US 20090188803A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2009/0188803 A1**

(43) **Pub. Date: Jul. 30, 2009**

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(54) **METHOD AND DEVICE FOR PROCESSING AT LEAST TWO WORKPIECES BY MEANS OF ELECTROCHEMICAL TREATMENT**

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(21) Appl. No.: **11/988,496**

(22) PCT Filed: **Jul. 4, 2006**

(86) PCT No.: **PCT/EP2006/063859**

§ 371 (c)(1),
(2), (4) Date: **Apr. 16, 2009**

(30) **Foreign Application Priority Data**

Jul. 8, 2005 (DE) 10 2005 032 738.9

Publication Classification

(51) **Int. Cl.**
C25D 17/02 (2006.01)
C25D 17/10 (2006.01)
C25D 3/00 (2006.01)

(52) **U.S. Cl.** **205/96**; 205/114; 204/230.7; 204/242

(57) **ABSTRACT**

The invention relates to a method for processing at least two workpieces by means of electrochemical treatment. During the method, the workpieces are provided as working electrodes in an electrolytic treatment solution inside of which a counter-electrode arrangement is assigned to each workpiece. One workpiece and the assigned counter-electrode arrangement form an electrolytic processing element. The electrolytic processing elements are connected in series.

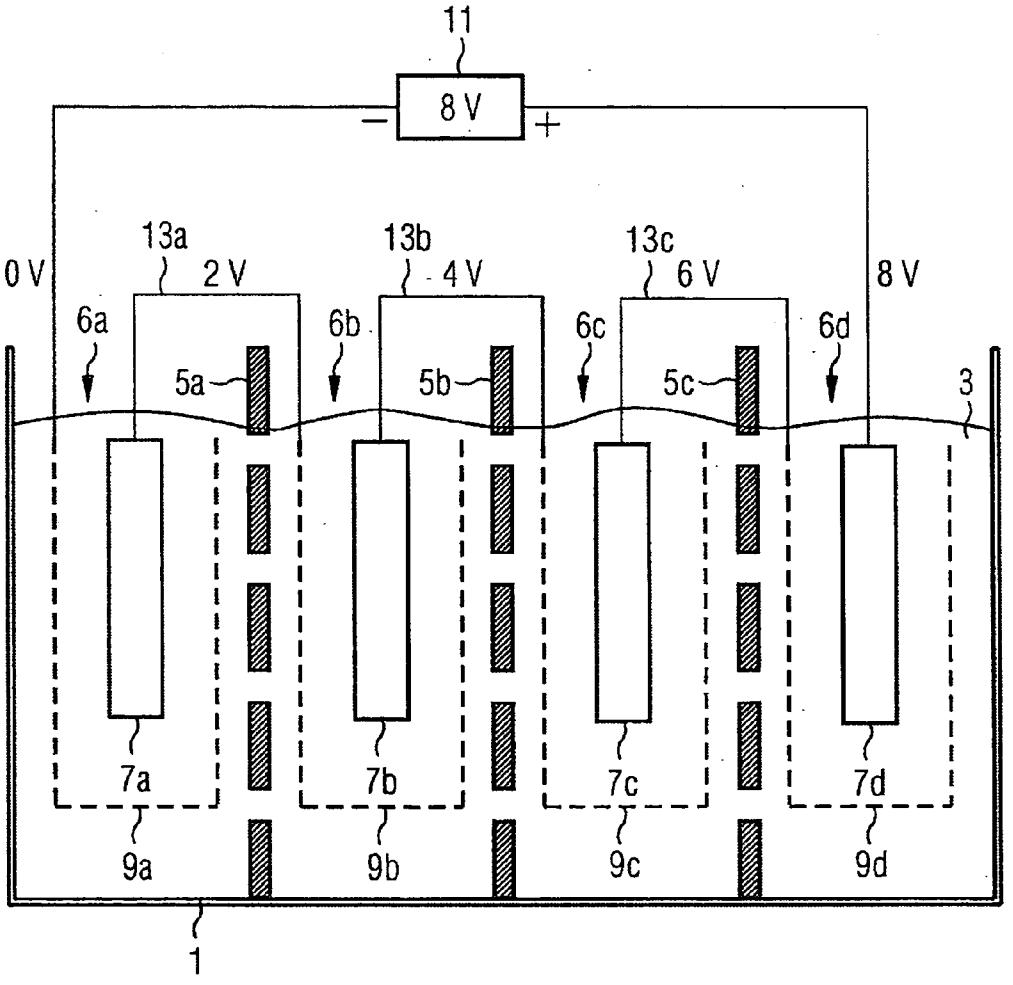


FIG 1

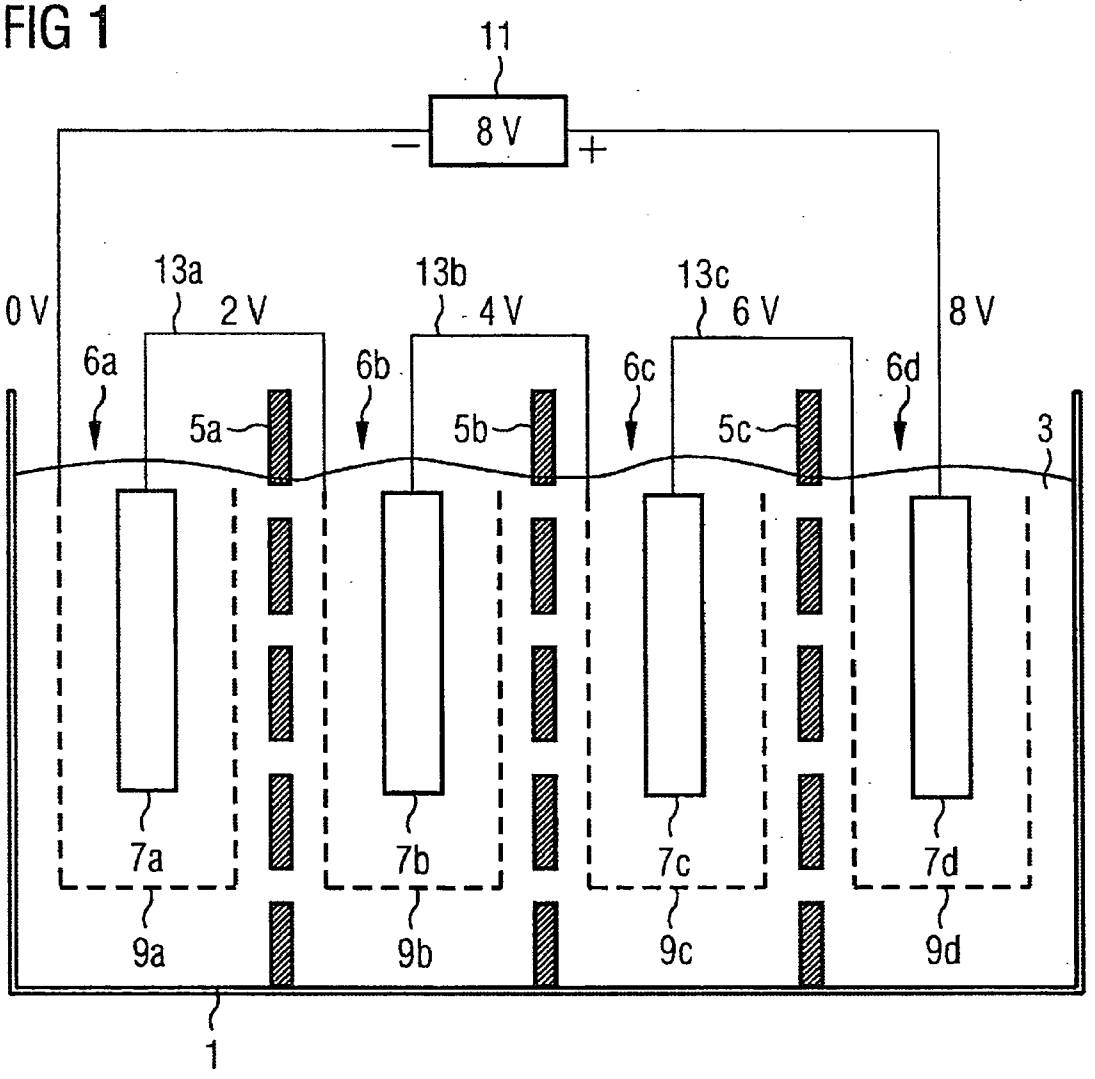
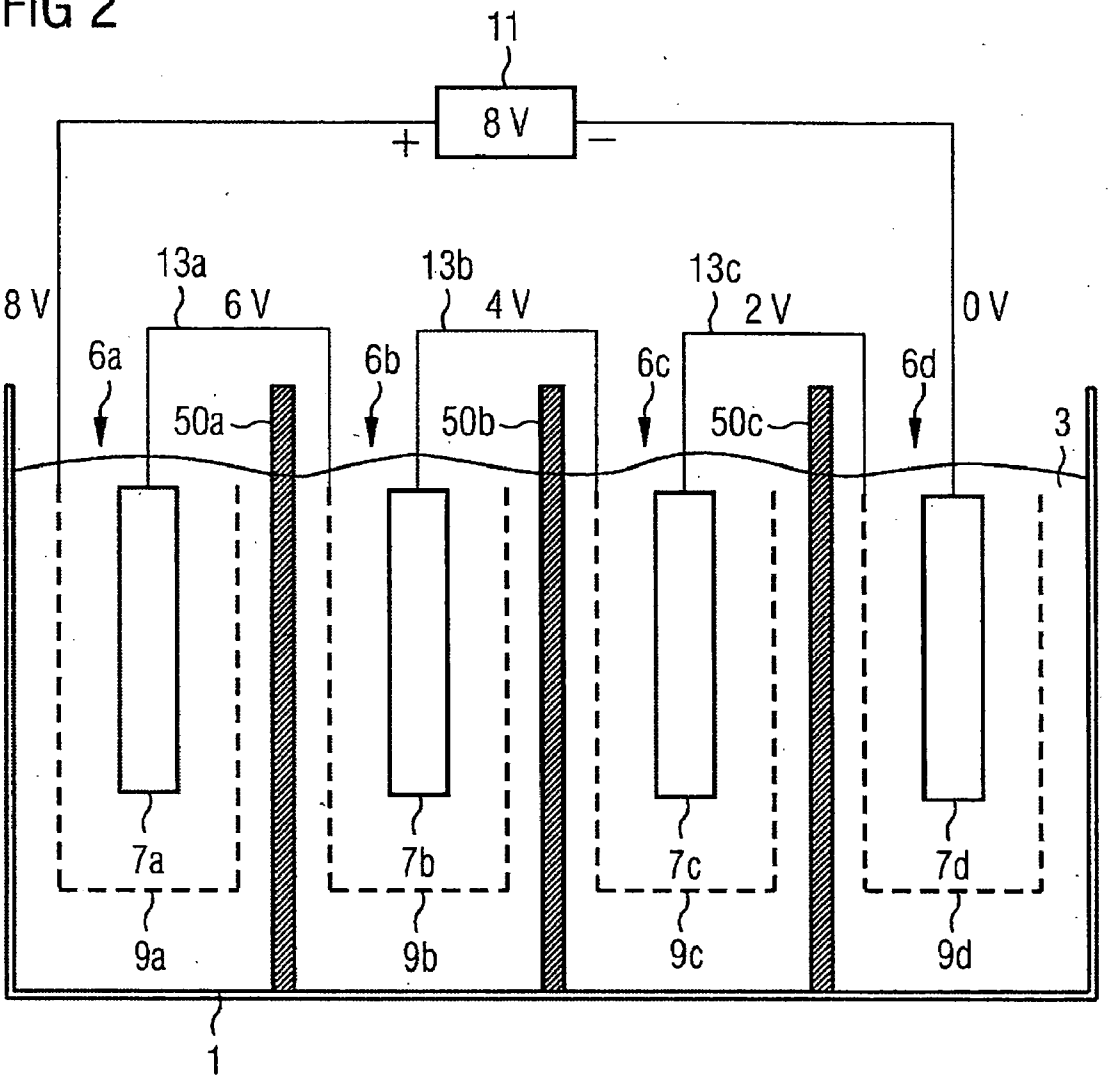

