US 20110000793A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2011/0000793 A1

(43) Pub. Date: Jan. 6, 2011

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(54) **COATING METHOD FOR A WORKPIECE**

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(21) Appl. No.: **12/919,697**

(22) PCT Filed: **Feb. 20, 2009**

(86) PCT No.: **PCT/EP2009/001243**

§ 371 (c)(1), (2), (4) Date: **Aug. 26, 2010**

(30) **Foreign Application Priority Data**

Feb. 26, 2008 (DE) 10 2008 011 204.6

Publication Classification

(51) **Int. Cl.**

C25D 5/48	(2006.01)
C25D 5/34	(2006.01)
C25D 5/04	(2006.01)
C23C 28/00	(2006.01)
C25D 17/00	(2006.01)
C25D 7/00	(2006.01)

(52) **U.S. Cl.** **205/50**; 205/220; 205/209; 205/205; 205/143; 205/206; 205/191; 205/198; 204/274

(57) **ABSTRACT**

The invention relates to a coating method for a workpiece, including the following method steps: a) applying a coating liquid to the workpiece, wherein the coating liquid comprises an ionic liquid containing ions of at least one element, b) electrochemically depositing a layer of the at least one element from the coating liquid on the workpiece, c) removing the workpiece from the coating liquid, d) removing excess coating liquid from the workpiece. In order to suggest an industrially suitable coating process, particularly for workpieces having at least a partial metal surface, using stable, durable baths, it is provided that the temperature of the workpiece is set such that the temperature of the coating liquid deviates by no more than 10° C. from a predetermined set temperature during the coating process

COATING METHOD FOR A WORKPIECE

BACKGROUND OF THE INVENTION

[0001] The invention relates to a coating method for a workpiece, and to an apparatus for coating a workpiece.

[0002] Since the useful life of metallic or metal-plated workpieces can be substantially limited by corrosion, the provision of reliable corrosion protection is crucial, in particular for workpieces exposed to the weather.

[0003] From the state of the art, coating methods are known for this purpose where a liquid coating agent is used based on a binder, it is also known to cover a workpiece with a metal coat that directly chemically or physically adheres to the substrate. A widely used approach for this is the electrochemical deposition of metal from a coating liquid in which a salt of this metal is dissolved. The workpiece to be coated is dipped into a bath of the coating liquid. The workpiece in most cases acts as a cathode on which the metal ions are reduced. For this purpose, a voltage is applied to the workpiece resulting in a predetermined, usually negative, potential on the workpiece with respect to a reference electrode.

[0004] This method allows excellently adhering, closed, anti-corrosive metal coatings to be produced, as the case may be after suitable pre-treatment. With the method described above, semi-metals and semiconductors, such as silicon, can be deposited as well as metals. It is also possible to electrochemically coat non-metallic workpieces, as long as their surfaces have been made conductive by a pre-treatment.

[0005] It must be noted that only certain specific metals can be deposited with this technique depending on the solvent used. If, for example, an aqueous solution is used, it is not possible to deposit elements having a deposition potential lying in the decomposition range of water. Instead, hydrogen gas accumulates at the cathode. Within certain limits, the problem mentioned may be solved by increasing the salt concentration, however, if the standard potential is too low, deposition of the element in question is impossible from an aqueous solution. This applies to aluminum, for example, which plays an important role in corrosion protection as it forms a strong, passivated oxide layer when exposed to ambient air, which prevents oxidation of the underlying metal, and also serves as a sacrificial anode for the underlying steel substrate in the case of damage to the coating. There is thus great interest in aluminum coatings in parts of the automotive industry, for example.

[0006] If the ions lost by deposition are to be replaced by means of dissolution from a sacrificial anode, a potential range of about 2V is defined by the deposition processes of oxygen on the one hand and hydrogen on the other, within which the elements must be present that are to be used for coating in aqueous solution. It is known from research that this drawback can also be overcome by the use of a different solvent. Ionic liquids are of growing importance in this context. They are salts having a melting temperature of below 100° C. The corresponding salt melt can also serve as a solvent for a salt of the desired coating metal. By using ionic liquids, according to the state of the art, the accessible potential range with respect to water is extended from about 2V to up to 6V.

