US 20240279836A1

(19) **United States**

(12) **Patent Application Publication**

Monpetit

(10) **Pub. No.: US 2024/0279836 A1**

(43) **Pub. Date: Aug. 22, 2024**

(54) **ELECTROLYTE COMPOSITION, ELECTROCHEMICAL PROCESS AND ANODIZED COMPONENT**

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(21) Appl. No.: **18/584,506**

(22) Filed: **Feb. 22, 2024**

(30) **Foreign Application Priority Data**

Feb. 22, 2023 (DE) 102023104364.1

Publication Classification

(51) **Int. Cl.**

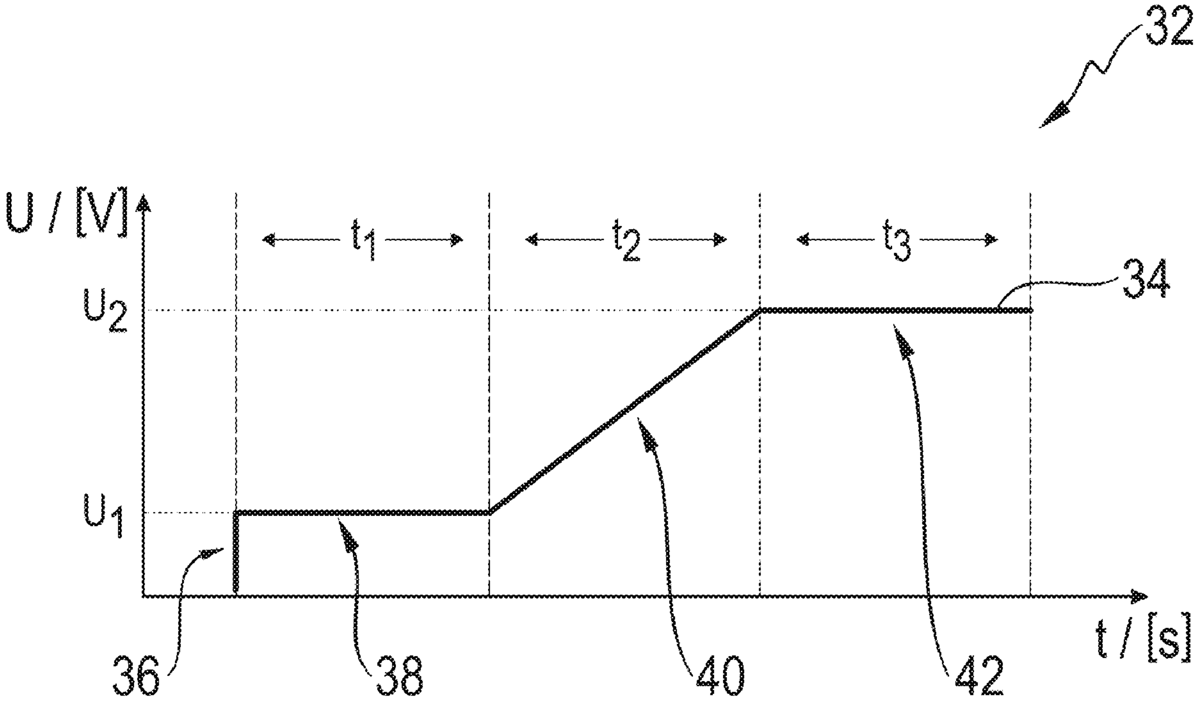
C25D 11/08	(2006.01)
C25D 21/12	(2006.01)

(52) **U.S. Cl.**

CPC ***C25D 11/08*** (2013.01); ***C25D 21/12*** (2013.01)

(57) **ABSTRACT**

The disclosure relates to an electrolyte composition for eloxation of a component, for example, a component for a vehicle braking system, wherein the electrolyte composition comprises an aqueous solution of the following components: (A) potassium titanium oxide oxalate; (B) oxalic acid; and (C) at least one buffer. The disclosure further relates to an electrochemical method of eloxation using the electrolyte and to an eloxed component.



