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- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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(54) Title: METHOD FOR MANUFACTURING A COPPER PRODUCT AND A COPPER PRODUCT

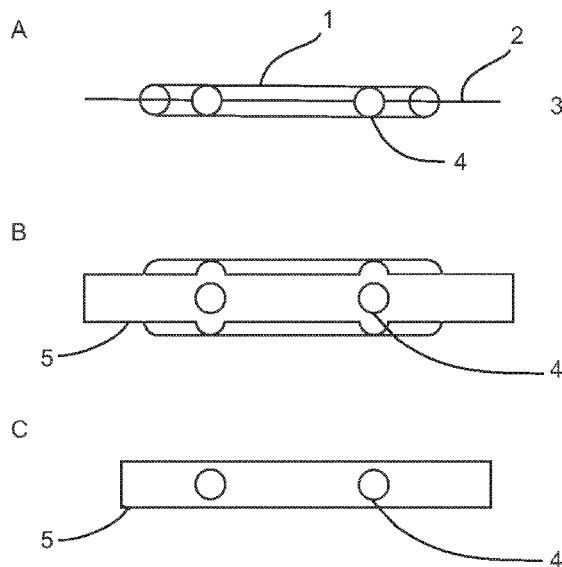


Figure 1

(57) Abstract: The invention concerns a method for manufacturing a copper product, wherein the copper product comprises a body made of copper; and the body is formed by electrolytically depositing copper.



— of inventorship (Rule 4.17(iv))

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METHOD FOR MANUFACTURING A COPPER PRODUCT AND A COPPER PRODUCT

5 FIELD OF THE INVENTION

The invention relates to a method for manufacturing a copper product and a copper product.

BACKGROUND OF THE INVENTION

10

The traditional way of manufacturing copper products is to melt copper deposited on a cathode in an electrodeposition process and to cast it into a billet or sand cast into a shape. This billet or shape
15 may then be machined or worked into the final properties and dimensions of the copper product.

However, the traditional process requires a significant amount of time and energy, and subsequently also costs, from the start of the electrodeposition
20 process e.g. up to a point in which the copper product is raw cast. There is thus always a need for improvements in the economy and sustainability of the process.

Further, the traditional process does not always
25 result in copper products that have the desired properties. For instance, in pyrometallurgical processes, the wearing of reactor linings in metallurgical furnaces is reduced by cooling elements, which transfer heat emitted on the lining surface to a cooling
30 agent such as water circulating in channel systems arranged in the cooling elements. Such cooling elements should have high heat transfer capacity and be able to withstand high temperatures and sudden temperature changes. Conventionally, cooling elements have
35 been manufactured e.g. by sand casting, in which an element made of material with high heat transfer ca-

capacity is cast around a channel system such as a pipework. Typically, both the element and the pipework are made of copper. Sand casting has, however, several problems such as the uneven attachment of the pipework to the casted element. Such uneven attachment leads to unoptimal heat transfer between the casted element and the pipework.

Various publications propose methods for the manufacture of cooling elements which aim at a good contact between the channel system and the element. For instance, the publication WO2007063164 describes a method for manufacturing a cooling element comprising a housing element mainly made of copper, provided with a channel system compiled of pipes mainly made of copper, so that on the outer surface of the channel system there is arranged a coating with a melting point lower than with the material of the housing element and the pipes. In that case, the housing element is cast around the pipes; the coating allows an improved contact with a good heat transfer capacity between the housing element and the pipes. Cooling elements that have an ideal heat transfer capacity still remain difficult to achieve. Another method used for the manufacture of cooling elements is the drill-and-plug technique, in which holes are drilled directly into a block of metal and unused external holes are plugged. This provides direct contact between the cooling agent and the metal of the block but has the major drawback that the plugs may leak. Thus the need remains for methods that allow for the manufacture of cooling elements with better heat transfer capacity and with complex geometries.