[0007] As the case may be, the anions of the ionic liquid can be identical to those of the dissolved salt. US 2004/0238352 thus discloses a method wherein aluminum chloride is dissolved in a melt of 1-butyl-3-methylimidazolium chloride and aluminum is deposited from this solution.

SUMMARY OF THE INVENTION

[0008] Considering this, it is the object of the present invention to suggest an industrially useful coating process, in particular for workpieces having at least a partial metallic surface, with stable, durable baths.

[0009] The object is achieved by a coating method for a workpiece, by an apparatus and by a workpiece as disclosed herein. The method comprises the following method steps:

[0010] a) applying a coating liquid on the workpiece, wherein the coating liquid comprises an ionic liquid containing ions of at least one element;

[0011] b) electrochemically depositing a layer of the at least one element from the coating liquid on the workpiece;

[0012] c) removing the workpiece from the coating liquid;

[0013] d) removing the excess coating liquid from the workpiece.

DETAILED DESCRIPTION

[0014] According to the present invention the temperature of the workpiece is adjusted in such a way that the temperature of the coating liquid only deviates from a predetermined set temperature by no more than 10° C. during the coating process.

[0015] The essential idea underlying the present invention is that the useful life of an ionic liquid used as a coating liquid is particularly stable and durable, and thus industrially useful, if it is maintained within a range of a predetermined temperature, the set temperature, that is within tight limits, i.e. deviating by no more than 10° C. from the set temperature. The term set temperature refers to a precisely defined temperature that is deemed optimal.

[0016] The temperature of the coating liquid—and thus the quality of the coating—is determined in the industrial method in particular by the fact that usually a great number of workpieces, or a large workpiece, is coated in the individual coating process. This is how the great mass of the workpiece(s) absorbs a lot of heat from the coating liquid (or introduces it, as the case may be). This applies all the more since metallic workpieces usually have excellent heat conductivity and high specific heat capacity. Moreover, industrial facilities usually work in a continuous operation, i.e. coating processes of the individual batches follow each other without major pauses. Keeping the temperature of the coating liquid as constant as possible has thus been shown to considerably extend the useful life of the ionic liquid for coating, and is advantageous for the quality of the coating when used in industrial coating methods.

[0017] This is why adjusting the temperature of the coating liquid is of particular importance in the method of the present invention. According to the present invention it is suggested that the workpiece to be coated is heated and/or cooled, either as a sole process or in combination with heating or temperature controlling the coating liquid. Heating or temperature controlling the workpiece has the advantage that there is no undesired cooling or heating effect on the coating liquid by the workpiece at precisely the point where the deposition takes place. By these means, an excellent quality of the deposited layer is ensured. The terms "heating" and "warming" will be used as synonyms in the following, i.e. they are not to be construed as identifying different strengths of heat flows or different temperature ranges.

[0018] It is advantageous that a deterioration of the conductivity of the coating liquid due to temperature variations is prevented by the method according to the present invention. By these means coating is made possible under uniform conditions resulting in a high-quality metal layer being produced which also fulfils premium requirements, as for example in the automotive industry.

[0019] Furthermore, one and the same coating bath can be used over long periods of time, i.e. there is less ionic liquid that has become unusable, which must be disposed of. This means on the one hand that costs can be saved and on the other hand that there is less impact on the environment.

[0020] With reference to the constant set temperature according to the present invention, preferably all components of the coating liquid are explicitly included, i.e. also excess components, still adhering to the workpiece until they are removed, or even beyond that, as the case may be, if removal is incomplete, and which are preferably recycled to be used for renewed coating of workpieces.

[0021] In the method according to the present invention, workpieces with a metallic surface are preferably coated, i.e. those that are either completely of metal, or an alloy, as the case may be, or are provided with a metallic coating. This metallic coating can also include non-metallic components. However, workpieces with a non-metallic surface can also be used, such as plastic parts that are prepared for electrochemical coating by means of activation, i.e. having a surface that has already been made conductive by means of pre-treatment, for example, with a suitable varnish, or that is already conductive due to the presence of additives in the plastic material.