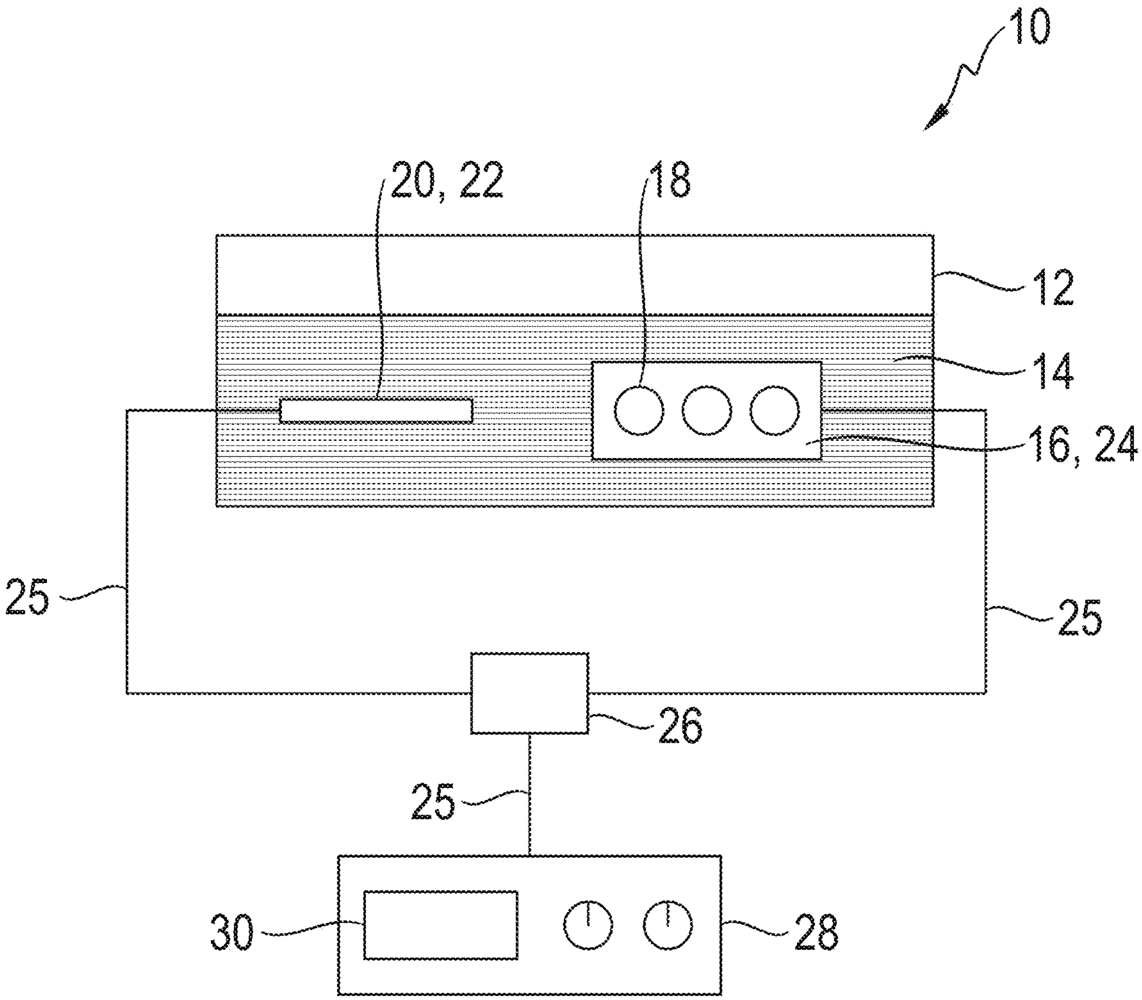


Fig. 1

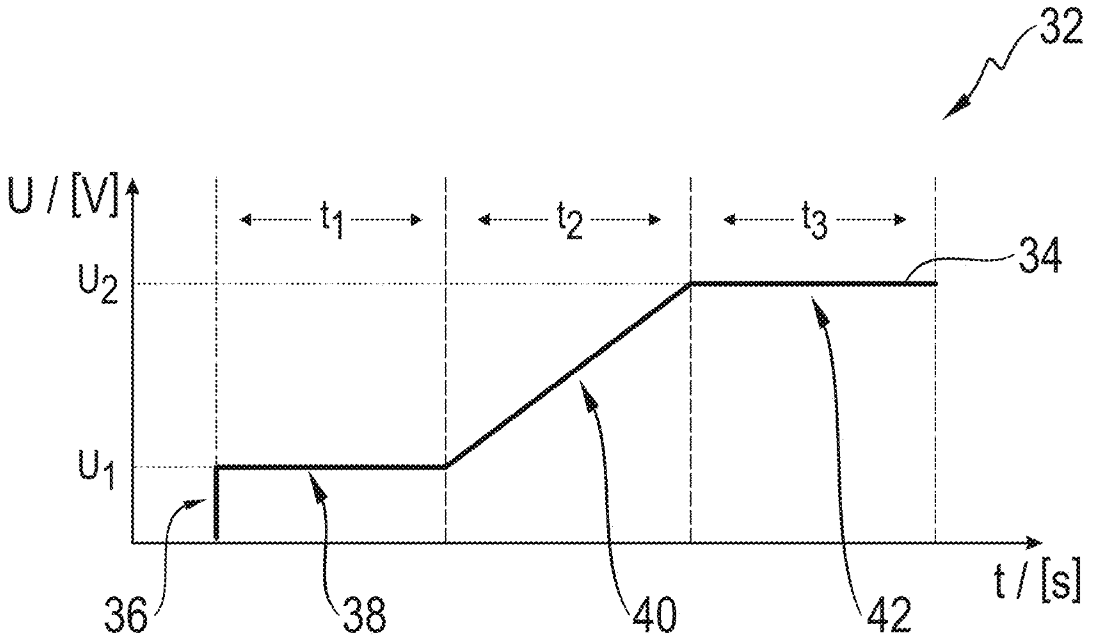

32
U / [V]
t1
t2
t3
U2
34
U1
t / [s]
36
38
40
42

Fig. 2

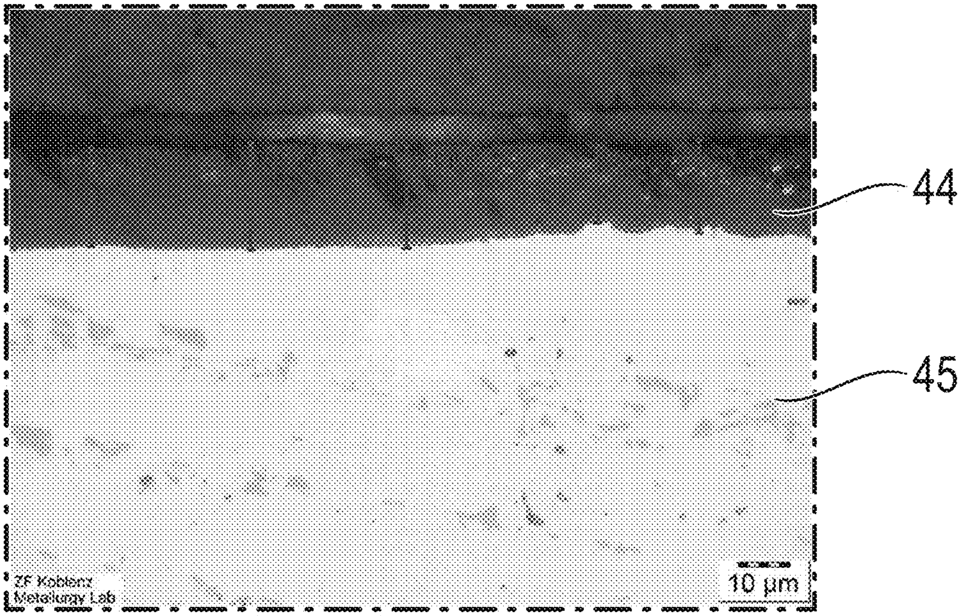

44
45
ZF Koblenz
Metallurgy Lab
10 µm

Fig. 3

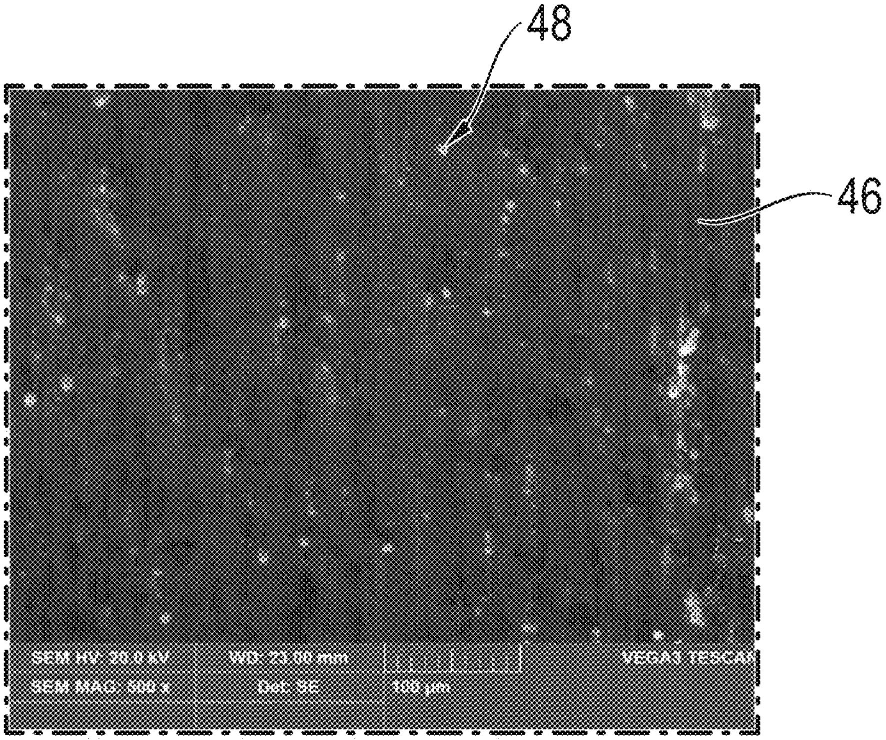

48
46
SEM HV: 20.0 kV
WD: 23.00 mm
VEGA3 TESCAN
SEM MAG: 500 x
Det: SE
100 μm

Fig. 4

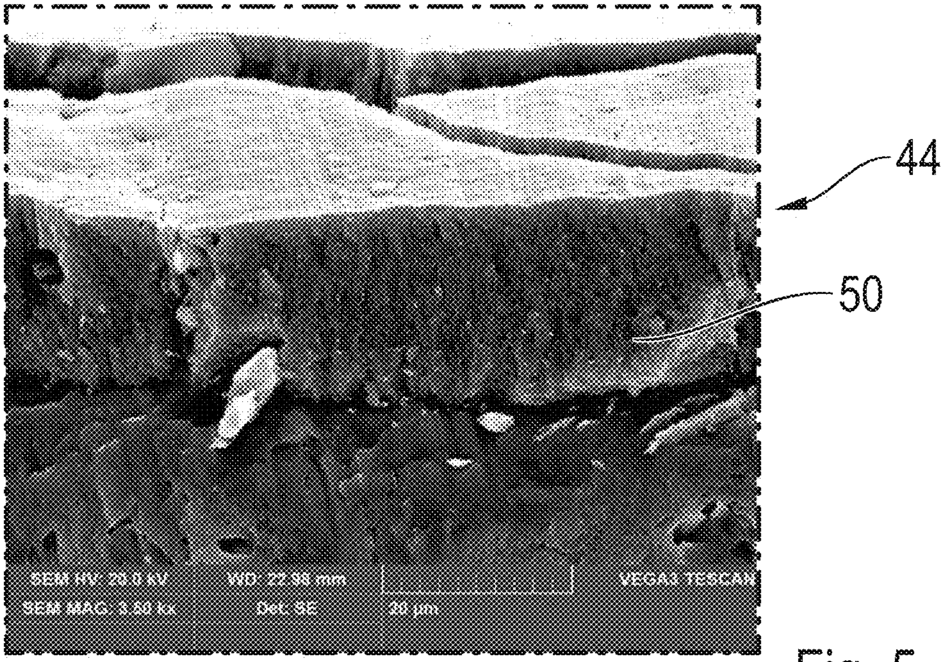

44
50
SEM HV: 20.0 kV
WD: 22.98 mm
VEGA3 TESCAN
SEM MAG: 3.50 kx
Det: SE
20 μm

Fig. 5

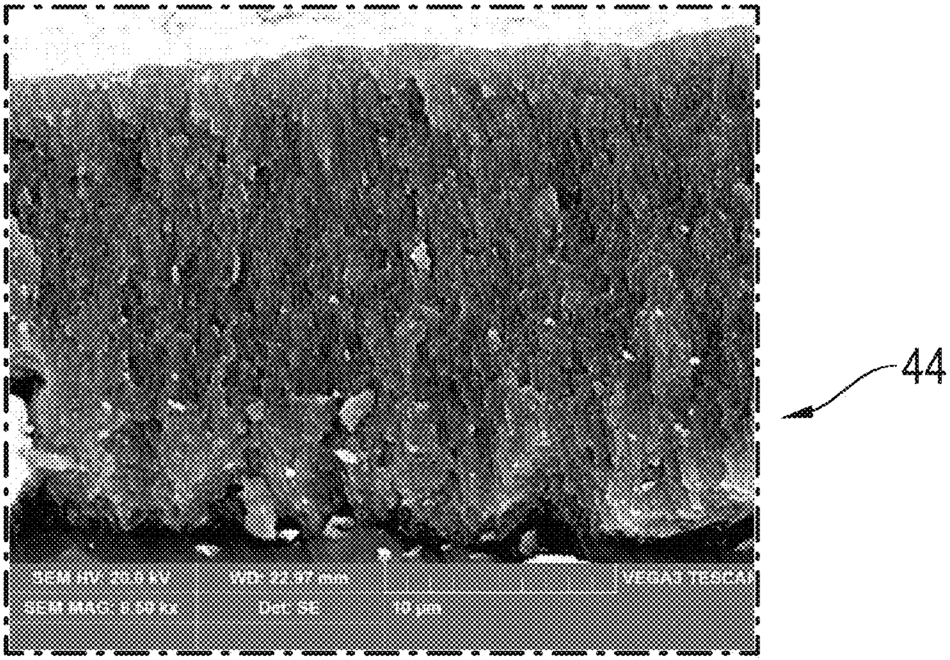

44
SEM HV: 20.0 kV
WD: 22.87 mm
VEGA3 TESCAN
SEM MAG: 6.00 kx
Det: SE
10 μm

Fig. 6

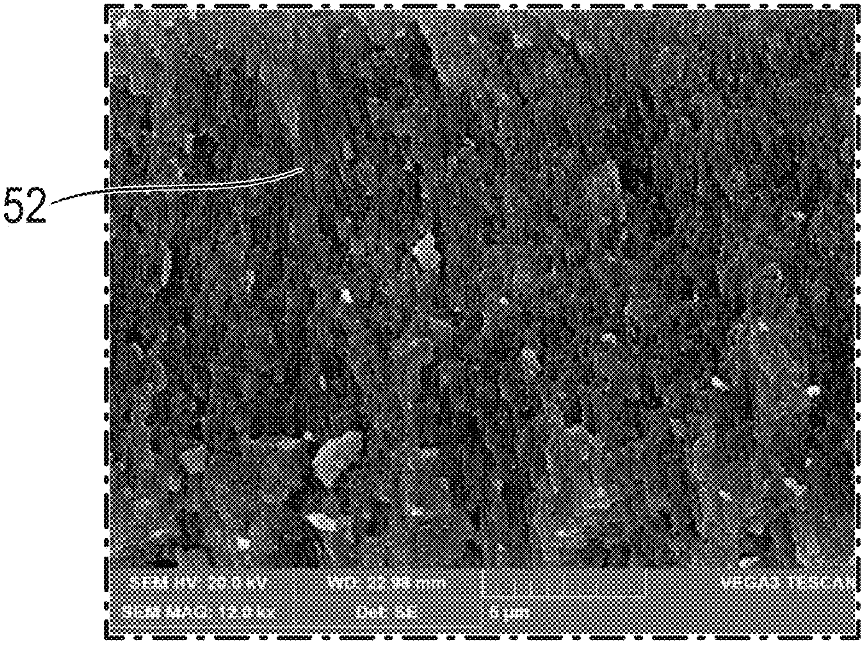

52
SEM HV: 20.0 kV
WD: 22.98 mm
VEGA3 TESCAN
SEM MAG: 12.0 kx
Det: SE
5 μm

Fig. 7

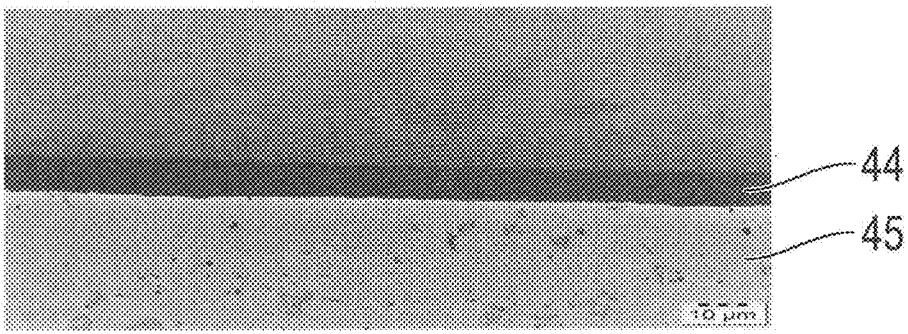


Fig. 8A

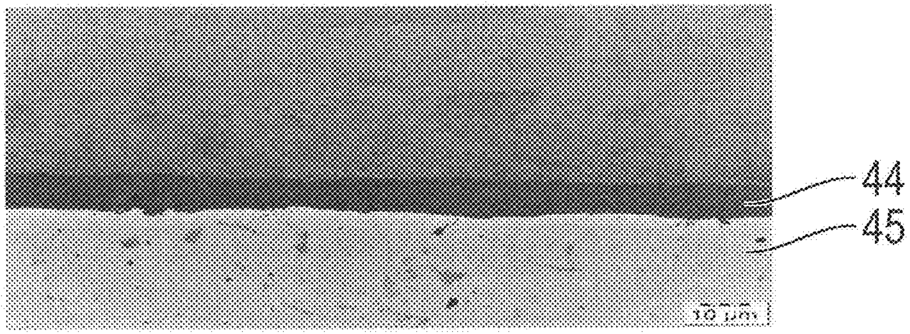


Fig. 8B

ELECTROLYTE COMPOSITION, ELECTROCHEMICAL PROCESS AND ANODIZED COMPONENT

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to German Priority Application No. 102023104364.1, filed Feb. 22, 2023, the disclosure of which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The disclosure relates to an electrolyte composition for eloxation of a component, to an electrochemical method using the electrolyte composition, and to an eloxed component.

BACKGROUND

[0003] In order to save weight in vehicles, particular components are typically made from aluminium. One reason for this is that aluminium is both a lightweight and a soft metal compared to other metallic materials. It therefore also has very good processability.

[0004] However, pure aluminium is unsuitable for particular applications in vehicle construction. This is the case especially when further components in a movable arrangement, such as pistons, are accommodated in an aluminium component.

[0005] Therefore, bores in aluminium components are often provided with an antiwear surface. It is thus possible for movable components such as pistons to be arranged in bores without damage to the surface of the bore by the pistons when they move.

[0006] It is customary to use the eloxal method known in the prior art for the surface treatment of pure aluminium surfaces.

