment of the present invention relate to process for forming coatings on metallic surfaces.

BACKGROUND

- 10 Various mechanical systems require the use of metallic parts. For many applications, the parts must not only perform mechanically, but must also appeal aesthetically. For example, automobile wheels are often made from light metals or light metallic compounds, such as aluminium, magnesium, alloys of aluminium, and alloys of magnesium. These wheels often have coatings that are used to improve the anti-
15 corrosion and wear resistance properties of the wheels.

Traditionally, wheels have been painted with polymer materials, including various powders, or chemically plated using, for example, metallic layers of copper, nickel and chrome with different thicknesses. In the painting process, paint sprayed onto a surface
20 with a tool, such as spray gun. The plating process could involve dipping the wheel into one or more containers filled with various chemical liquids, then cleaning and allowing the wheel to dry. One problem with these processes, especially the chemical plating process, is that they are very environmentally unfriendly.

- 25 One process for forming a multi-layer coating on car wheel rim applies a base-coat paint layer. A Nickel Chromium (NiCr) and Chromium (Cr) layer are then individually applied using a physical vapour deposition (PVD) process. Finally, a clear organic top-coat is applied and cured. The process provides a wheel having a shiny appearance. The process was developed to eliminate the prior art chemical plating processes.

30 Unfortunately, the hardness of the coating provided in the process above is lower than that produced by prior art chemical plating processes. Therefore, the coating is easily

scratched or abraded. Once abraded, the underlying base metal of the wheel is subject to corrosion. Moreover, the sub-processes used above, i.e. painting/plating of the base layer and top layer, gives rise to pollution to the environment. Usually, a lacquer is employed as the material for the base layer and the top layer, which may irritate or damage the lungs if it is breathed in. In the course of forming the layers, a spraying tool, such as a spray gun, is used to change the lacquer into a fog with a particle diameter ranging from several nanometers to tens of micrometers. The fog is then deposited on the metallic surface, such as a wheel, thus forming the coating on the surface.

- 10 It would therefore be a great improvement in the art if one process for forming coatings on a metallic surface could be provided that overcomes at least one of the problems discussed above.

SUMMARY

- 15 One aspect of the present invention provides a process for forming coatings, the process including the steps of: providing a metallic base having an outside metallic surface; depositing a ceramic coating on said outside surface using a micro-arc oxidation process such that one or more additional metallic coatings may be applied to said ceramic coating with a greater adhesion compared to applying said metallic
20 coatings directly on said outside surface.

- In some embodiments, the step of depositing the ceramic coating may include the steps of: immersing the metallic base in an electrolyte solution contained in a metallic electrolyte cell; applying a pulsed electrical current to the base and the
25 metallic cell to establish a microplasmic discharge between the base and the electrolyte; and continuing the pulsed electrical current until the first coating has reached a desired thickness. The electrolyte may be at least one of a silicate and an aluminate.

- 30 In some embodiments, the ceramic coating may provide an anti-corrosion barrier on the surface. The ceramic coating may have a thickness of between 5 and 200 micrometers.

In alternate embodiments, the process may further include: preparing a surface of the ceramic coating; depositing a first metallic coating over the surface of the ceramic coating. In some embodiments, the process may further include depositing a second metallic coating over the first metallic coating. In other embodiments, the steps of depositing the first and second metallic coatings may be accomplished using a physical vapour deposition process. The physical vapour deposition process may include one of sputter deposition and multi-arc deposition.

In some embodiments, the physical vapour deposition process may be performed in the presence of one or more inert gasses, a mixture of the gasses being adjusted to obtain a desired colour for the second metallic coatings. The one or more inert gases may be selected from a group consisting of argon, nitrogen, and acetylene.

In some embodiments, the preparing step may further include: polishing the surface of the first coating; washing the surface of the first coating; and drying the surface of the first coating. The polishing step may include rough polishing the surface of the first coating until the surface has a surface roughness of less than 8 micrometers.