11
8 V
−
+
0 V
13a
2 V
13b
4 V
13c
6 V
8 V
6a
6b
6c
6d
5a
5b
5c
3
7a
7b
7c
7d
9a
9b
9c
9d
1

FIG 2


11
8 V
+
−
8 V
13a
6 V
13b
4 V
13c
2 V
0 V
6a
6b
6c
6d
50a
50b
50c
3
7a
7b
7c
7d
9a
9b
9c
9d
1

METHOD AND DEVICE FOR PROCESSING AT LEAST TWO WORKPIECES BY MEANS OF ELECTROCHEMICAL TREATMENT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is the US National Stage of International Application No. PCT/EP2006/063859, filed Jul. 4, 2006 and claims the benefit thereof The International Application claims the benefits of German application No. 10 2005 032 738.9 filed Jul. 8, 2005, both of the applications are incorporated by reference herein in their entirety.

FIELD OF INVENTION

[0002] The present invention relates to a method for processing at least two workpieces by means of electrochemical treatment and to an apparatus for carrying out the method.

BACKGROUND OF THE INVENTION

[0003] Methods for electrochemically treating workpieces are nowadays used e.g. for coating or de-coating workpieces, for polishing workpieces or for cleaning workpieces. Specific applications include for example the coating and de-coating of turbine blades.

[0004] EP 1 094 134 A1 describes a method and an apparatus for electrochemically removing a metal coating from a turbine blade. The turbine blade is placed as the positively poled working electrode in a tank containing an electrolytic bath. The electrolytic bath also contains a number of cathodes which constitute counter-electrodes to the turbine blade. To remove the metal coating, a voltage is built up between the turbine blade and the cathodes. The turbine blade and counter-electrodes are assigned a voltage source which supplies them with the necessary voltage.

[0005] A method for producing electroplated coatings is described in EP 0 748 883 A1. In this method the workpiece to be coated is placed in an electroplating bath. The coating material is dissolved in the electroplating bath in the form of positively charged ions. By applying a voltage between the negatively poled workpiece and a positively poled counter-electrode, the dissolved metal ions are transported to the workpiece surface where they are deposited as a coating.

[0006] A method for electrochemically de-coating turbine blades is also described in U.S. Pat. No. 6,165,345.

SUMMARY OF INVENTION

[0007] The object of the present invention is to provide a method and an apparatus which, compared to the prior art described, enable workpieces to be electrochemically processed efficiently and on a commercial scale.

[0008] This object is achieved by a method for processing at least two workpieces by means of electrochemical treatment as claimed in the claims, and by an apparatus as claimed in the claims. The dependent claims contain advantageous embodiments of the invention.

[0009] In the method according to the invention for processing at least two workpieces by means of electrochemical treatment, the workpieces are placed as working electrodes in an electrolytic treatment solution. In the electrolytic treatment solution, each workpiece is assigned a counter-electrode arrangement which can consist of a single electrode or a plurality of counter-electrodes. A workpiece and the counter-electrode arrangement assigned thereto together form an electrolytic processing element in each case. According to the invention, the electrolytic processing elements are connected in series.

[0010] In this context, connection in series means that at least a predominant part of the current flowing during the electrochemical treatment passes through the electrolytic treatment elements one after the other. In order to be able to ensure series connection, it is advantageous if current flow through the electrolytic treatment solution between the electrolytic processing elements is selectively counteracted. This can be achieved, for example, by shielding the individual electrolytic processing elements from the electric fields of the other electrolytic processing elements. The current can then flow e.g. via cables in a defined manner from one electric processing element to another.

[0011] As an alternative to electric field shielding, it is also possible to electrically isolate the electrolytic treatment solutions of the electrolytic treatment elements from one another.

[0012] The series connection can be established, for example, by connecting the workpiece of one electrolytic processing element to the counter-electrode arrangement of another electrolytic processing element via an electrically conductive path which has a much lower electrical resistance than possible current paths through the electrolytic treatment solution between the electrolytic processing elements. Workpieces and counter-electrode arrangements which are interconnected by such a low-resistance electrically conductive path are preferably at the same electrical potential. In other words, the counter-electrode arrangement of one electrolytic processing element is at the same potential as the working electrode of the following electrolytic processing element connected thereto via the low-resistance path. Said working electrode is then electrically connected to the assigned counter-electrode arrangement in the electrolytic processing element via the electrolytic treatment solution in the electrolytic processing element, said counter-electrode arrangement being in turn connected to the working electrode of another electrolytic processing element via a low-resistance path. A potential difference between the working electrode and the associated counter-electrode is present in each case in the individual electrolytic treatment elements.

