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(54) **METHOD FOR MANUFACTURING A COPPER-BASED COMPOSITE MATERIAL FOR ELECTRICAL CONTACTS**

(57) The invention relates to methods for manufacturing a copper-based composite material for manufacturing electrical contacts that can be used in high-voltage electric apparatuses, for example as contacts in an arc-suppression vacuum chamber. Once two compression-molded briquettes have been produced from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between said briquettes and heating is carried out up to a temperature of 700-900°C in a vacuum at  $10^{-3}$ - $10^{-5}$  Torr, which is maintained for 30-60 minutes, followed by agglomeration in a hydrogen atmosphere or inert gas atmosphere at a temperature of 1085-1150°C until a copper layer of a thickness of 2.5-5.0 mm is formed above the briquette compression-molded from a mixture of copper and chromium powder. The resultant blank is cooled to a temperature of 900-920°C at a rate equal to or exceeding 20°C/min, and annealing is carried out at a temperature of 500-700°C for 30-120 minutes. The proposed method makes it possible to produce a composite material containing a copper layer of the necessary thickness with a finely dispersed structure without internal tensions and to simultaneously combine three separate technological operations involved in the process of agglomerating the composite material in one batch in the vacuum chamber, thereby reducing the production cost of the material.

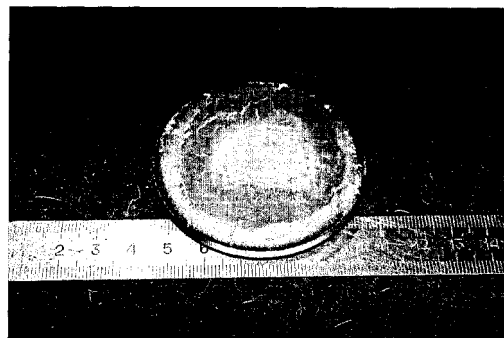


Fig. 1

## Description

**[0001]** The invention relates to powder metallurgy, in particular to methods of manufacturing sintered materials based on copper for electrical contacts used in low voltage and high voltage electrical devices switching circuits, preferably AC circuits with current up to 630 A. In details, the invention relates to method for manufacturing a copper-based composite material for electrical contacts.

**[0002]** In terms of technical essence, the closest analog is a method of manufacturing a copper-based composite material for electrical contacts, comprising preparation of a powder mixture of at least two powder components - conductive and heat resistant components, pressing powder mixture and obtaining a blank, which is sintered to obtain a copper-based composite material for electrical contacts [RF Patent N2 2063086, IPC 6 NH01H33/66, Publ. 1996.06.27].

**[0003]** The disadvantage of the described method is the long duration of the process and, consequently, the high cost of the resulting material for electrical contacts. The long duration of the process is due to the need to perform multiple loadings and unloadings of a vacuum chamber to carry out separate manufacturing operations. In addition, the quality of the produced material is insufficient, in particular, for making contacts of vacuum circuit breakers switching AC circuits with currents even below 400 A due to the impossibility to achieve the required degree of impregnation of the powder mixture of conductive and heat-resistant materials with copper.

**[0004]** The goal of the proposed invention is to provide such method of manufacturing a copper-based composite material for electrical contacts, which would reduce the cost of manufacturing a copper-based composite material for electrical contacts by way of reducing the number of loadings and unloadings of a vacuum chamber to perform three separate technological operations with one vacuum chamber loading, i.e. heating blanks in inert gas or hydrogen atmosphere to a temperature of alloying of interphase border of chromium-copper powder components by a surface-active agent, impregnation of a blank made of copper and chromium powder mixture with alloying components to produce copper layer over blank made of copper and chromium powder mixture, cooling the obtained blank and annealing the blank.

**[0005]** This goal is achieved by the proposed method, which, like the known method of manufacturing a copper-based composite material for electrical contacts, comprises preparation of a powder mixture of at least two powder components - conductive and heat resistant components, pressing powder mixture and obtaining a workpiece, which is sintered to obtain a copper-based composite material for electrical contacts, and, *according to the invention*, copper and chromium powders are preliminarily mixed in a high-power mill to obtain a fine homogenized copper and chromium powder mixture, the obtained powders are pressed to produce two compression-molded briquettes: one of copper and chromium