[0007] The eloxal method is an electrochemical process in which an oxidic protective layer consisting aluminium oxide is formed on the aluminium component. Such an oxidic protective layer, also known as eloxal layer, is extremely hard and therefore protects the aluminium component from wear. These properties are achieved even in the case of layer thicknesses of a few micrometres.

[0008] There follows a brief elucidation of the eloxal method. The aluminium component to be eloxed is first immersed into an electrolyte solution. A cathode is additionally immersed into the solution. In the next step, a voltage is applied between the cathode and the aluminium component. The aluminium component is connected at the anode. Because of the voltage applied, on the anode side, aluminium is transformed to aluminium oxide, which forms an oxidation layer on the anode. Hydrogen is formed at the electrode on the cathode side in the eloxal method. With increasing duration, the layer thickness of the oxide layer increases, since the aluminium beneath is likewise transformed to aluminium oxide. The oxidation layer thus grows from the outside inward. The eloxal method differs in this aspect from other electrochemical methods, for example an electrolytic deposition of metals, in which the layer grows from the inside outward.

[0009] The electrolyte solution used for the eloxal method has a crucial effect on the properties of an eloxal layer produced therewith. For example, it is possible thereby to influence the homogeneity of the layer, surface roughness, hardness and scratch resistance.

[0010] Rough, uneven eloxal layers are unsuitable as coating for bores in which a piston is to be guided. Such layers can lead to piston wear in the most unfavourable case.

[0011] For that reason, it is desirable to provide new electrolytes and to develop new electrochemical methods with these electrolytes in order to improve the properties of eloxal layers produced therewith.