SUMMARY OF THE INVENTION

The purpose of the present invention is to provide a new method for manufacturing a copper prod-

uct, which saves time and energy as compared to traditional methods; further, the purpose of the present invention is to provide a new method resulting in a highly improved metallic contact and also improved
5 heat transfer properties, e.g. heat transfer between a cooling element and its channel system.

The invention discloses a method for manufacturing a copper product, wherein the copper product comprises a body made of copper; and the body is
10 formed by electrolytically depositing copper.

The invention further relates to copper product obtainable by the method according to one or more embodiments of the invention.

The invention also discloses a copper product
15 comprising a body made of copper, wherein the body is formed by electrolytically depositing copper.

The body made of copper, e.g. a copper block, may be formed entirely by electrolytically depositing copper. The body made of copper is thus grown directly
20 into shape by electrolytically depositing copper. The electrolytic depositing may be performed using a variety of electrolytic processes, including electrowinning processes as well as electrorefining processes involving dissolving copper anodes.

25 In an embodiment of the present invention, the copper product is a cooling element, a busbar, a billet for a forged product, a valve housing, a valve stem, a semi-finished product or alike.

The semi-finished product may be e.g. a raw
30 casting or a pre-fabricated product, i.e. a copper product comprising the body made of copper formed by electrolytically depositing copper that has not been further processed e.g. by machining, working or forging.

35 In an embodiment of the present invention, the copper product is machined, worked or forged after forming the body made of copper.

In an embodiment of the invention,
a billet for the body made of copper is prepared; and

the body is formed by electrolytically depositing copper on the surface of the billet.

The billet may in principle be a nucleus or a substrate of any type, provided that copper can be electrolytically deposited thereon.

In an embodiment of the invention,
a billet for the body made of copper is prepared;

the body is formed by electrolytically depositing copper on the surface of the billet; and

the body made of copper electrolytically deposited on the surface of the billet is machined or forged so that the copper product obtains its final shape.

In an embodiment of the invention,
a billet for the body made of copper is prepared;

the body is formed by electrolytically depositing copper on the surface of the billet; and

the billet and the body made of copper electrolytically deposited on the surface of the billet are machined or forged so that the copper product obtains its final shape.

The body made of copper may, in principle, be of any shape and size that can be formed by electrolytically depositing copper.

In an embodiment of the present invention, the body made of copper is a block, a bar, a rail, a disc or a wheel.

The body made of copper may be formed in an electrolytic system by placing a suitable core or nucleus, e.g. the billet, in an electrolytic bath comprising copper sulphate solution. The cathodic contact of the electrolytic system may be connected to the

core or billet and/or the channel system. The anodic contact may be connected e.g. to a lead anode or other anode suitable for use in the electrolytic system.

5 In an embodiment of the invention, a portion of the core or billet and/or the channel system is positioned above the surface of the electrolytic bath. Copper will not be deposited on said portion of the core or billet and/or the channel system.

10 If the copper product, e.g. a cooling element, to be manufactured has a complex geometry, it is possible to shape the anode according to the shape of the core or billet and/or the channel system. Furthermore, portions of the core or billet and/or channel system on which copper should not be deposited may be
15 protected during the electrolytic deposition e.g. by taping said portions.

The parameters of the electrolysis, such as the concentration of the copper sulphate solution or the current density, may be adjusted so as to allow
20 optimal deposition of copper. In an electrowinning process, the current density may be e.g. 200-250 A/m². Solution circulation may also be adjusted so that copper e.g. in the form of copper sulphate and any additives are always present in a sufficient amount to
25 achieve an optimal deposition rate.

During the electrolytic deposition, the core or billet and the deposited body made of copper, e.g. a copper block, may be removed from the electrolytic bath for e.g. machining and returned back to the electrolytic bath so as to obtain the best possible quality of the body made of copper, e.g. the copper block and the cooling element.
30

It is typically possible to electrolytically deposit copper approx. 2 mm per day, corresponding to
35 approx. 20 mm per week.