[0022] Preferably the ions of the at least one element to be deposited are metal ions. Particularly preferred are ions of at least one of the elements aluminum, zinc, magnesium, nickel, chromium, tantalum, titanium, copper, silver and/or gold. In particular, it is possible to deposit a layer of an alloy of these metals from an ionic liquid containing ions of a plurality of metals. Ions of semimetals or semiconductors, in particular silicon and/or germanium ions, are also preferred, however. Again, it is possible to deposit a layer constituting a mixed phase of the respective elements from an ionic liquid containing ions of a plurality of semiconductors or semimetals. The deposition of mixed phases of at least one metal and at least one semiconductor or semimetal (e.g. of aluminum and silicon) is also conceivable in the context of the present invention. In the following "metal layers" will be used as a simplified expression, but the explanations will always refer to all layers of at least one element.

[0023] The coating liquid according to method step a) is usually applied by dipping the workpiece into the coating liquid. It is also conceivable to apply the coating liquid by different means, e.g. by means of casting devices.

[0024] To remove the excess liquid in method step d) various methods are possible, such as draining, spinning-off or blow-removing by means of an air flow (temperature controlled, as the case may be). All the methods mentioned can also be combined.

[0025] In a further development of the inventive method, for those cases in which maintaining the set temperature is particularly important, the temperature of the workpiece is adjusted in such a manner that the temperature of the coating liquid deviates during the coating process by no more than 5° C. from the predetermined set temperature.

[0026] As already explained, the temperature of the coating liquid is critically influenced by its contact with the workpiece. One way of preventing any deleterious effects by the workpiece is to maintain its surface temperature within the range of the set temperature to a sufficient degree. This is why in a preferred embodiment of the invention, care is taken that the surface temperature of the workpiece does not deviate from the set temperature by more than 10° C. during the method steps a) to d). If this temperature range is adhered to, a substantial interfering factor in the deposition of metal layers from ionic liquids is eliminated. In this context, surface means all surfaces of the workpiece with which the coating liquid can come into contact.

[0027] To ensure the above-described controlled temperature, various measures are conceivable. Preferably, the workpiece is heated for this purpose prior to and/or during the method steps a)-d) at least on its surface by means of hot air, infrared irradiation, by blasting the surface, by contact with a heat bath or in an inductive manner. Whether advance heating is sufficient can depend, for example, on the size or geometry of the workpiece. A large workpiece with a relatively small surface area loses its initial temperature more slowly than a small workpiece with a relatively large surface area.

[0028] Heating with hot air has the advantage that all exposed surfaces of a plurality of workpieces, as the case may be, can be treated. Infrared irradiation is advantageous due to the more efficient heat transfer. Inductive heating has the advantage that the workpiece is not only heated on the surface but also in its interior. This method is also particularly efficient. Heating by means of blasting (e.g. sand blasting) the surface has the advantage that heating is accompanied by a pre-treatment of the surface. Heating in a heat bath in which the workpiece is dipped, can also be combined, as the case may be, with degreasing or the like of the workpiece in the same bath. Furthermore, heating in a bath can be realized with relatively little technical overhead, and good heat transfer to the workpiece is ensured.

[0029] If, for example, a workpiece heated too much due to pre-treatment, is to be coated, it is preferable to cool the workpiece prior to and/or during the method steps a)-d) at least on its surface by means of cold air, by contact with a cold bath, or by means of evaporation. The cold air can either be stagnant or flow around the workpiece as an air flow. A cold bath can either be a solid body or a liquid, which are cooler than the workpiece. Herein, even a holding or receiving device can serve as a cold bath. For example, a gripping arm, guiding the workpiece, or a basket in which the workpiece resides, can be cooled in turn, in order to cool the workpiece. A particularly effective method of cooling is by means of evaporation. Herein, a liquid is evaporated on the surface of the workpiece, whereby a particularly large amount of heat is removed from the workpiece. If the temperature of the workpiece is below the boiling temperature of the liquid, evaporation can be forced by an air flow or a reduction of the air pressure.