powder mixture and another from copper powder, a source of alloying components is arranged between said compression-molded briquettes, the mixture is heated up to a temperature of 700-900°C in a vacuum chamber under vacuum of  $10^{-3}$  -  $10^{-5}$  Torr and is kept under these conditions 30-60 minutes to remove unwanted impurities and/or admixtures, which is followed by alloying of interphase border of chromium-copper powder components by surface-active agent in inert gas atmosphere or in hydrogen obtained from metal hydride at a temperature of 1085-1150°C with simultaneous impregnation of compression-molded briquettes of copper and chromium powders with alloying components until a copper layer of a thickness of 2.5-5.0 mm is formed above the compression-molded briquette from a mixture of copper and chromium powder, the obtained blank is cooled from impregnation temperature of 1085-1150°C to a temperature of 900-920°C at a rate equal to or exceeding 20°C/min, the cooled blank is annealed at a temperature of 500-700°C for 30-120 minutes, and a blank of copper-based composite material for producing electrical contacts is obtained.

**[0006]** Another feature of the proposed method is that after obtaining two compression-molded briquettes - from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between these briquettes, such source having a form of a grid.

**[0007]** Another feature of the proposed method is that after obtaining two compression-molded briquettes - from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between these briquettes, such source having a form of a film or foil.

**[0008]** Another feature of the proposed method is that after obtaining two compression-molded briquettes - from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between these briquettes, such source having a form of a coating applied onto the surface of one of the compression-molded briquettes.

**[0009]** Another feature of the proposed method is that after obtaining two compression-molded briquettes - from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between these briquettes, such source having a form of a vacuum coating deposited onto the surface of one of the compression-molded briquettes through mask.

**[0010]** Another feature of the proposed method is that alloying of interphase border of chromium-copper powder components is carried out using surface-active agent of the following composition (in wt.%):

carbon-0.10-0.12  
silicon - 0.06 - 0.08  
manganese - 1.80 - 2.00  
chromium -17.0 -18.0

nickel - 8.90 - 9.00  
titanium - 0.70 - 0.80  
iron - the rest.

**[0011]** Preliminary processing and blending of copper and chromium powders in high-power mill is aimed at the destruction and deformation of the original powder particles, resulting in formation of active surfaces which are capable of "cold welding" and formation of fine homogenized copper and chromium (Cu-Cr) powder mixture. Such mixture does not segregate by density during unloading from the drum, transportation and loading into the mold matrix. During the processing the mixture is activated, which intensifies the subsequent processes of impregnation and liquid-phase sintering.

**[0012]** The authors have experimentally found the optimal operating conditions of heat treatment of copper and chromium powder mixture in a vacuum chamber. These parameters are: the temperature of 700-900°C, vacuum of  $10^{-3}$  -  $10^{-5}$  Torr and maintaining under these conditions for 30 - 60 minutes to remove unwanted impurities and/or admixtures. It was found out that under temperatures below 700°C and keeping in a vacuum chamber during less than 30 minutes copper and chromium powder mixture still contains volatile oxides, which have a negative impact on the quality of the obtained product. Heating of the mixture above 900°C triggers evaporation of chromium (at the temperature of 907°C) and copper (at the temperature of 946°C). Vacuum below  $10^{-3}$  Torr is not effective, because there were cases of powders oxidation observed. Vacuum over  $10^{-5}$  Torr is not economically justified, because further vacuum increase does not significantly improve the quality of the resulting material. In case of keeping the powders under these conditions for less than 30 minutes, the cases of incomplete removal of unwanted impurities, in particular oxide films, were observed. Increase of dwelling time over 60 minutes is not economically justified, because it does not significantly improve the quality of the resulting material.

**[0013]** Placement of the source of alloying components between obtained compression-molded briquettes of copper powder and copper-chromium powder mixture enables, under further heating of the blanks in an inert gas atmosphere at a temperature of 1085-1150°C and dwelling time of 15-20 minutes, to perform the alloying of interphase border of chromium-copper powder components with surface-active substance with simultaneous impregnation of copper and chromium powder mixture briquette with alloying components to form 2.5 - 5.0 mm thick copper layer over the briquette of copper and chromium powder mixture. This process occurs due to improvement of chromium wetting with copper, which results in more intense impregnation, reducing the number and size of closed pores in the contact material, improvement of thermal-physical properties and reducing the process time. The optimum temperature in a vacuum chamber 1085-1150°C is determined experimentally by

the authors. The lower limit of temperature in the vacuum chamber 1085°C corresponds to copper melting point, so it can not be lowered. Increasing the temperature above 1150°C leads to copper evaporation, which reduces the effectiveness of briquette impregnation. The copper layer thickness of 2.5 - 5.0 mm over the briquette of copper and chromium powder mixture is determined by the future operating conditions of the contact pair manufactured from the produced material, i.e. rated current, switching frequency, the nature of the load. The thickness of the copper layer is determined by the concentration of surface-active components, which are intended to improve the wettability of chromium powder by liquid copper and decrease the surface tension of molten copper, i.e. reducing the height of liquid copper meniscus over the surface of the briquette of chromium and copper powder mixture, as well as the copper quantity itself.