In an embodiment of the invention, the thickness of the body made of copper is at least 1 mm, or

at least 2 mm, or at least 5 mm, or at least 10 mm, or at least 20 mm.

In an embodiment of the present invention, the copper product is a cooling element for use in connection with a metallurgical furnace, wherein a channel system for circulation of a cooling agent is arranged in the cooling element, and wherein the cooling element comprises a copper block; wherein the copper block is formed by electrolytically depositing copper.

The cooling element may be suitable for use in different types of furnaces, e.g. in an electric furnace or in a flash smelting furnace.

In an embodiment of the invention, the method is a method for manufacturing a cooling element for use in connection with a metallurgical furnace, wherein a channel system for circulation of a cooling agent is arranged in the cooling element, and wherein the cooling element comprises a copper block; wherein the copper block is formed by electrolytically depositing copper.

In an embodiment of the invention, the copper block is formed by electrolytically depositing copper on the surface of the channel system.

In an embodiment of the invention, a billet mainly formed of a refractory material and comprising a channel system for circulation of a cooling agent is prepared;

a copper block is formed by electrolytically depositing copper on the surface of the billet; and

the billet and the copper block electrolytically deposited on the surface of the billet are machined so that the cooling element obtains its final shape.

In an embodiment of the invention, the channel system for circulation of a cooling agent is mainly formed of a refractory material.

The cooling agent is typically water.

In an embodiment of the invention, the copper block is in contact with the channel system.

5 In an embodiment of the invention, the refractory material is copper.

In an embodiment of the invention, the channel system is mainly formed of a copper pipe.

In an embodiment of the invention, the refractory material is a ceramic material.

10 In an embodiment of the invention, the billet is prepared by attaching an element mainly formed of copper to a channel system mainly formed of a copper pipe.

15 The shape of the element may be selected depending on its intended use. The element may be e.g. a plate.

In an embodiment of the invention, the billet comprises an element mainly formed of a refractory material;

20 the element mainly formed of a refractory material is coated with a metallic thin film; and

a copper block is formed by electrolytically depositing copper on the surface of the element mainly formed of a refractory material.

25 In an embodiment of the invention, the billet comprises an element mainly formed of a ceramic material;

the element mainly formed of a ceramic material is coated with a metallic thin film; and

30 a copper block is formed by electrolytically depositing copper on the surface of the element mainly formed of a ceramic material.

35 These embodiments have the added utility that the element mainly formed of a refractory material, such as a ceramic material, may be arranged so as to protect the copper block and the channel system. Yet a close contact between the copper block and the element

mainly formed of a refractory material is achieved, thus allowing the cooling effect to reach the element mainly formed of a refractory material. Cooling elements according to this embodiment may be used e.g. in demanding applications such as the cooling of the tap-hole of a furnace.

The channel system may be arranged either in the element mainly formed of a refractory material, or it may be arranged inside the copper block. In these embodiments, the channel system may be arranged so that the copper block is electrolytically deposited on the surface of the element mainly formed of a refractory material and on the surface of the channels system simultaneously. The channel system may e.g. be mounted on the element using suitable means or fastenings.

The metallic thin film may comprise any pure metal, e.g. copper or nickel.

In an embodiment of the invention, the refractory material is coated with a metallic thin film using vapour deposition. Methods of vapour deposition, such as sputtering, are well known in the art.

In this context, the body made of copper, e.g. a copper block, should be understood as being a body of substantial thickness or a massive body. Thus the body made of copper should not be understood as being a coating or a thin layer.

In an embodiment of the invention, the thickness of the copper block is at least 20 mm.

In an embodiment of the invention, copper is electrolytically deposited on the surface of the core or billet as a layer having a thickness of at least 20 mm.

The invention provides a number of benefits.

The manufacturing costs are relatively low and the method has improved sustainability, because the copper may be deposited electrolytically directly

from a copper sulphate solution without the need for separate melting and casting steps. A significant amount of energy and subsequently a significant amount of costs can be saved.