[0012] For example, DE 10 2018 110 905 A1 discloses an eloxal method for eloxation of a vehicle braking system made of aluminium. Also known is an electrolyte for the eloxal method. The electrolyte used is either a sulfuric acid solution (220 g/L of a 90% sulfuric acid solution), a titanium calcium oxalate solution, an oxalic acid solution, a tartaric acid solution, a phosphoric acid-based solution or a citric acid-based solution. In addition, a wetting agent (surfactant) may be added to the electrolyte. In addition, it is suggested that the electrolyte not contain any chromium ions. The eloxal method as described in the publication is conducted at a temperature of −10° ° C. to 20° C., especially at 10° C.

[0013] The fundamental aim is to provide eloxal layers having a particular hardness, such that the eloxal layers are more resistant to mechanical influences. When electrolyte solutions known from the prior art are used, hardness correlates with layer thickness. This is disadvantageous in that the roughness of the eloxal layer typically also increases with increasing layer thickness.

[0014] What is therefore needed is the ability to provide an electrolyte that eliminates the disadvantages from the prior art that are known for eloxal methods and enables production of eloxal layers that meet the mechanical performance demands in relation to vehicle technology that are placed on eloxal layers.

SUMMARY

[0015] An electrolyte composition for eloxation of a component is disclosed, for example, for a component for a vehicle braking system, wherein the electrolyte composition comprises an aqueous solution of the following components:

[0016] (A) potassium titanium oxide oxalate;

[0017] (B) oxalic acid; and

[0018] (C) at least one buffer

[0019] It is a feature of the electrolyte composition proposed in accordance with the disclosure that it creates eloxal layers that are simultaneously hard and smooth. The combination of smoothness and hardness is advantageous for the coating of bores in vehicle components in which pistons are movably accommodated. The layers produced with the electrolyte composition according to the disclosure enable particularly low-friction movement of the piston along the layer. Moreover, the components eloxed with this electrolyte are more stable to wear and hence also have a longer life.