[0030] To ensure a sufficiently constant surface temperature of the workpiece, a plurality of different temporal sequences are suitable for heating. With reference to each individual method step, it is conceivable to heat prior to and/or during said step in such a manner that, during method steps a)-d), the surface temperature of the workpiece deviates from the predetermined set temperature by no more than 10°

C. It is thus possible to heat the workpiece, for example, prior to being dipped into a coating bath, stop heating during coating, and resume it subsequently prior to and during spinning-off of the liquid residue. Alternatively, it is possible to dispense with heating prior to and during coating, but to heat the workpiece during spinning-off of excess liquid to prevent the spun-off ionic liquid from cooling off too much. Which temporal sequence is chosen in each individual case depends, for example, on the duration of the individual method steps and the nature of the workpiece (size, surface area, material etc.).

[0031] It is recommendable to estimate or compute for coating a batch of workpieces, the amount of heat that is removed from the coating liquid during coating and then to ensure that this amount of heat is delivered to the workpieces in such a way that undesirable cooling of the coating liquid is prevented. A suitable guideline for estimating the required heat amount is the mass to be coated. If the mass of the workpieces to be coated is known, the required heat amount can still vary, e.g. depending on the heat conductance of the workpieces and on the surface area of the workpieces. If the coating liquid is temperature controlled, the amount of heat introduced by temperature controlling must also be considered in the estimation. Taking all these factors into account, the amount of heat necessary for heating or temperature controlling the workpieces can usually be estimated or calculated with sufficient precision.

[0032] To prevent any deleterious effects on the coating liquid due to unwanted chemical reactions with the ambient air, in a further development of the method, the above-mentioned method steps are carried out in an inert gas atmosphere. This precaution is necessary for a number of ionic liquids to ensure durable quality, typically with those ionic liquids that are strongly hygroscopic. It must be taken care of, in particular, that in the method steps c) and d), liquid is exposed to the atmosphere in film or drop form, which means with a relatively large surface area. If the components of the liquid in question are to be recuperated, protection by inert gas is particularly important.

[0033] Almost all coating liquids show sedimenting behavior. It is thus advantageous if the coating liquid is mixed prior to and/or during the method steps a)-d). This can be done by means of a mechanical stirrer that is driven by a motor and a shaft. Magnetic stirrers are also advantageous, however, since they do not need an additional opening in a container wall for mechanical coupling. Mixing by means of ultrasonic waves is particularly advantageous since no additional parts are needed inside of the respective container at all. The respective means for mixing can be periodically or continuously operated. In addition to homogenizing the coating liquid, mixing also contributes to the uniform temperature control of the coating liquid.

[0034] For the electrochemical coating of a workpiece, various apparatuses are known. It has been found that these apparatuses are also suitable for coating with ionic liquids. In a preferred embodiment of the method the workpiece is moved during coating with ionic liquid within an apparatus according to the principle of a conveyor screw, a rotating drum or a G-type drum (patent application filed with the official file no. DE 10 2007 018 887.2). The above-mentioned apparatuses have the advantage that seamless coating in a single coating process can be guaranteed also with small bulk pieces, such as bolts, nuts, washers, rivets etc. This is because the workpieces are rolled over which means that there are no fixed points of contact which would otherwise prevent overall treatment by the coating substance. Particularly preferable are apparatuses that work according to the conveyor screw principle. Such an apparatus is known, for example, from DE 42 05 672.

[0035] Due to the high investment needed for ionic liquids, all losses of the coating liquid should be avoided. This is why in a further embodiment of the method, the excess coating liquid removed from the workpiece is at least partially recycled into the bath. Recycling can be passive, by draining back, or active, by means of pumping or the like. By these means, the losses due to removal of liquid together with the workpiece can be substantially reduced, which leads to high cost-savings in particular when a great number of coating processes are involved.