In some embodiments, the process may further include a step for preparing the outside metallic surface after the providing step, where the preparing step includes polishing the outside metallic surface; washing the outside metallic surface; and drying the outside metallic surface. The polishing step may include fine polishing the outside metallic surface until the outside metallic surface has a surface roughness of less than 2 micrometers.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiment of the invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figure 1 is a cross-sectional view of one embodiment of a surface of an object that results from application of the process of Figure 2 using the apparatus of Figure 3, according to the present invention;

- 5 Figure 2 is a flow diagram showing the steps of one example embodiment of a process for applying coatings to the surface of the object of Figure 1, according to the present invention; and

10 Figure 3 illustrates one embodiment of an apparatus for providing micro-arc oxidation that forms part of the coating process of Figure 2.

DETAILED DESCRIPTION

- 15 In order to overcome some of the problems cited above, embodiments of the present invention provide a process for coating a metallic surface of an object, such as a wheel, that is environmentally friendly, yet produces coatings that are sufficiently hard to withstand environmental hazards. One process provides a ceramic coating directly onto the surface of the wheel. This process is described
20 below, with reference to Figures 1-3.

Figure 1 illustrates a cross-sectional view of one embodiment of a surface of an object 100 that results from application of the process of Figure 2 using the apparatus of Figure 3. The object 100 has a base 102, having a top metallic surface
25 103. A first coating 104 may be applied to the top surface 103. In some embodiments, a second coating 106 may be applied to a top surface 105 of the first coating 104. In other embodiments, an additional top coating 108 may be applied to a top surface 107 of the second coating 106.

- 30 In this embodiment, the base 102 can be any type of metallic material capable of receiving a coating. In a preferred embodiment, the base 102 can be a metal wheel, such as those used in transportation applications. The metal may be, by way of example and not limitation, aluminum or an aluminum alloy, magnesium or

magnesium alloys, any other type of light metal or light metal alloy, or any one of various types of steel or steel alloys.

One example embodiment of a flow diagram showing the steps of a process for applying coatings to the surface 100 according to the present invention is illustrated in Figure 1, and designated generally as reference numeral 200. Figure 3 illustrates one embodiment of an apparatus 300 for providing micro-arc oxidation that forms part of the coating process 200 of Figure 2.

With continuing reference to Figures 1-3, the process 200 begins with an optional pre-treatment step, designated generally as reference numeral 202. The pretreatment step 202 may be used to provide a uniform surface roughness across the entire top surface 103 of the base 102. This may be required, for example, if the top surface 103 of the base 102 of the object 100 has a high degree of roughness prior to the application of the method 200. The pre-treatment step 202 allows for a more uniform adhesion of the first coating 104 when it is later applied to the top surface 103 of the base 102. The pre-treatment step 202 may include a step for rough polishing the top surface 103 of the base 102, as represented with reference numeral 204. The pretreatment step 202 may also include a next step of cleaning the top surface 103 of the base 102, as represented with reference numeral 206.

The rough polishing step 204 may be accomplished, by way of example and not limitation, using various abrasive media known to those of skill in the art. In a preferred embodiment, the abrasive media may be 200-800 grit sandpaper. A polishing machine (not shown) may be used for preparing large and relatively flat areas of the top surface 103 of the base 102. Other areas may be polished by hand, or using fine polishing tools known to those of skill in the art. In some embodiments, the polishing step 204 may also use a wax, oil, or other substance to increase efficiency and provide a uniform top surface 103.

In a preferred embodiment, the rough polishing step 204 is continued until the top surface 103 of the base 102 has a surface roughness that is less than 8

micrometers. It is understood that other surface roughness measurements, both larger and smaller, may also be used.

The cleaning step 206 may use any cleaning technique known to those of skill in the art to remove any contamination that may be present on the top surface 103 of the base 102. For example, ultrasonic cleaning techniques, washing with various liquids to include water, etc., may be employed for the cleaning step 206. In a preferred embodiment, an ultrasonic cleaning process may be used.