5 While the electrolytic deposition typically requires a time period of at least a week, the combined time required for manufacturing the copper according to one or more embodiments of the invention still remains reasonable, because the amount of further processing, e.g. machining, required after the
10 electrolytic deposition is relatively small. Furthermore, it should be noted that also conventional manufacturing methods require an electrolytic step for recovering copper prior to melting and casting.

15 As the copper is electrolytically deposited, a very good metallic bond is created between the copper atoms of the body made of copper. A very good metallic bond between the copper atoms of the body made of copper and a core or a billet may also be obtained.

20 In one or more embodiments of the cooling element according to the invention, a metallic bond is created between the copper block and other components of a cooling element, because the copper of the copper block is electrolytically deposited. Therefore an ideal
25 contact is formed between the copper block and the channel system, providing a very high heat transfer capacity between the channel system and the copper block.

 No time is required for casting portions of
30 the copper product, such as a cooling element. No time is required for drilling holes in the cooling element. Furthermore, it should be noted that also conventional manufacturing methods require an electrolytic step for recovering copper prior to melting and casting. The
35 manufacturing process is flexible, because there is no need to wait for the casting of a billet; the manufac-

ture of a billet may commence as soon as it has been designed.

Unlike in cooling elements in which a channel system is formed e.g. by drilling, there are no unused
5 external holes which would require plugging and which could be prone to leaking. The cooling element does not require further waterproofing.

The method according to the present invention also allows for manufacturing geometrically complex
10 copper products, e.g. curved cooling elements, and cooling elements comprising geometrically complex channel systems, because copper may be deposited on a surface having virtually any shape. Several channel systems may be included in a single cooling element,
15 which allows fine-tuning, boosting or phasing of the cooling.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included
20 to provide a further understanding of the invention and constitute a part of this specification, illustrate embodiments of the invention and together with the description help to explain the principles of the invention. In the drawings:

25 **Figure 1** shows the steps of manufacturing a cooling element,

Figure 2 shows different views of a billet for manufacturing the cooling element,

Figure 3 demonstrates electrolytic deposition
30 of copper to form a copper block, and

Figure 4 illustrates an embodiment of the cooling element.

DETAILED DESCRIPTION

Reference will now be made in detail to the embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

For reasons of simplicity, item numbers will
5 be maintained in the following exemplary embodiments in the case of repeating components.

Figure 1 illustrates by way of example the steps of manufacturing a cooling element according to an embodiment the invention. A channel system 1 for
10 circulation of a cooling agent is attached to an element 2 to form a billet 3 shown in Fig. 1A. Inlet apertures 4 are provided for circulating the cooling agent in and out of the channel system. In this exemplary embodiment, the channel system 1 is mainly
15 formed of copper pipes. The copper pipe may be any thick-walled copper pipe that has measures suited for the purpose. The element 2 is a plate formed of copper. The channel system 1 and the element are arranged in a planar arrangement so that the element 2 covers
20 the area between the copper pipes. A copper block 5 is subsequently formed by depositing copper on the surface of the billet 3 comprising the channel system 1 and the element 2 as demonstrated in Fig. 1B. The deposited copper assumes the shape of the billet 3. The
25 copper block 5 and the billet 3 may be machined further. Fig. 1C shows the cooling element having its final shape after machining of the copper block 5 and the element 2 inside the copper block 5.

Figure 2A shows a side view and Figure 2B an
30 end view of the billet 3 comprising the channel system 1 comprising inlet apertures 4 and the element 2. Again, the channel system 1 is mainly formed of a copper pipe, and the element 2 is a plate formed of copper. Forming the channel system in advance and covering
35 the area between the copper pipes forming the channel system 1 with the element 2 provides a compact

structure on the surface of which to form the copper block 5 by electrolytic deposition.