[0013] The method according to the invention enables several workpieces to be processed simultaneously using just a single power source. The series connection means that the current flow through all the workpieces is essentially identical. The method can therefore be controlled as hitherto via the current density. Since in the method according to the invention a separate voltage source such as a separate generator is not necessary for each workpiece, the capital investment for commercial-scale use can be reduced, as the number of high cost incurring generators can be reduced.

[0014] An apparatus according to the invention for processing at least two workpieces by means of electrochemical treatment comprises a tank which is to be filled with an electrolytic treatment solution and into which the workpieces can be placed as working electrodes. In the tank a counter-electrode arrangement is either disposed or must be inserted for each workpiece. The counter-electrode arrangement can comprise a single counter-electrode or a plurality of counter-electrodes. Finally there is provided a voltage source to be connected in an electrically conductive manner to a workpiece and to a counter-electrode arrangement. A workpiece in combination with an assigned counter-electrode arrangement forms an electrolytic processing element, at least one work-

piece of an electrolytic processing element having to be connected to the counter-electrode arrangement of another electrolytic processing element via an electrically conductive path which has a much lower electrical resistance than the electrolytic treatment solution between the two electrolytic processing elements.

[0015] The apparatus according to the invention allows the electrolytic processing elements to be connected in series, thereby enabling the method according to the invention to be carried out. It therefore provides the advantages already described with reference to the method.

[0016] In order to ensure that, during processing, the current flows essentially consecutively through the individual electrolytic processing elements, devices for preventing current flow through the electrolytic treatment solution between two electrolytic processing elements can be provided. These devices can be, for example, Faraday walls e.g. in the form of grounded wire grids. Alternatively, however, it is also possible to implement the devices by walls of electrically isolating material. In both cases it is advantageous if the devices are made from a material that is chemically inert to the electrolytic treatment solution. In this way it can be ensured that current flow through the electrolytic treatment solution between adjacent electrolytic processing elements can also be effectively suppressed over the long term.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Further features, characteristics and advantages of the present invention will emerge from the following description of exemplary embodiments with reference to the accompanying drawings in which:

[0018] FIG. **1** shows a first exemplary embodiment of the apparatus according to the invention.

[0019] FIG. **2** shows a second exemplary embodiment of the apparatus according to the invention.

DETAILED DESCRIPTION OF INVENTION

[0020] The apparatuses described below with reference to FIGS. **1** and **2** for electrochemically processing at least two workpieces can be used in all electroplating processes which are controlled via a pulsed or unpulsed current. Such processes are, for example, the electrochemical de-coating of workpieces, the electrochemical coating of workpieces, the electrochemical cleaning of workpieces, the electrochemical polishing of workpieces, etc.

[0021] The apparatus shown in FIG. **1** will now be described with reference to electrochemical removal of MCrAlY coatings from turbine blades. In an electrochemical de-coating process of this kind, a turbine blade is placed in an electrolytic treatment solution, e.g. a salt solution, as a positively i.e. anodically poled working electrode. In the electrolytic treatment solution there is also a counter-electrode arrangement which is negatively i.e. cathodically poled. As a result of the flow of current, the metal ions dissolved out of the MCrAlY coating are transported away from the turbine blade.

[0022] The apparatus shown in FIG. **1** for electrochemically treating workpieces comprises a tank **1** which can be filled with an electrolytic treatment solution **3**. The tank is subdivided into different receptacles **6** by means of wire grids **5**. Into each of the receptacles **6**, turbine blades to be de-coated are placed as workpieces **7** which constitute working electrodes, and also counter-electrode arrangements **9** assigned to the workpieces **7**. The electrolytic treatment solution **3** can either be supplied to the tank **1** in advance or after the workpieces **7** have been placed in the tank.