[0020] The disclosure is based on an unexpected finding that the eloxal layers produced with the electrolytes according to the disclosure become smoother and not rougher with increasing layer thickness. Other electrolyte compositions known from the prior art do not show this behaviour. In the case of known electrolyte compositions, roughness increases proportionally with layer thickness. Consequently, the electrolyte according to the disclosure can achieve higher layer thicknesses without being limited by roughness.

[0021] In a first aspect of the disclosure, the potassium titanium oxide oxalate is present in a concentration of 30-50 g/L in the aqueous solution, for example, of 35-45 g/L.

[0022] In another aspect, the oxalic acid is present in a concentration of 5-85 g/L in the aqueous solution, and in one exemplary arrangement of 15-55 g/L.

[0023] In a further configuration of the disclosure, the buffer is selected from the group consisting of citric acid and boric acid, and a combination thereof.

[0024] The use of a buffer in the electrolyte composition makes it possible to exactly adjust the pH prior to commencement of the eloxal method, and additionally to keep the pH within a constant range during the eloxal method. In this way, it is possible to ensure a uniform process regime during the eloxal method.

[0025] The buffer may be present in a concentration of 1-30 g/L in the aqueous solution, preferably of 2-16 g/L.

[0026] The aqueous solution may also have a pH within a range of 0.1-5, preferably a pH of 0.65-2.0.

[0027] In one exemplary arrangement, the pH is set abovementioned range. In these ranges, uniform formation of the eloxal layers on the aluminium component takes place.

[0028] In another exemplary arrangement, the aqueous solution further comprises aluminium oxalate, which is present in a concentration of 1-15 g/L in the aqueous solution, and in one exemplary arrangement of 2-8 g/L.

[0029] The disclosure further relates to an electrochemical method for eloxation of a component, especially a component for a vehicle braking system, using the electrolyte composition as described above, wherein the method comprises the following steps:

- **[0030]** a) applying a voltage with a first voltage value between a component immersed in the electrolyte composition and an electrode;
- **[0031]** b) optionally maintaining the first voltage value for a first time interval,
- **[0032]** c) increasing the first voltage value within a second time interval to a second voltage value, and
- **[0033]** d) holding the second voltage value for a third time interval.

[0034] The disclosure proposes an electrochemical method, i.e. an eloxal method, that synergistically interacts with the abovementioned electrolyte according to the disclosure in order to create defined eloxal layers of an aluminium component. The method proposed, in combination with the electrolyte according to the disclosure, is suitable for creating simultaneously smooth and hard eloxal layers.

[0035] The first step a) of the method proposed constitutes the starting point of the actual eloxal process. In this step, the electrode acts as cathode and the component to be eloxed as anode.

[0036] The first voltage value may, for example, be within a range of 60-160 V, for example within a range of 70-130 V.

[0037] The optional step b) in the first time interval serves to be able to stabilize the first voltage value between the immersed component and the electrode.

[0038] The first time interval in step b) may have a duration within a range of 2-120 s, and in one exemplary arrangement, within a range of 40-80 s.

[0039] Subsequently, in step c), a voltage ramp is traversed with the first voltage value as the starting point and the second voltage value as the target point.

[0040] The second voltage value may be within a range of 100-220 V, in one exemplary arrangement, within a range of 120-195 V. Fundamentally, the second voltage value is always greater than the first voltage value, and so the first voltage value has to be increased to the second voltage value.

[0041] The progression of the voltage between the first voltage value and the second voltage value is essentially linear. In other words, a linear voltage ramp (constant slope with unit V/s) between the first voltage value and the second voltage value is traversed over time. The traversing of this voltage ramp is advantageous in order to create homogeneous eloxal layers in a simple manner. In addition, the voltage, by virtue of the traversing of the voltage ramp, is merely increased stepwise and not abruptly, such that the layers grow in a more controlled manner overall.

[0042] The voltage ramp is traversed in the second time interval in step c), which has a duration within a range of 40-400 s, and in one exemplary arrangement within a range of 100-300 s.

[0043] After the voltage ramp has been traversed in step c), step d) is performed in a third time interval.

[0044] The third time interval may have a duration within a range of 400-1200 s, and in one exemplary arrangement, within a range of 650-1000 s.

[0045] The third time interval defines the period of time in which the actual eloxal process takes place, i.e. in which the actual eloxal layer forms.

[0046] In order to obtain eloxal layers having a sufficient layer thickness for the requirements in vehicle technology, it has been found that the above-described ranges for the third time interval have certain advantages. The observation of a shorter period of time leads to formation of eloxal layers having too low a layer thickness, whereas the prolonging of the period of time in the third time interval beyond the range described above leads to undesirably thick layers.

[0047] Advantageously, the temperature of the electrolyte composition during the process is within a range of 1-45° C., and in one exemplary arrangement, within the range of 20-35° C.

[0048] In a further aspect of the disclosure, during the method, at least one control sequence comprising the following steps is conducted:

- **[0049]** a) detecting at least one actual current value,
- **[0050]** b) comparing the actual current value with a range of values predetermined for the actual current value in which an eloxal layer with predetermined properties is formed on the component, and
- **[0051]** c) if the comparison shows that the actual current value is outside the predetermined range of values: adjusting a method-relevant parameter such that the actual current value drops into the predetermined range of values.

[0052] During the method, the control sequence verifies the process on the basis of an actual current value and enables correction of the method if the actual current value is outside the predetermined range of values. The current value is a suitable indicator in order to monitor the process regime. Moreover, the actual current value during the eloxal method is easily accessible and can therefore be read out in an uncomplicated manner.

[0053] For example, it is possible in advance to experimentally determine ranges of values for the actual current value and to associate these with predetermined properties of an eloxal layer produced therewith on the component. The properties linked to the range of values for the current value may then be recorded in a database which may be accessed during the process. The predetermined properties include, for example, the hardness, layer thickness and roughness of the eloxal layer.

[0054] In this respect, it is possible with the aid of the control sequence to form an eloxal layer having predetermined properties.

[0055] According to the above aspect, the control sequence is conducted at least once during the method. However, it is also conceivable that the control sequence is conducted more than once during the electrochemical method.

[0056] For example, it is conceivable that the control sequence is conducted once each at the start and at the end of the first, second and third time intervals.

[0057] The control sequence may also be conducted at periodic intervals. For example, the control sequence may be conducted every 0.1, 1, 5, 10 or 15 seconds.

[0058] In a further aspect of the disclosure, the method-relevant parameter is selected from the group consisting of voltage value between component and electrode, current between component and electrode, electrolyte temperature, electrolyte flow rate, electrolyte backpressure, pressure in the pressure chamber.

[0059] The electrolyte flow rate is understood to mean the volume of electrolyte that flows between cathode and anode.

[0060] The electrolyte backpressure is understood to mean the volume pressure of the electrolyte between the cathode and anode.

[0061] The pressure in the pressure chamber is understood to mean the volume pressure of the electrolyte not between the cathode and anode but in another region of the electrolyte solution.