Figure 3 demonstrates electrolytic deposition of copper on the surface of the billet 3 to form a copper block. In this embodiment, the electrolytic deposition is performed using a typical electrowinning process. The billet 3 is placed in an electrolyte bath 6 containing a solution comprising e.g. copper sulphate and sulphuric acid together with one or more lead anodes 7; the billet 3 functions as the cathode. Several billets 3 may be placed in the electrolyte bath 6 simultaneously so as to allow industrial production of the cooling elements.

Figure 4 illustrates a cross-section of one embodiment of the cooling element. In this embodiment, the cooling element surrounds a taphole 8 used in a reactor for tapping molten metal. An element 2 mainly formed of ceramic material has been coated with a metallic thin film 9, and a copper block 5 has been electrolytically deposited on the surface of the metallic thin film 9 and of the channel system 1.

It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be implemented in various ways. The invention and its embodiments are thus not limited to the examples described above, instead they may vary within the scope of the claims.

CLAIMS

1. A method for manufacturing a copper product, wherein the copper product comprises a body made of copper (5); characterized in that the body
5 is formed by electrolytically depositing copper.

2. The method according to claim 1, characterized in that the copper product is a cooling element, a busbar, a billet for a forged product, a valve housing, a valve stem, a semi-finished product
10 or alike.

3. The method according to claim 1 or 2, characterized in that the copper product is machined, worked or forged after forming the body made of copper.

4. The method according to any one of claims
15 1 - 3, characterized in that

a billet (3) for the body made of copper (5) is prepared;

the body (5) is formed by electrolytically
20 depositing copper on the surface of the billet (3);
and

the body made of copper (5) electrolytically deposited on the surface of the billet (3) is machined or forged so that the copper product obtains its final
25 shape.

5. The method according to any one of claims 1 - 4, characterized in that the body made of copper is a block, a bar, a rail, a disc or a wheel.

6. The method according to any one of claims
30 1 - 5 for manufacturing a cooling element for use in connection with a metallurgical furnace, wherein a channel system (1) for circulation of a cooling agent is arranged in the cooling element, and wherein the cooling element comprises a copper block (5); wherein
35 the copper block (5) is formed by electrolytically depositing copper.

7. The method according to claim 6, characterized in that

a billet (3) mainly formed of a refractory material and comprising a channel system (1) for circulation of a cooling agent is prepared;

a copper block (5) is formed by electrolytically depositing copper on the surface of the billet (3); and

the billet (3) and the copper block (5) electrolytically deposited on the surface of the billet (3) are machined so that the cooling element obtains its final shape.

8. The method according to claim 7, characterized in that the billet (3) comprises an element (2) mainly formed of a refractory material;

the element (2) mainly formed of a refractory material is coated with a metallic thin film (9); and

a copper block (5) is formed by electrolytically depositing copper on the surface of the element (2) mainly formed of a refractory material.

9. The method according to claim 8, characterized in that the refractory material is coated with a metallic thin film (9) using vapour deposition.

10. The method according to any one of claims 6 - 9, characterized in that the channel system (1) is mainly formed of a refractory material.

11. The method according to any one of claims 7 - 10, characterized in that the refractory material is copper or a ceramic material.

12. The method according to any one of claims 6 - 11, characterized in that the channel system (1) is mainly formed of a copper pipe.

13. The method according to any one of claims 7 - 12, characterized in that the billet (3) is prepared by attaching an element (2) mainly formed

of copper to a channel system (1) mainly formed of a copper pipe.

14. The method according to any one of claims 1 - 13, characterized in that the thickness of the body made of copper (5), such as a copper block, is at least 1 mm, or at least 2 mm, or at least 5 mm, or at least 10 mm, or at least 20 mm.

15. A copper product comprising a body made of copper (5), characterized in that the body (5) is formed by electrolytically depositing copper.

16. The copper product according to claim 15, characterized in that the copper product is a cooling element, a busbar, a billet for a forged product, a valve housing, a valve stem, a semi-finished product or alike.