[0036] In many cases it makes sense to appropriately prepare the workpiece for coating. The workpiece is thus preferably cleaned and/or dried for introduction into the coating bath. Various methods are suitable for cleaning. This can be done mechanically, such as by sand blasting, metal blasting, glass bead blasting or soda blasting of the workpiece. Chemical cleaning steps are also of particular importance, such as etching, pickling or degreasing of the workpiece. Degreasing substances, in addition to organic solvents, are, in particular, aqueous solutions, in particular alkaline solutions or those to which additives, such as tensides, have been added. Degreasing can be done by spraying under pressure or in a dip bath, wherein, in the latter case, the degreasing process is substantially improved by the use of ultrasonic waves. The efficiency can also be increased by higher temperatures, such as with hot alkaline degreasing. Drying the workpiece can be carried out by means of cold or hot air, by irradiation with infrared or microwaves and/or by means of negative pressure. According to a preferred embodiment of the invention, drying of the cleaned workpieces can be used for heating or cooling the workpiece. The above described measures for preparing the workpiece are of particular importance for working with ionic liquids, since they are often sensitive with respect to contamination of any kind, and in particular with respect to introduced moisture.

[0037] To ensure a particularly clean surface of the workpiece, in a preferred embodiment of the method, the workpiece is electrolytically polished prior to the deposition process. This is also referred to as "in situ" electrochemical etching. In this process, ions are detached from the surface of the workpiece by applying a suitable voltage (usually over a short period of time), i.e. the workpiece functions as an anode. On the one hand, microscopic bumps are thus removed, and on the other hand microscopic contamination is removed from or out of the surface. This method is also suitable, for example, to remove oxide layers from steel, which would interfere with the adhesion of any coating to be deposited. This cleaning step can be carried out in the ionic liquid that is also used for coating, wherein the voltage is reversed with respect to the coating process. It is also conceivable, however, to provide a separate bath for this purpose. While the first variant needs simpler apparatuses and saves time, the latter variant helps to avoid that the coating liquid is contaminated by substances removed from the workpiece.

[0038] While it is possible to remove most of the adhering liquid from the workpiece by spinning the workpiece in method step d), residues will usually remain. For this reason, in a further development of the method, the workpiece is rinsed by means of a rinsing liquid after removing the excess liquid. The term rinsing liquid also includes liquids in which the ionic liquid can be emulsified, in addition to those in which it is dissolvable. Rinsing on the one hand is for cleaning the workpiece. The workpiece can also be prepared for any other coating processes by means of the rinsing process. Finally there is the possibility, in a further improvement of the method, to recover the residues of the coating substance removed from the workpiece from the rinsing liquid and to recycle them into the bath. In this case, care must be taken that the rinsing liquid used for rinsing does not react with the ionic liquid.

[0039] After the rinsing process, rinsing liquid residue often still adheres to the workpiece. In order to remove this, it is preferred to dry the workpiece after rinsing. This can be done by renewed spinning, drying in a cold or hot airflow, or by other means known from the state of the art.

[0040] While it is possible, with the method according to the present invention, to create closed layers, ensuring excellent corrosion protection, for example, it may be desirable to adjust certain surface properties by means of an additional coating. It may be desirable, for example, to create a colored graphic design or to adjust a coefficient of friction. Moreover, the electrochemically applied coating can be protected against mechanical damage by an additional coating. For this reason, according to a further development of the method, a top coat is applied after coating. Suitable top coats are known from the state of the art.

[0041] The usability of an ionic liquid in the context of an industrial coating process is ensured over long periods of time by the method according to the present invention. Degradation of the conductivity of the coating liquid due to temperature changes is prevented. The method thus enables the deposition of high quality metal layers, in particular of aluminum, from a coating bath, which remains useful over a long period. The coating bath thus only rarely needs to be refilled or exchanged, which results in substantial cost savings. Furthermore, the disposal of ionic liquid that has become useless is far less frequent, which is advantageous both from an economic and an ecological point of view.

[0042] The method according to the present invention can be carried out by means of an apparatus for coating a workpiece. Since coating is achieved by means of deposition from a coating liquid, which comprises an ionic liquid containing ions of at least one element, the apparatus must comprise at least two electrodes according to the state of the art (one electrode for contacting the workpiece, and a counter electrode). Usually a coating container for receiving the coating liquid during the coating process is also necessary. It may be advantageous to carry out the coating process with a so-called "three-electrode arrangement" to apply a precise potential to the workpiece.