**[0014]** The subsequent cooling of the blank from impregnation temperature to the temperature of 900-920°C is performed at a rate equal to or greater than 20 degrees per minute in order to fix the fine structure of chromium-copper and copper and to reduce the likelihood of shrinkage cavities. The authors have experimentally determined that the blank cooling rate below 20 degrees per minute results in increasing grains in the structure of the future blank, which does not allow to obtain high-quality material.

**[0015]** The resulting blank is annealed under these optimal parameters: temperature of 500-700°C, 30 - 120 minutes. Because only with these parameters the blank maintains fine structure and tensions in the lattice are decreased. These optimal parameters were found experimentally by the authors. The heating to a temperature below 500°C and during less than 30 minutes adversely affects the quality of the finished product, since there were cases of incomplete relaxation of stresses in the blank. Heating at the temperature over 700°C during more than 120 minutes is not justified economically, because it practically has no effect on the quality of the finished product.

**[0016]** Source of alloying components can be made in the form of foil, grid or vacuum coating. Its design is determined by the technological possibilities of the material manufacturer. The authors believe, the most promising structure is a vacuum coating deposited on the flat surface of one of the blanks through a mask, because it provides the desired composition and necessary amount of alloying components. The simplest structure is a foil. In this case it is sufficient to obtain the melt of necessary composition or select a ready metallic material or alloy in the form of an ingot of the necessary composition and with required amount of alloying components, heat it and roll it between the rollers to obtain a foil of the desired thickness.

**[0017]** Surface-active agents are used in an amount of 1-3 wt.% of the total weight of the contact material to improve wettability and activation of the sintering and impregnation process.

**[0018]** The composition and quantity of the alloying components for alloying the interphase border of chromium-copper powder components are selected experimentally based on conditions to improve the wetting of interphase border by copper melt and to reduce the surface tension of molten copper in the mixture of chromium-copper powders. Such substances for chrome-copper - copper melts may be substances based on silicon, manganese, nickel, and are selected experimentally based on the technological possibilities of the material manufacturer and the intended working conditions of the contact material.

**[0019]** As an example, the authors have used for alloying of interphase border of chromium-copper powder components a source of alloying components of the following composition (in wt.%):

carbon-0.10-0.12  
silicon - 0.06 - 0.08  
manganese - 1.80 - 2.00  
chromium - 17.0 - 18.0  
nickel - 8.90 - 9.00  
titanium - 0.70 - 0.80  
iron - the rest.

**[0020]** Fig. 1 illustrates a blank of electric contact Cu-Cr material with a copper sublayer, obtained by the proposed method.

**[0021]** Example. The copper-based composite material for electrical contacts was produced. The following materials were used: electrolytic copper powder according to GOST 4960-75, PMS-1 grade with a copper content of 99.72%, and chromium powder of PH-1M grade, a certificate # 22-03 of 02.10.2008.

**[0022]** The operations of mixing and grinding of copper and chromium powders was carried out in a high power mill. A planetary mill, attritor, ball mill etc. may be used as a device for mixing and grinding powders. Blend modes (operating tools rotation speed, mixing time, balls mass to material mass ratio, etc.) were selected experimentally. The balls impact on the components of the treated powder material exceeds the ultimate compressive strength and shear of plastic copper and solid chromium. The amount of copper (Cu) powder introduced into chromium (Cr) during the mixture preparation was 10-40 wt.%, depending on the Cr content in the composition of the contact material, with increasing of Cr content in the Cu-Cr composition from 45 to 70 wt.%, the amount of copper in Cu-Cr mixture was decreased from 40 to 10 wt.%, respectively. The processing and blending of copper and chromium powders in high-power mill resulted in destruction and deformation of the original powder particles, which led to formation of active surfaces which were capable of "cold welding" of microgranules that caused formation of fine homogenized copper and chromium (Cu-Cr) powder mixture. Such mixture did not segregate by density during unloading from the drum, transportation and loading into the mold matrix. During the

processing the mixture was activated, which intensified the subsequent processes of impregnation and liquid-phase sintering.