The ultrasonic cleaning process may include steps for de-waxing, de-oiling, rinsing, and drying the top surface 103 of the base 102. The base 102 is first placed in a bath, which contains a liquid with a commercial water-soluble substance for de-waxing and de-oiling known to those of skill in the art. To improve the cleaning efficiency, an ultrasonic vibration tool may be used to generate ultrasonic waves with a desired frequency or a tunable frequency. These waves assist in removing particles from the base 102. Moreover, the liquid may be warmed using, for example, an electrical resistance heater, to a temperature of 60-80 °C. With the mechanical force from the ultrasonic waves and the chemical force from the water-soluble substance cited above, the wax, oil and other debris are removed from the surface of the base 102. Then the base 102 may be placed in a second bath, i.e. a rinsing bath. In some embodiments, particularly in the rinsing phase, de-ionized water may be used as the rinsing agent. De-ionized water can prevent water stains, which may be associated with tap water, from forming on the base. The ultrasonic vibration and heating processes described above may also be applied in this rinsing step. Finally, the base 102 may be subjected to a drying step using, for example, heated air produced by an electric-resistance heater and a fan.

Once the pre-treatment stage 202 has been completed, the first coating 104 may be applied to the top surface 103 of the base 102 using a microarc oxidation (MAO) process, as indicated by reference numeral 208. In some embodiments, the pre-treatment stage 202 helps to ensure that the surface 103 of the base 102 is free from contaminants. This allows the electrolyte used in the MAO process (described below) to be re-used, thus resulting in a coating process 200 that is significantly more environmentally friendly than those of the prior art.

The MAO process can include a step of applying the first coating 104, as indicated with reference numeral 210, and an additional rinse step, as indicated with reference numeral 212. With reference to Figure 3, the MAO process 210 may be accomplished with a MAO apparatus 300. The apparatus 300 may include an insulating container 302 that contains a metallic electrolytic cell 304 that is filled with an electrolyte 306. In a preferred embodiment, the electrolytic cell may be made from stainless steel. A pulse power supply 308 has a first electrode 310 connected to the electrolytic cell 304 (cathode), and a second electrode 312 connected to the base 102 (anode) that is at least partially immersed in the electrolyte 306.

The MAO process 210 may be used to deposit a ceramic coating(s) on the surface of, for example, valve metals and their alloys. For the purposes of this discussion, valve metals may be taken to generally include aluminium, magnesium, tantalum, tungsten, zinc, zirconium, and their various alloys. These valve metals, in their original state, are protected by thin, self-healing, tightly adherent dielectric oxide films which resist the passage of current in the anodic direction. Therefore, if using a valve metal as an anode, it is necessary to raise the potential of the valve metal surface to a high value in order to pass significant current through the anode. In the MAO process 210, the base 102 is immersed in the electrolyte 306, and voltages of asymmetric alternating current are applied from the pulse power supply 308 between the base 102 (anode) and the electrolyte cell 304 (cathode). In the anodic half circle the voltage may be in the range of 150–1000 Volts, while in the cathodic half circle the voltage may be in the range of 0–150 Volts.

In the MAO process 210, an electrochemical reaction occurs between the base 102 and the electrolyte 306 that results in an electric discharge on the base 102 to form the coating 104. The coatings 104 produced by the MAO process 210 have a high micro-hardness, high adhesion, and high strength. In some embodiments, the electrolyte 306 may be a solution of sodium silicate in distilled water with other additives, such as sodium tungstate (Na_2WO_4). It is understood that other additives and/or electrolytes may also be used, including, but not limited to various silicates and aluminates. In some embodiments, the temperature of the electrolyte 306 may be controlled to remain lower

than 80 °C during the MAO treatment by cooling the electrolyte 306 with a heat exchanger 313 connected to the cell 304 via an inlet 314 and an outlet 316. It is understood that other types of heat exchangers, including immersion chillers, could also be used.