[0043] According to the present invention, such an apparatus comprises means for temperature measurement, by means of which a deviation of the temperature of the workpiece by 10° C., preferably by 5° C., from a predetermined set temperature can be determined, and means for heating and/or cooling the workpiece.

[0044] The means for temperature measurement can either work in a contact-free manner (by measuring the infrared radiation) or by contacting the workpiece or the coating liquid respectively (for example as a bimetal thermometer or a resistance thermometer). Such temperature sensors are known from the state of the art and usually work with a sufficiently high (usually substantially better) measuring accuracy to be able to determine temperature differences of 5° C. or 10° C.

[0045] As already explained, such an apparatus can optionally comprise further components, for example, for spinning off coating liquid from the workpiece or for mixing the coating liquid.

[0046] Furthermore, in view of the chemical offensiveness of many ionic liquids, it is also suitable to manufacture those parts of the apparatus that come into contact with the coating liquid of a chemically insensitive material, such as ceramics.

[0047] The functioning of the invention will now be explained with reference to exemplary embodiments.

EXAMPLE 1

State of the Art

[0048] 20 kg of steel bolts are to be coated with aluminum. 80° C. has been determined as the set temperature for the coating process. The bolts are prepared for coating first by sand blasting and then by degreasing in a basket in a cleaning solution consisting of water in which 9 g of potassium phosphate and 27 g of potassium hydroxide have been dissolved per one liter of water, at 85° C.

[0049] A thermostat connected to the bath is used to ensure that its temperature is within a range of between 80° C. and 90° C. After a soaking time of 5 minutes, the basket is lifted out of the bath. The basket with the bolts is rinsed with tap water at a temperature of about 80° C. and subsequently spun dry. Thereafter, the bolts are further dried by means of an airflow preheated to about 90° C.

[0050] After completion of drying, the basket is introduced through a first lock door into a lock chamber, the first lock door is closed, and the lock chamber is partially evacuated to 0.05 bar. By these means, the last moisture residue evaporates. Subsequently, the lock chamber is flooded with nitrogen. Induction coils are integrated in the walls of the chamber, by means of which the bolts can be inductively heated, if necessary. Herein, it is checked by means of an infrared camera, whether the temperature of the bolts is within the predetermined range of between 70° C. and 90° C.

[0051] The lock chamber communicates with a coating chamber filled with a nitrogen atmosphere via a second lock door. The bottom of the coating chamber is configured as a basin filled with a coating bath. The coating bath consists of a melt of 1-ethyl-3-methyl-1H-imidazolium chloride (EMIC), in which aluminum chloride is dissolved. The mass ratio of EMIC:$AlCl_3$ is 1.7:1. Temperature sensors are used to continuously check whether the temperature of the walls of the coating chamber deviates from the set temperature. In the case of a deviation, additional heating is carried out by means of heating elements integrated into the walls, wherein the heating power is adjusted in dependence on the magnitude of the deviation. In this way it is ensured that the temperature never deviates from the set temperature by more than 10° C. A plurality of temperature sensors is also spatially distributed in the basin, which check the temperature of the coating liquid itself. Furthermore, a vertically traversable coating drum with perforated walls is arranged in the coating chamber. The drum can be rotated about its longitudinal axis by means of a motor. The drum itself is also heatable and is maintained within the predetermined temperature range by means of a thermostat.

[0052] The basket is introduced into the coating chamber through the second lock door, then the second lock door is closed. At this point, the coating drum is located outside of the coating bath. The bolts are introduced into the coating drum through an opening, subsequently the drum is traversed downwards into the coating bath. In the interior of the drum, the coating liquid flows around an aluminum electrode, which is connected to the outer wall of the drum via a voltage supply. For coating, the drum is slowly rotated at 20 rpm while a voltage of 20V is applied between the aluminum electrode and the outer wall of the drum so that the aluminum electrode functions as an anode. As a result, the bolts in contact with the walls of the drum are coated by the deposition of aluminum from the coating liquid, while aluminum ions are continuously detached from the anode by oxidation, so that the aluminum concentration remains constant in the coating liquid.