[0023] The workpieces **7** and the assigned counter-electrode arrangements **9** are placed in the tank **1** in such a way that each receptacle contains a single workpiece **7** and an assigned counter-electrode arrangement **9** in each case, a workpiece and an assigned counter-electrode arrangement **9** constituting a configuration hereinafter referred to as an electrochemical processing element.

[0024] One of the workpieces **7***d* is electrically connected to the positive terminal of a voltage source **11**. The counter-electrode arrangement **9***d* assigned to said workpiece **7***d* is connected via a maximally low-resistance electrical connection **13***c* to the workpiece **7***c* of the next electrochemical processing element. The latter's counter-electrode arrangement **9***c* is in turn connected via a maximally low-resistance electrical connection **13***d* to the workpiece **7***b* of the third electrochemical processing element. The latter's counter-electrode arrangement **9***b* is in turn connected via a maximally low-resistance electrical connection **13***a* to the workpiece **7***a* of the last electrochemical processing element. The counter-electrode arrangement **9***a* of this electrochemical processing element is finally connected to the negative terminal of the voltage source **11**.

[0025] The wire grids **5** which separate the individual receptacles **6** with the thereon disposed electrochemical processing elements are grounded and shield the electrochemical treatment elements from the electric fields emanating from the other electrolytic treatment elements. In this way any flow of current through the electrolytic treatment solution between the individual electrolytic treatment elements can be effectively prevented. In order to protect the material of the wire grids **5** from chemical attack, these are made from a material which is chemically inert to the electrolytic treatment solution **3**.

[0026] The electrically conductive connections **13** between the workpieces **7** and the counter-electrode arrangements **9** of different electrochemical treatment elements produce a series connection of the individual electrochemical treatment elements, each electrochemical treatment element constituting an element of the series connection in which the workpiece **7** is positively poled and the associated counter-electrode arrangement is negatively poled. The electrical connection **13** is selected with a low resistance such that a workpiece **7** is at the same potential as the counter-electrode arrangement **9** connected thereto via the electrical connection **13**, the wire grids **5** ensuring that for current flow between the two terminals of the voltage source **11** a single current path is available, namely that via the electrical connection **13** and—in the individual electrolytic processing elements—through the electrolytic treatment solution **3** between the workpiece **7** and the associated counter-electrode arrangement **9**.

[0027] If the voltage source **11** supplies e.g. 8 volts and, as shown in FIG. **1**, four electrolytic treatment elements are connected in series, a voltage of 2 V is dropped across each electrolytic treatment element. In other words, a voltage of 2 V is always present between the workpiece **7** and the associated counter-electrode **9** of an electrochemical treatment element. The potentials dropped across the workpieces **7** and counter-electrodes **9** are indicated in FIG. **1**.

[0028] During the electrochemical treatment process, the electrolytic treatment solution **3** can be continuously exchanged via suitable feed inlets and drain outlets, e.g. in order to take away ions introduced into the electrolytic treat-

ment solution during de-coating of the turbine blades. In the case of coating, new ions can be constantly supplied via the feed inlet and deposited as a coating on the surface of the workpiece **7**. The feed inlets and drain outlets are preferably disposed in such a way that all the receptacles essentially have the same ion density. In the apparatus shown in FIG. **1** a single feed inlet and a single drain outlet basically suffices, as all the receptacles **6** are fluidically interconnected because of the meshes of the grids **5**.

[0029] Although the tank **1** of the apparatus described with reference to FIG. **1** has four receptacles, it can also have more than four or fewer than four receptacles. Accordingly the series connection can also be comprised of more or fewer than four electrolytic treatment elements. Limits for the number of electrolytic treatment elements from which the series circuit can be constituted result from the desired voltage drop between the workpieces and the associated counter-electrode arrangements in conjunction with the voltage which can be provided by the voltage source. In addition, the size of the tank **1** in relation to the size of the workpieces to be processed represents a limitation for the possible number of receptacles.

[0030] Since, because of the series connection, the current flowing through all the electrolytic processing elements is the same, the electrolytic process can take place via the current density as in the case of a single electrolytic cell.