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For an aluminium or aluminium alloy base 102, the coating 104 may be aluminium oxide (α -Al₂O₃ and γ -Al₂O₃) having a thickness of 5-200 μ m. The growth rate of the coating 104 mainly depends on the duration of the process and the current density used. For example, a 5- μ m coating 104 can be obtained by using a current density of 40 amperes per square meter with a 30-minute process duration. It is understood that different coating thicknesses, current densities, and/or process durations can also be used. The coating 104 produced by the MAO process 210 has the properties of a hard ceramic and provides corrosion and abrasion resistance to the base 102. Additionally, the hard ceramic layer provides a more adhesive base layer for any additional metallic coatings that may be applied over the ceramic coating 104.

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Once the coating 104 has been applied to the base 102 using the MAO process 210, the surface 105 of the coating 104 may then be rinsed, as shown with reference numeral 212. In some embodiments, the rinse step 212 may include rinsing with de-ionized water. An optional drying step may also be performed.

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Once the rinse step 212 has been completed, the surface 105 of the coating 104 may be subjected to an optional fine polishing and cleaning stage, as represented by reference numeral 214. The fine polishing and cleaning stage 214 can include a first step of fine polishing the surface 105, as represented with reference numeral 216. Additional washing and drying steps may then be performed, as represented by reference numerals 218 and 220. These additional washing and drying steps may be similar to those described with respect to the cleaning step 206. Other processes may also be used.

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The fine polishing process 216 may be accomplished using various abrasive media known to those of skill in the art. In a preferred embodiment, the abrasive media may be 1000-1500 grit sandpaper. A polishing machine (not shown) may be used

for preparing large and relatively flat areas of the top surface 105 of the coating 104. Other areas may be polished by hand, or using fine polishing tools known to those of skill in the art. In some embodiments, the polishing step 216 may also use a wax, oil, or other substance to increase efficiency and provide a uniform top surface 105.

5 In a preferred embodiment, the fine polishing process 214 provides a surface roughness of less than 2 micrometers for the surface 105 of the coating 104.

As the fine polishing process 216 may result in latent wax, oil, and/or dust and debris clinging to the surface 105 of the coating 104, an additional step of washing,

10 including de-waxing and de-greasing, may be applied, as indicated with reference numeral 218. The washing, de-waxing and degreasing steps may be similar to those performed during the cleaning step 206. In some embodiments, an ultrasonic washing process may be used. The next step is drying of the object 100, as shown with reference numeral 220.

15 Once the fine polishing and cleaning stage 214 has been completed, a Physical Vapour Deposition (PVD) Coating (second coating) 106 may be applied to the surface 105 of the first coating 104, as shown with reference numeral 224. The polished, clean and dry base 102 may be deposited in a vacuum chamber for the application of an integrated

20 PVD technology process. The PVD process may include sputter deposition or multi-arc deposition of the second coating 106. In some embodiments, the PVD deposition stage may also include depositing a top coating 108 on a surface 107 of the second coating 106. The coating thickness for each of the coatings 106, 108 may range from 5 nanometres to 5 micrometers, as desired.

25 The adhesion and colour of the coatings 106, 108 may be adjusted depending on various working parameters. These working parameters may include, but are not limited to, the type of metal used for the coating(s) 106, 108, the amount of particle energy used, the specific gas mixture and/or gas pressure inside the chamber, etc. The

30 strength and hardness of the coatings 106, 108 may be determined by the coating materials. These materials may include, but are not limited to, chromium, titanium, tantalum, aluminium, zirconium, and stainless or other types of steels. Additionally, alloys and/or nitrides and/or carbides of these metals may also be used as the top

coating 108. In some embodiments, these coatings 106, 108 may have a thickness that is less than 500 nanometers. A minimum thickness of 5 nanometers is preferred.

5 In some embodiments, the color of the top coating 108 may also be adjusted. For example, when applying a titanium second coating 106, adjusting the gas mixture within the PVD chamber may produce a different color for the deposited coating. In one embodiment, using pure argon as the gas produces a titanium coating 108 that has a light black color. Alternately, by adding nitrogen (N_2) to the argon gas, varying colors from a light yellow, to yellow, to golden yellow, to a dark golden yellow, to pink, may be produced. The color becomes darker as the ratio of nitrogen to argon increases.