[0062] The change in the method-relevant parameter affects the eloxal process per se, such that the actual current value changes again. Advantageously, the method-relevant parameter is changed in that the actual current value drops into the predetermined range of values.

[0063] The abovementioned method-relevant parameters are particularly suitable for influencing the actual current value. For example, the increasing or lowering of a voltage value can directly influence the actual current value. It is thus possible to directly influence the process and to correct the process if necessary, and so it is preferably possible to form eloxal layers with predetermined, i.e. defined, properties on the component.

[0064] The disclosure further relates to an eloxed component, wherein the component has been provided with an eloxal layer obtainable by a method as described above.

[0065] In one exemplary arrangement, the component is a vehicle braking system.

[0066] In one exemplary arrangement, the component is a section of a bore of a vehicle braking system.

[0067] The eloxal layer advantageously has a Vickers hardness within a range of 375-650 HV, and in one exemplary arrangement, in a range of 450-475 HV, where the Vickers hardness has been measured as described below.

[0068] Vickers hardness is measured by a test method in which a force F is used to press a diamond pyramid into the surface of the sample to be tested. The two diagonals of the remaining indentation are measured and arithmetically averaged. This method can be used to very efficiently ascertain the hardness of the very thin eloxal layers.

[0069] The eloxal layer advantageously has a roughness of R_{pk}=0.05-0.2, R_a=0.1-0.3 and R_{max}=1.5-2.0. The roughness parameters R_{pk}, R_a and R_{max} were measured according to standard ISO 13565.

[0070] Advantageously, the eloxal layer has a layer thickness within a range of 5-30 μm, and in one exemplary arrangement, within a range of 10-25 μm. The layer thickness was determined in a scanning electron microscope by breaking up the eloxal layer and analysing the cross section.

[0071] In one exemplary arrangement, the eloxal layer in the section view has a homogeneous coral structure, wherein the coral structure is defined by a multitude of hexagonal, tubular rod structures that are aligned essentially orthogonal to the substrate and have an average length within a range of 0.1-2.5 μm.

[0072] The length of the hexagonal, tubular rod structures is determined with a scanning electron microscope.

[0073] An eloxal layer having at least one of the abovementioned properties is suitable for use as an eloxal layer on a vehicle component, especially a vehicle braking system.

[0074] In one exemplary arrangement, the eloxal layer is provided in at least one bore of the component.

[0075] The bore of a vehicle braking system, in the later use, accommodates pistons in a movable arrangement that rest on the bore wall in operation of the vehicle braking system. In operation, the pistons slide along the bore wall, such that the surface of the wall is subjected to mechanical stress. As a result, the bore wall can be subject to severe wear. For that reason, it is advantageous to provide the bore wall with the above-described eloxal layer.

BRIEF DESCRIPTION OF DRAWINGS

[0076] Further features and advantages of the disclosure will be apparent from the description of exemplary arrangements that follows and from the drawings that follow, to which reference is made. The drawings show:

[0077] FIG. **1**: a schematic diagram of an electrochemical device for eloxation of a component;

[0078] FIG. **2**: a schematic voltage diagram for an electrochemical device from FIG. **1** for eloxation of a component;

[0079] FIG. **3**: a section view of an eloxed component of the disclosure, obtainable using the electrochemical device from FIG. **1**, imaged with a light microscope;

[0080] FIG. **4**: a top view of the eloxal layer from FIG. **3**, imaged with a scanning electron microscope;

[0081] FIG. **5**: a further section view of the eloxal layer from FIG. **3**, imaged with a scanning electron microscope;

[0082] FIG. **6**: an enlarged detail of the section view from FIG. **5**, imaged with a scanning electron microscope; and

[0083] FIG. **7**: a greatly enlarged view of the section view from FIG. **6**, imaged with a scanning electron microscope;

[0084] FIG. **8**A: a further eloxal layer according to the disclosure, imaged with a light microscope, and

[0085] FIG. **8**B: a noninventive eloxal layer, imaged with a light microscope.

DETAILED DESCRIPTION

[0086] FIG. **1** shows the schematic structure of an electrochemical device **10** for eloxation of a component.

[0087] The electrochemical device **10** comprises a vessel **12**.

[0088] The vessel **12** may be designed as a pressure chamber in which the actual eloxal process takes place. In addition, a circulation system may be provided in the vessel, set up to circulate the electrolyte in the vessel (not shown here). The circulation system may be disposed within or outside the vessel **12**. In the latter case, the circulation system is connected to the vessel **12** for flow purposes. In this way, the electrolyte may advantageously be used as cooling for the electrodes.

[0089] The vessel **12** is filled with a liquid electrolyte solution **14**. For example, the vessel **12** may be completely filled with the liquid electrolyte composition **14**. The electrolyte composition **14** is an aqueous solution of the following components:

- **[0090]** (A) potassium titanium oxide oxalate;
- **[0091]** (B) oxalic acid; and
- **[0092]** (C) at least one buffer.

[0093] The potassium titanium oxide oxalate of component (A) may be present in a concentration of 30-50 g/L in the aqueous solution, and in one exemplary arrangement, in a concentration of 35-45 g/L.

[0094] The oxalic acid of component (B) may be present in a concentration of 5-85 g/L in the aqueous solution, and in one exemplary arrangement, in a concentration of 15-55 g/L.

[0095] The buffer of component (C) may be selected from the group consisting of citric acid and boric acid and a combination thereof.

[0096] The buffer of component (C) may be present in a concentration of 1-30 g/L in the aqueous solution, and in one exemplary arrangement, in a concentration of 2-16 g/L.

[0097] The aqueous solution may also have a pH within a range of 0.1-5, and in one exemplary arrangement, a pH within a range of 0.65-2.0.

[0098] In addition, the aqueous solution may comprise aluminium oxalate as a further component (D), which is present in a concentration of 1-15 g/L in the aqueous solution, and in one exemplary arrangement, in a concentration of 2-8 g/L.

[0099] The vessel **12** is designed such that it can accommodate an electrolyte composition **14**, and additionally a component **16** to be eloxed. The component **16** to be eloxed is an aluminium component, for example an aluminium component for a vehicle. In one exemplary arrangement, the aluminium component for a vehicle is part of the vehicle braking system.

[0100] The component **16** has at least one bore **18** which either extends completely through the component **16** or only partly into the component **16**. As can be seen in FIG. **1**, it is also possible for two or more bores **18** to be executed in the component **16**.

[0101] The component **16** is immersed completely in the aqueous electrolyte solution **14**, such that the complete surface of the component **16** is wetted by the electrolyte composition **14**.

[0102] An electrode **20**, which is likewise provided in the vessel **12**, is likewise immersed into the electrolyte composition **14**. The electrode **20** is a titanium electrode. The titanium electrode has an elongated cylindrical shape, such that it can be introduced into the bores **18** of the component **16**. In this way, it is possible to specifically elox the bore **18** through the electrode **20** on application of a voltage.