17. The copper product according to claim 15 or 16, characterized in that the body made of copper is a block, a bar, a rail, a disc or a wheel.

18. The copper product according to any one of claims 15 - 17, characterized in that the copper product is a cooling element for use in connection with a metallurgical furnace, wherein a channel system (1) for circulation of a cooling agent is arranged in the cooling element, and wherein the cooling element comprises a copper block (5); and wherein the copper block (5) is formed by electrolytically depositing copper.

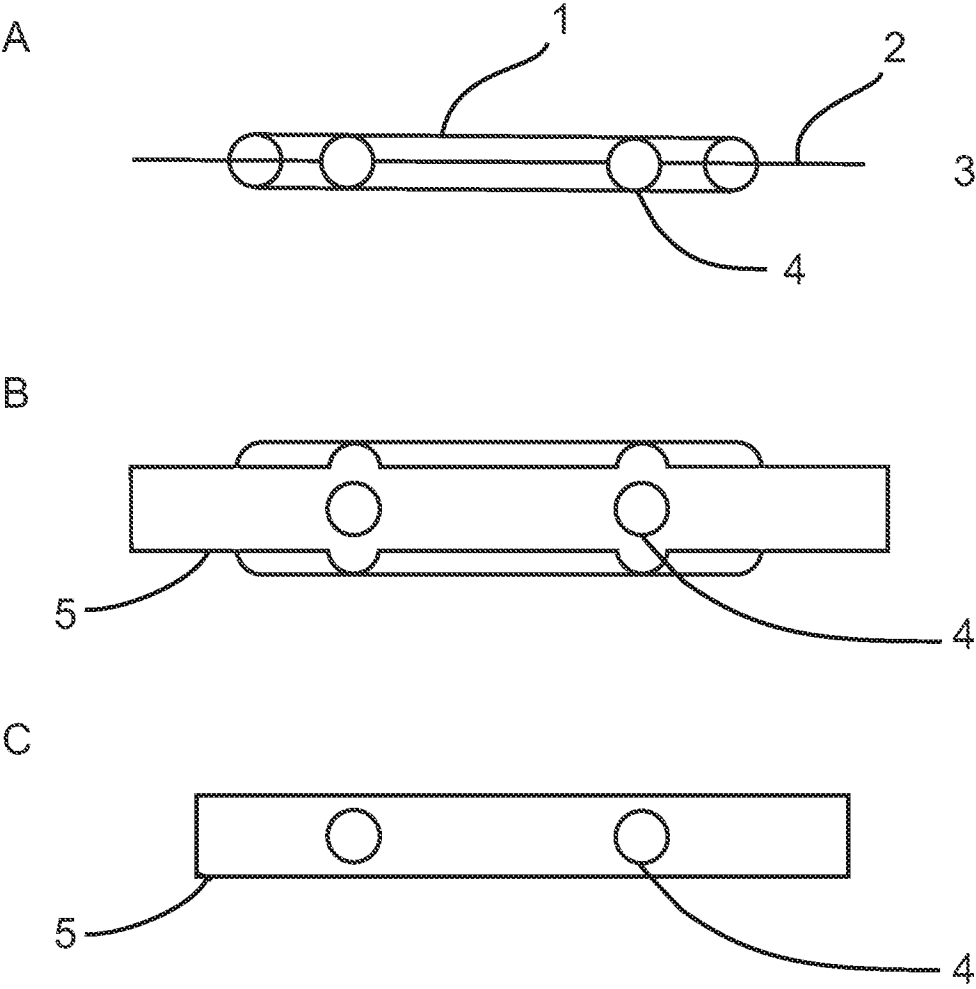


Figure 1