[0053] After a coating duration of 5 minutes, an Al layer having a thickness of about 10 μm has been deposited on the bolts, the voltage is switched off, the drum is stopped and lifted up out of the bath, wherein most of the liquid drains off. Subsequently, the drum is caused to rotate in a fast rotation at 300 rpm, to spin off liquid residue. After spinning, the basket is traversed to a position below the drum to receive the bolts, the drum is opened and emptied into the basket through the opening rotated into a bottom position.

[0054] Hereafter, the basket is introduced into a rinsing chamber filled with nitrogen through a third lock door, and the third lock door is closed. There are a number of spraying nozzles in the rinsing chamber, by means of which an aprotic rinsing substance is sprayed onto the bolts. In this way final residues of the coating liquid are removed, which are carried off together with the rinsing substance for separation and recycling into the coating bath. Subsequently, the basket is spun again and traversed out of the rinsing chamber through a fourth lock door.

EXAMPLE 2

[0055] As in example 1, 20 kg of steel bolts are to be coated with aluminum. This time, 20° C. is set as the set temperature for the coating process. Again, the bolts are sand blasted and degreased in a fashion analogous to example 1. Since the degreasing process is substantially more efficient at higher temperatures, it is similarly carried out at 85° C. for 5 min.

[0056] Rinsing, in this case, is carried out with tap water at a temperature of about 20° C. This is followed, again, by a spin drying process.

[0057] Treatment in diluted hydrochloric acid at about 20° C. for 5 min. is next, whereby most of the oxide layer on the bolts is removed. Subsequently, they are rinsed in distilled water at 20° C. and spun dry.

[0058] Then the bolts are further dried by means of an airflow heated to about 40° C. The temperature of the airflow which is increased with respect to the set temperature, is for compensating heat losses due to the evaporation of liquid.

[0059] After drying, the basket is, again, introduced through a first lock door into a lock chamber, where last liquid residues are evaporated by means of partial evacuation. Subsequently, the lock chamber is flooded with nitrogen having a temperature of 20° C. Induction coils are integrated in the chamber walls, by means of which the bolts can be inductively heated as needed. There is an additional possibility of directing a flow of nitrogen at a temperature of 0° C. onto the bolts by means of a nozzle integrated in the chamber wall to cool them if necessary. An infrared camera is used to check whether the temperature of the bolts is within the predetermined range of between 10° C. and 30° C.

[0060] The lock chamber communicates via a second lock door with a coating chamber filled with a nitrogen atmosphere. The structure of the coating chamber is similar to the one in example 1. Again, the bottom of the coating chamber is configured as a basin filled with a coating bath. This basin is made of a ceramic material that is chemically particularly insensitive. The coating bath consists of a melt of 1-ethyl-3-methylimidazolium chloride, in which aluminum chloride is dissolved. The molar ratio of 1-ethyl-3-methylimidazolium chloride to $ALCl_3$ is 2:3. Temperature sensors are used to continuously check whether the temperature of the walls of the coating chamber deviates from the set temperature. If there is any deviation, heating or cooling can be carried out by passing water at a suitable temperature through the heating/cooling pipes integrated into the walls. In the normal state, the above mentioned pipes have water flowing in them at a temperature of 20° C. A plurality of temperature sensors is also spatially distributed in the basin for checking the temperature of the coating liquid itself.

[0061] In order to be able to carry out cooling of the coating liquid if needed, the coating chamber comprises a snake-like heat exchanger system arranged within the basin and extending through the coating liquid. To avoid damage, the arrangement is chosen in such a manner that any contact between the drum and the heat exchanger system is prevented. Cool water can be caused to flow through this heat exchanger system while, in the normal state, water at a temperature of 20° C. is used.

[0062] The above mentioned cooling systems are necessary since, even if the workpieces are carefully temperature-controlled, the workpiece and the coating liquid can be heated by the deposition process, since it involves the transformation of electrical energy into heat.

[0063] Also, at the bottom of the basin, there is a continuously operated magnetic stirrer, which, on the one hand, homogenizes the coating liquid and, on the other hand, ensures uniform temperature control and, by moving the coating liquid, also promotes the heat exchange between the liquid and the heat exchanger system.