[0103] In the present case, on application of a voltage, the electrode **20** is connected as cathode **22** and the component **16** as anode **24**. For this purpose, the cathode **22** and the anode **24** are connected to one another in an electrically conductive manner outside the vessel **12** via a connection **25**.

[0104] More specifically, the cathode **22** and the anode **24** are connected to one another via a current and voltage source **26**.

[0105] The current and voltage source **26** is set up to apply a voltage between the cathode **22** and the anode **24**. For this purpose, the current and voltage source **26** can apply a particular voltage value or a particular current value, for example.

[0106] The current and voltage source **26** is connected to a control and evaluation unit **28** via a connection **25**.

[0107] The control and evaluation unit **28** is set up to read out, to monitor and, if necessary, to adjust the current values and voltage values output from the current and voltage unit **26**. In principle, it is also conceivable that the current and voltage unit **26** and the control and evaluation unit **28** are designed as a common unit.

[0108] In addition, the control and evaluation unit **28** has been provided with a user interface **30**.

[0109] The user interface **30** is set up to display a current or voltage value between the cathode **22** and the anode **24** to a user. For example, it is possible to display a voltage diagram to the user that describes the plot over time between voltage applied and time.

[0110] In addition, via the user interface **30**, it is also possible for a user to make inputs in order to actuate the control and evaluation unit **28** and the current and voltage unit **26**. In this respect, a user can also manually input current values or voltage values that are passed on by the control and evaluation unit **28** to the current and voltage unit, which then varies the current applied between the electrodes **22**, **24** and/or the voltage.

[0111] There follows a description by way of example of an eloxal process which is executed by the electrochemical device **10** shown in FIG. **1**.

[0112] The electrochemical device **10** conducts an eloxal process using a defined voltage diagram **32** recorded in the control and evaluation unit **28**.

[0113] In other words, the electrochemical device **10** attempts to traverse a predefined voltage curve **34** over time.

[0114] In a first step, a voltage is applied with a first voltage value U_1 between the component **16** immersed in the electrolyte composition **14** and the electrode **20**. In the electrochemical voltage diagram **32**, this is apparent as an abrupt rise **36** in the voltage. The adjustment of the voltage value U_1 is undertaken by the control and evaluation unit **28**, which actuates the current and voltage unit **26** that applies the voltage value U_1 between the component **16** and the electrode **20**.

[0115] The first voltage value U_1 may be within a range of 60-140 V, for example, within a range of 70-130 V.

[0116] In a next step, the first voltage value U_1 can optionally be maintained for a first time interval t_1. In that case, the evaluation unit **28** causes the current and voltage unit **26** to observe the voltage value U_1 for a time interval t_1. This is apparent as a horizontal section **38** in FIG. **2**.

[0117] The first time interval may additionally have a duration within a range of 2-120 s, and in one exemplary arrangement, within a range of 40-80 s.

[0118] Next, the evaluation unit **28** actuates the current and voltage unit **26** in such a way that the first voltage value U_1 is increased to a second voltage value U_2 within a time interval t_2.

[0119] The second voltage value may be within a range of 100-220 V, and in one exemplary arrangement, within a range of 120-195 V.

[0120] The second interval has a duration within a range of 40-400 s, and in one exemplary arrangement, within a range of 100-300 s.

[0121] It is apparent in the electrochemical voltage diagram **32** that the electrochemical voltage curve **34** runs as a voltage ramp **40** within the range of the second time interval t_2. The rise in voltage between the first voltage value U_1 and the second voltage value U_2 runs essentially linear. The slope in the linear region is preferably 0.05-0.065 V/s.

[0122] In the last step, the evaluation unit **28** actuates the current and voltage unit **26** in order to keep the second voltage value U_2 constant for a third time interval t_3.

[0123] The third time interval t_3 may have a duration within a range of 400-1200 s, for example, within a range of 650-1000 s.

[0124] It is apparent in the electrochemical voltage diagram **32** that the voltage curve **34** reaches a plateau and runs essentially horizontally in the third time interval t_3. This plateau section **42** ends after the third time interval t_3 has elapsed. When the third time interval t_3 elapses, the voltage and hence the current between the cathode **22** and the anode **24** is switched off. The eloxal process has thus ended.

[0125] The temperature of the electrolyte composition **14** is within a range of 1-45° C. throughout the method, and in one exemplary arrangement, within a range of 20-35° C.

[0126] During the traversing of the voltage curve **34** in FIG. **2**, the control and evaluation unit **28** can perform at least one control sequence at any time, which comprises the following steps:

[0127] a) detecting at least one actual current value,

[0128] b) comparing the actual current value with a range of values predetermined for the actual current value in which an eloxal layer with predetermined properties is formed on the component, and

[0129] c) if the comparison shows that the actual current value is outside the range of values: adjusting a method-relevant parameter such that the actual current value drops into the predetermined range of values.

[0130] The method-relevant parameter is selected from the group consisting of voltage value between component and electrode, current between component and electrode, electrolyte temperature, electrolyte flow rate, electrolyte backpressure, pressure in the pressure chamber.

[0131] The control sequence may also be conducted at periodic time intervals during the method. For example, the control sequence can be conducted in the first time interval t_1, in the second time interval t_2 and/or in the third time interval t_3. The control sequence can also be conducted repeatedly in one of the aforementioned time intervals.

[0132] The method-relevant parameter can be adjusted directly by the control and evaluation unit **28**.

[0133] The control and evaluation unit **28** is also set up to access a predetermined range of values and to compare the measured actual current value with the range of values predetermined for the actual current value. The predetermined range of values for the actual current value may be recorded, for example, in a database (not shown here), which is accessed by the evaluation unit **28**. For example, the predetermined range of values for the actual current value may be determined experimentally in advance for particular properties of the eloxal layer on the component. For example, it is possible to record the actual current value at which particular values are obtained for the roughness and layer thickness of an eloxal layer in the predetermined range of values or in the database.

[0134] FIGS. **3** to **7** show various views of an eloxal layer of the disclosure that have been obtained using an electrochemical device **10** and using the electrolyte composition **14**.

[0135] FIG. **3** shows a light micrograph of a section view of an eloxal layer **44** according to the disclosure.

[0136] As is readily apparent in FIG. **3**, the eloxal layer has an average thickness of 22 μm.

[0137] The eloxal layer **44** runs homogeneously and parallel to the interface layer of the aluminium body **45**. The aluminium body **45** is clearly apparent in FIG. **3** as a relatively light-coloured section.

[0138] FIG. **4** shows a top view by electron microscope of the eloxal layer **44** from FIG. **3**.

[0139] As is readily apparent in the top view in FIG. **4**, the eloxal layer **44** has a homogeneous constant surface **46**. The surface **46** is covered with relatively few defects **48**, which are smaller than 0.5 μm, and in some exemplary arrangements, smaller than 0.1 μm.