10 In an alternate embodiment using aluminum as the top coating 108 and pure argon as the gas, a silver coating 108 may be produced. When varying amounts of N_2 is added to the argon gas, the coating 108 may turn black. In a preferred embodiment, the ratio of Nitrogen to Argon used for the mixed reactive gases is no less 10%.

15 Additionally, carbides of the metals cited above may also be used to adjust the colour of the top layer 108. They may be formed either by an alloy targeting method or by the reactive deposition method using sputtering or multi-arc as cited above. In one embodiment, the mixed working gases may be Argon and acetylene (C_2H_2). Various colours may be obtained by changing the target materials and mixed working gases as known to those of skill in the art.

20 Embodiments of the present invention provide several advantages over prior art processes. For example, the electrolyte used in the MAO process is re-usable, thus resulting in a more environmentally friendly coating process. Additionally, the coatings formed by the MAO process have a higher hardness than those available in the prior art.

25 The various coatings produced by the processes outlined above may be known as 'Fulastern'_{tm} coatings. The term Fulastern_{tm} derives from 'Ful', meaning Fulita International Enterprises Pte. Ltd, (Singapore), the applicant of the invention, and 'stern' German for star. As such, Fulastern_{tm} means one star of Fulita. . Also, within the characters of Fulastern_{tm}, the 'last' indicates that the coating can last for a long time.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly
5 described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

What is claimed is:

1. A process for forming coatings, the process comprising the steps of:
providing a metallic base having an outside metallic surface;
5 depositing a ceramic coating on said outside surface using a micro-arc oxidation process such that one or more additional metallic coatings may be applied to said ceramic coating with a greater adhesion compared to applying said metallic coatings directly on said outside surface.
- 10 2. The process of claim 1, wherein said step of depositing said ceramic coating comprises the steps of:
immersing said metallic base in an electrolyte solution contained in a metallic electrolyte cell;
applying a pulsed electrical current to said base and said metallic cell
15 to establish a microplasmic discharge between said base and said electrolyte; and
continuing said pulsed electrical current until said first coating has reached a desired thickness.
- 20 3. The process of claim 2, wherein said electrolyte comprises at least one of a silicate and an aluminate.
4. The process of any one of the previous claims, wherein said ceramic coating provides an anti-corrosion barrier on said surface.
- 25 5. The process of any one of the previous claims, wherein said ceramic coating has a thickness of between 5 and 200 micrometers.
6. The process of any one of the previous claims, further comprising:
30 preparing a surface of said ceramic coating;
depositing a first metallic coating over said surface of said ceramic coating.

7. The process of claim 6, further comprising depositing a second metallic coating over said first metallic coating.
- 5 8. The process of claim 7, wherein said steps of depositing said first and second metallic coatings are accomplished using a physical vapour deposition process.
9. The process of claim 8, wherein said physical vapour deposition process comprises one of sputter deposition and multi-arc deposition.
- 10 10. The process of any one of claims 8 and 9, wherein said physical vapour deposition process comprises performing said physical vapour deposition process in the presence of one or more inert gasses, a mixture of said gasses being adjusted to obtain a desired colour for at least one of said
- 15 first and second metallic coatings.
11. The process of claim 10, wherein said one or more inert gases are selected from a group consisting of argon, nitrogen, and acetylene.
- 20 12. The process of any one of claims 6-11, wherein said preparing step further comprises:
polishing said surface of said first coating;
washing said surface of said first coating; and
drying said surface of said first coating.
- 25 13. The process of claim 12, wherein said polishing step comprises rough polishing said surface of said first coating until said surface has a surface roughness of less than 8 micrometers.
- 30 14. The process of any one of the previous claims, further comprising a step for preparing said outside metallic surface after said providing step; said preparing step comprising:
polishing said outside metallic surface;

washing said outside metallic surface; and
drying said outside metallic surface.

- 5 15. The process of claim 14, wherein said polishing step comprises fine
 polishing said outside metallic surface until said outside metallic surface
 has a surface roughness of less than 2 micrometers.