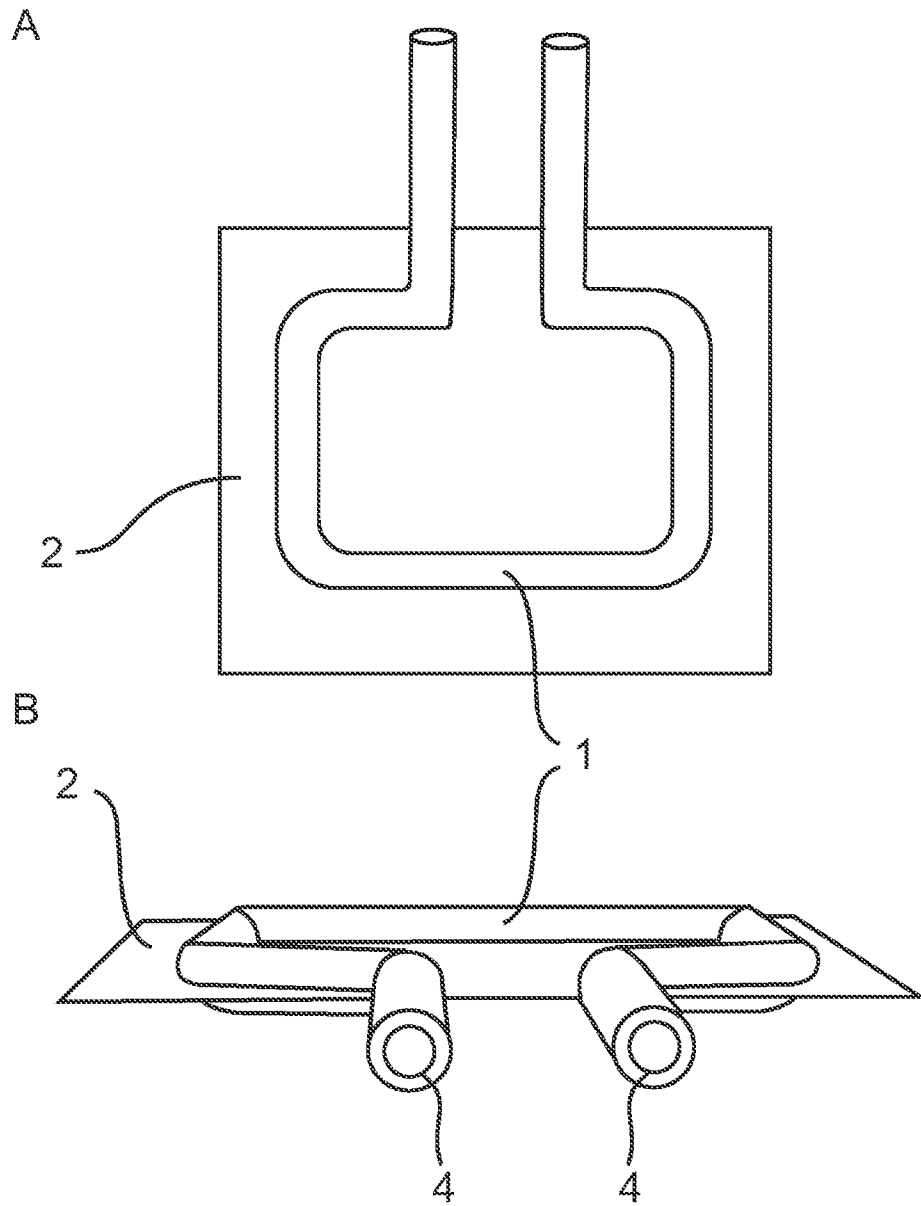


Figure 2

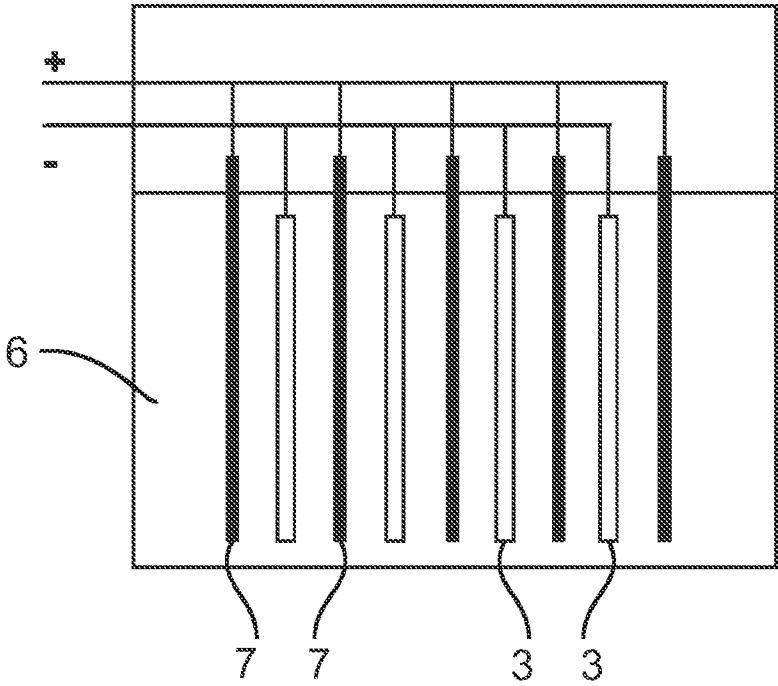


Figure 3

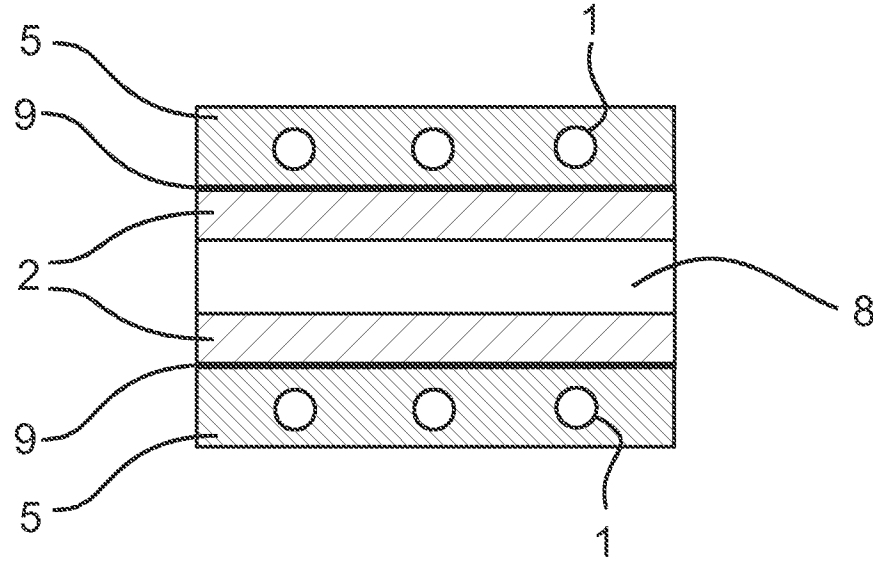


Figure 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2014/050494

A. CLASSIFICATION OF SUBJECT MATTER
INV. C25D5/48 C25D7/04
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C25D B23K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EP0-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	EP 1 892 322 A1 (NOMURA PLATING CO LTD [JP]; HIGH ENERGY ACCELERATOR RES [JP]) 27 February 2008 (2008-02-27) abstract paragraph [0001] paragraph [0026] paragraph [0046] paragraph [0050] example 1	1-5, 14-17
X	US 2012/240400 A1 (IOANNOU IOANNIS [GR]) 27 September 2012 (2012-09-27) abstract paragraph [0001] paragraph [0024] paragraphs [0028] - [0035] ----- -/--	1-5, 15-17



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search

14 October 2014

Date of mailing of the international search report

21/10/2014

Name and mailing address of the ISA/

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Picard, Sybille

INTERNATIONAL SEARCH REPORT

International application No
PCT/FI2014/050494

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/FI2014/050494

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