[0140] FIG. **5** shows a section view by electron microscope of the eloxal layer **44** from FIG. **3**. It is apparent in the scanning electron microscope that the eloxal layer **44** has a coral-like structure **50**.

[0141] FIGS. **6** and **7** show enlarged details of the section view from FIG. **5**.

[0142] For example, it is readily apparent in FIG. **7** that the coral-like structure **50** is formed from a multitude of hexagonal, tubular rod structures that are aligned essentially orthogonal to the substrate and have an average length within a range of 0.1-2.5 μm.

[0143] The substrate is regarded here as the aluminium body **45**, from which the hexagonal, tubular rod structures grow. In addition, it is apparent that the inventive eloxal layers **44** form a constant layer having no defects or pore-like structures.

EXAMPLES

[0144] The disclosure is elucidated hereinafter by examples, but these should not be interpreted in a restrictive manner.

Example 1

[0145] For the eloxal process according to the disclosure that follows, the following electrolyte composition is used: 40 g/L potassium titanium oxide oxalate, 8 g/L boric acid, 30 g/L oxalic acid. The electrolyte is adjusted to a pH of 2.3.

[0146] In addition, the whole process is conducted at a temperature of 30° C.

[0147] The first voltage value is 60 V, while the second voltage value U_2 is 180 V. The second time interval is 60 s; the third time interval is 1000 s.

[0148] An eloxal layer obtained on an aluminium component has a hardness of 454 HV. In addition, the following roughness values are measured: R_{pk}=0.1232, R_a=0.2002 and R_{max}=2.3221.

[0149] The layer thickness is 30 μm.

Comparative Example 1

[0150] The electrolyte chosen is a 90% sulfuric acid solution.

[0151] The method parameters are the same as already described in Example 1.

[0152] An eloxal layer obtained has a hardness in the region of 280 HV. In addition, the following roughness values are measured: R_{pk}=0.4016, R_a=0.4452 and R_{max}=3.2646.

[0153] The layer thickness is 19 μm.

Comparison of Inventive Example 1 with Comparative Example 1

[0154] The differences between the two eloxal layers are apparent in FIGS. **8**A and **8**B.

[0155] By comparison with Inventive Example 1, an eloxal layer obtained in Comparative Example 1 is noticeably rougher than the eloxal layer from the inventive example. Even though the eloxal layer from Comparative Example 1 is rougher, it has a lower layer thickness. By comparison, the eloxal layer from Inventive Example 1 is both smoother and has a higher layer thickness.

1. An electrolyte composition for eloxation of a component, wherein the electrolyte composition comprises an aqueous solution of the following components:

(A) potassium titanium oxide oxalate;
(B) oxalic acid; and
(C) at least one buffer.

2. The electrolyte composition according to claim **1**, wherein the potassium titanium oxide oxalate is present in a concentration of 30-50 g/L in the aqueous solution.

3. The electrolyte composition according to claim **1**, wherein the oxalic acid is present in a concentration of 5-85 g/L in the aqueous solution.

4. The electrolyte composition according to claim **1**, wherein the buffer is selected from the group consisting of citric acid and boric acid and a combination thereof.

5. The electrolyte composition according to claim **1**, wherein the buffer is present in a concentration of 1-30 g/L in the aqueous solution.

6. The electrolyte composition according to claim **1**, wherein the aqueous solution has a pH within a range of 0.1-5.

7. The electrolyte composition according to claim **1**, wherein that the aqueous solution further comprises aluminium oxalate as a component present in a concentration of 1-15 g/L in the aqueous solution.

8. The electrochemical method for eloxation of a component, especially a component for a vehicle braking system, using an electrolyte composition according to, wherein the method comprises the following steps:

a) applying a voltage with a first voltage value U_1 between a component immersed an the electrolyte composition and an electrode, wherein the electrolyte composition comprises an aqueous solution of the following components: potassium titanium oxide oxalate; oxalic acid; and at least one buffer;
b) optionally maintaining the first voltage value for a first time interval,
c) increasing the first voltage value within a second time interval to a second voltage value, and
d) holding the second voltage value for a third time interval.

9. The electrochemical method according to claim **8**, wherein the method has at least one of the following features:

the first voltage value is within a range of 60-140 V,
the second voltage value is within a range of 100-220 V,
the first time interval in step b) has a duration within a range of 2 to 120 s,
the second time interval in step c) has a duration within a range of 40 to 400 s,
the third time interval in step d) has a duration within a range of 400-1200 s,
the increase in the first voltage value within the second time interval to the second voltage value is essentially linear, and
a temperature of the electrolyte composition during the method is within a range of 1-45° C.

10. The electrochemical method according to claim **8** wherein, during the method, at least one control sequence comprising the following steps is conducted:

a) detecting at least one actual current value,
b) comparing the actual current value with a range of values predetermined for the actual current value in which an eloxal layer with predetermined properties is formed on the component, and
c) if the comparison shows that the actual current value is outside the range of values: adjusting a method-relevant parameter such that the actual current value drops into the predetermined range of values.

11. The electrochemical method according to claim **10**, wherein the method-relevant parameter is selected from the group consisting of voltage value between component and electrode, current between component and electrode, electrolyte temperature, electrolyte flow rate, electrolyte back-pressure, pressure in the pressure chamber.

12. The electrochemical method according to claim **10**, wherein the control sequence is conducted at periodic time intervals during the method.

13. An eloxed component, wherein characterized in that the component has been provided with an eloxal layer obtainable by a method according to claim **9**.

14. The eloxed component according to claim **13**, wherein the eloxal layer has at least one of the following features:

the eloxal layer has a Vickers hardness within a range of 375-650 HV,
the eloxal layer has a roughness of R_{pk}=0.05-0.2, R_a=0.1-0.3 and R_{max}=1.5-2.0, where the roughness parameters R_{pk}, R_a and R_{max} have been measured according to ISO 13565,
the eloxal layer has a layer thickness within a range of 5-30 μm, and
the eloxal layer has a homogeneous coral structure, where the coral structure is defined by a multitude of hexagonal, tubular rod structures that are aligned essentially orthogonally to the substrate and have an average length within a range of 0.1 to 2.5 μm.

15. The eloxed component according to claim **13** wherein the eloxal layer is provided in at least one bore of the component.

16. The electrolyte composition according to claim **2**, wherein the oxalic acid is present in a concentration of 5-85 g/L in the aqueous solution.

17. The electrolyte composition according to claim **16**, wherein the buffer is selected from the group consisting of citric acid and boric acid and a combination thereof.

18. The electrolyte composition according to claim **17**, wherein the buffer is selected from the group consisting of citric acid and boric acid and a combination thereof.

19. The electrolyte composition according to claim **17**, wherein the aqueous solution has a pH within a range of 0.1-5.

20. The electrolyte composition according to claim **1**, wherein that the aqueous solution further comprises aluminium oxalate as a component present in a concentration of 1-15 g/L in the aqueous solution.

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