[0031] A second exemplary embodiment of the apparatus according to the invention will now be described with reference to FIG. **2**. The apparatus shown in FIG. **2** only differs from the apparatus shown in FIG. **1** in that the grounded wire grids **5** are replaced by walls **50** of isolator material. Like the material of the wire grids in the first exemplary embodiment, the material of the isolator walls **50** is also selected such that it is chemically inert to the electrolytic treatment solution **3**. As the other elements of the exemplary embodiment illustrated in FIG. **2** correspond to those in FIG. **1**, they are designated by the same reference signs as in FIG. **1** and will not therefore be explained again at this point.

[0032] The apparatus shown in FIG. **2** is configured for depositing a metallic coating on a workpiece such as a turbine blade. This means that the voltage source **11** is of opposite polarity to the voltage source shown in FIG. **1**. In other words, with the polarity shown in FIG. **2**, in each electrolytic treatment element the workpiece **7** constitutes a negatively poled electrode, while the counter-electrode arrangement **9** constitutes a positively poled electrode. Current flow through the electrolytic treatment solution **3** between the individual electrolytic treatment elements is prevented by the isolator walls **50**.

[0033] To coat the workpieces **7**, metal ions are fed to the electrolytic treatment solution **3** which, because of the voltage present between the workpieces **7** and the assigned counter-electrode arrangements **9**, are transported to the surfaces of the workpieces **7** where they are deposited as a coating.

[0034] As the isolator walls **50** constitute flow barriers, in the second example each receptacle **6** in the tank I is assigned its own feed inlet and its own drain outlet for electrolytic treatment solution.

1.-**12**. (canceled)

13. A method for processing a plurality of workpieces via an electrochemical treatment, comprising:

placing the plurality of workpieces as working electrodes in an electrolytic treatment solution;

assigning each workpiece a respective counter-electrode workpiece; and

forming an electrolytic processing element in each case between an individual workpiece and its respectively assigned counter-electrode workpiece by connecting each electrolytic processing element in series.

14. The method as claimed in claim **13**, wherein current flow through the electrolytic treatment solution between the electrolytic processing elements is selectively counteracted.

15. The method as claimed in claim **14**, wherein the electrolytic processing elements are shielded from electric fields emanating from the other electrolytic processing elements.

16. The method as. claimed in claim **14**, wherein the electrolytic treatment solutions of the individual electrolytic treatment elements are electrically isolated from one another.

17. The method as claimed in claim **16**, wherein to form the series connection, the workpiece of an electrolytic processing element is connected to the counter-electrode arrangement of another electrolytic processing element via a low-resistance electrically conductive path having a much lower electrical resistance than possible current paths through the electrolytic treatment solution between the electrolytic processing elements.

18. The method as claimed in claim **17**, wherein workpieces interconnected via the low-resistance electrically conductive path, and the counter-electrode arrangements are at the same electrical potential.

19. An apparatus for processing a plurality of workpieces via electrochemical treatment, comprising:

a tank filled with an electrolytic treatment solution sized and configured for placing the workpieces as working electrodes;

a counter-electrode arrangement disposed in the tank for each workpiece; and

a voltage source connected in an electrically conductive manner to each workpiece and a counter-electrode arrangement, wherein an individual workpiece together with an associated counter-electrode arrangement constitutes an electrolytic processing element and wherein at least one workpiece of an electrolytic processing element must be connected to the counter-electrode arrangements of another electrolytic processing element via an electrically conductive path having a much lower electrical resistance than the electrolytic treatment solution between the two electrolytic processing elements.

20. The apparatus as claimed in claim **19**, wherein devices are provided for preventing current flow through the electrolytic treatment solution between two electrolytic processing elements.

21. The apparatus as claimed in claim **20**, wherein the devices for preventing current flow through the electrolytic treatment solution between two electrolytic processing elements are Faraday walls.

22. The apparatus as claimed in claim **21**, wherein grounded wire grids are provided as Faraday walls.

23. The apparatus as claimed in claim **22**, wherein the Faraday walls are produced from a material that is chemically inert to the electrolytic treatment solution.

24. The apparatus as claimed in claim **20**, wherein the devices for preventing current flow through the electrolytic treatment- solution between two electrolytic processing elements are walls made of an electrically isolating material.

25. The apparatus as claimed in claim **24**, wherein the walls made of an electrically isolating material are produced from a material that is chemically inert to the electrolytic treatment solution.

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