[0064] A coating drum with an aluminum electrode is used as in example 1. The drum is coated with a ceramic material, a series of electrodes for contacting the bolts are, however, provided on the inner wall.

[0065] The introduction of the workpieces and the traversal of the coating drum is carried out as in example 1. To prepare the bolts for the coating process, they are treated with in situ electrochemical etching. For this purpose, a voltage of 0.8V is applied between the electrodes in the wall of the drum and the aluminum electrode. The drum is caused to rotate at a slow 20 rpm, wherein the bolts function as an anode due to their contact with the electrodes in the drum wall. By these means, the last residue of oxide is removed. After 2 min., the etching process is finished, and an opposite voltage of −0.2V is applied, whereby the aluminum electrode now functions as an anode, while the bolts are coated by the deposition of aluminum from the coating liquid. The rotation of the drum is continued during the coating process lasting 10 min.

[0066] Lifting the drum out of the bath, spinning off of liquid residues and the further treatment of the bolts is analogous to example 1.

1-15. (canceled)

16. A coating method for a workpiece, comprising the following method steps:

a) applying a coating liquid on the workpiece, wherein the coating liquid comprises an ionic liquid containing ions of at least one element;

b) electrochemically depositing a layer of the at least one element from the coating liquid on the workpiece;
c) removing the workpiece from the coating liquid;
d) removing excess coating liquid from the workpiece, wherein the temperature of the workpiece is adjusted in such a way that the temperature of the coating liquid deviates by no more than 10° C. from a predetermined set temperature during the coating method.

17. The method according to claim **16**, wherein the temperature of the workpiece is adjusted in such a way that the temperature of the coating liquid deviates by no more than 5° C. from the predetermined set temperature during the coating method.

18. The method according to claim **16**, wherein the surface temperature of the workpiece is adjusted in such a way that it deviates by no more than 10° C., from the predetermined set temperature during the method steps a)-d).

19. The method according to claim **16**, wherein the workpiece is heated prior to and/or during the method steps a)-d) at least on its surface by means of hot air, infrared irradiation, by blasting the surface, by contact with a hot bath or in an inductive manner, and/or is cooled by means of cold air, by contact with a cold bath or by means of evaporation.

20. The method according to claim **18**, wherein the workpiece is heated and/or cooled
a) exclusively prior to, or
b) exclusively during, or
c) prior to and during
at least one of method steps a)-d), so that its surface temperature deviates by no more than 10° C., from the predetermined set temperature during the method steps a)-d).

21. The method according to claim **16**, wherein a layer of a metal or an alloy, preferably comprising at least one of the elements aluminum, magnesium, zinc, nickel, chromium, tantalum, titanium, copper, silver or gold, or a layer of a semiconductor is deposited.

22. The method according to claim **16**, wherein the said method steps are carried out in an inert gas atmosphere.

23. The method according to claim **16**, wherein the coating liquid is mixed prior to and/or during at least one of method steps a)-d).

24. The method according to claim **16**, wherein the workpiece is moved during coating within an apparatus, wherein the apparatus preferably works according to the principle of a conveyer screw, a rotating drum, or a G-type drum.

25. The method according to claim **16**, wherein the coating liquid removed from the workpiece is at least partially recycled into the bath.

26. The method according to claim **16**, wherein the workpiece is cleaned and/or dried and/or electrolytically polished prior to method step a).

27. The method according to claim **16**, wherein the workpiece is rinsed after method step d), and dried after the rinse and/or rinsed residues of the coating liquid are recovered and recycled into the bath.

28. The method according to claim **16**, wherein a top coat is applied after coating.

29. An apparatus for coating a workpiece by depositing a layer of at least one element from a coating liquid onto the workpiece, wherein the coating liquid comprises an ionic liquid containing ions of the at least one element, characterized by
means for temperature measurement, by means of which a deviation of the temperature of the coating liquid and/or the temperature of the workpiece by 10° C., from a predetermined set temperature is determinable, and
means for heating and/or cooling the workpiece.

30. A workpiece coated using a method according to claim **16**.

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