**[0023]** To obtain the briquettes of required shape and size, the Cu-Cr powder mixture was subjected to pressing in molds. Cu concentration in Cu-Cr mixture and the residual porosity of the compressed briquette are the main parameters determining the amount of Cr in the manufactured composite material after the obtaining a blank impregnated with copper melt. The minimum Cr amount in Cu-Cr composite material manufactured according to the principle of forming rigid Cr structure impregnated with Cu is about 45 wt.% according to specific weights of Cr - 7.15 g/cm<sup>3</sup> and Cu - 8.93 g/cm<sup>3</sup>.

**[0024]** The maximum amount of Cr in the composite material is determined by the possibility to form a raw briquette with a minimum amount of Cu in Cu-Cr mixture and minimum porosity of compression-molded briquette without cracking and is about 70 wt.%. Cu-Cr blanks were pressed using the pressure from 2 to 8 tons per square cm. Increasing of the compression pressure over 8 tons per square cm results in delamination of the compression-molded blanks. With increasing Cr concentration in the composite material the compression pressure was increased. In order to impregnate the blanks, the briquettes of copper powder (chips) were pressed together with alloying components source. For uniform distribution of surface-active elements at the Cr-Cu interphase border and facilitation of compression, the source of alloying components is made in the form of foil, grids of different shape, discrete vacuum coating. Such coating may be applied by known methods, for example, using a process described in the article:

Износостойкость керамических  
режущих инструментов на  
основе нитрида кремния  
сплошными и дискретными  
нитридотитановыми покрытиями.

Гнесин Г.Г., Ляшенко Б.А., Фоменко  
С.Н. и др. Порошковая металлургия  
-1997. - No11/12. - P.93-96. (The wear resistance of silicon nitride based ceramic cutting tools with continuous and discrete nitride titanium coatings. Gnesin, G.G., Lyashenko, B.A., Fomenko, S.N. et al. - Powder Metallurgy). A grid or foil of alloying components is placed into the lower mold die and covered with necessary amount of copper powder or chips, and then press the composite blank using the pressure of 1.5-3.0 tons per square cm.  
**[0025]** For uniform distribution of surface-active elements at the Cr-Cu interphase border and facilitation of compression, the source of alloying components is made

in the form of foil, grids of different shape, vacuum coating.

#### Heat vacuum treatment:

[0026] Connected porous briquette of Cu-Cr powders mixture, Cu powder briquette and a source of alloying components located between the briquettes were subjected to heat vacuum treatment together. Briquettes were placed into container made of a material which does not react with molten Cu and Cr. The copper briquette was placed onto upper surface of the briquette in such a way that grid with surface-active substance was in contact with the surface of Cu-Cr blank. Container was placed into vacuum over chamber. Heat vacuum treatment was performed in a vacuum chamber in vacuum of  $10^{-5}$  Torr, at  $800^{\circ}\text{C}$  for 60 min to remove adsorbed gases, volatile components from the blanks, to destroy and remove oxide films. After heating and keeping for 60 minutes inert gas or hydrogen produced from the metal hydride was supplied into vacuum chamber through the inlet valve to produce a pressure of 200 Torr and the temperature was raised to  $1150^{\circ}\text{C}$  at a rate of 10-15 degrees per minute.

#### Impregnation.

[0027] Copper melting and alloying of chromium-copper (Cr-Cu) interphase border with surface-active components, liquid-phase sintering of briquettes and their impregnation with copper occurs in the temperature range of  $1085-1150^{\circ}\text{C}$  in inert gas or hydrogen atmosphere. The blank was kept during 10-20 minutes in this temperature interval. Optimum dwelling time was selected experimentally depending on the blank mass, heat capacity and pressure of the gas atmosphere.

[0028] The amount of copper necessary for impregnation of the blank (structure) was calculated on the basis of its residual porosity and the amount of copper required for the formation of a 2.5 - 5 mm thick layer intended to divert heat flow from the working surface of the contact assembly and welding or soldering of the contact to arc-suppression vacuum chamber terminals.

[0029] In the example, the source of alloying components is in the form of a grid having the following composition (in wt.%): C-0.12; Si-0.08; Mn-2.0; Cr-18.0; Ni-9.0; Ti-0.8; Fe - up to total of 100.0. The mass of the source of the alloying components is in the range from 1.0 to 3.0 wt.% of the total mass of the contact material. A source of alloying components is used in order to improve the wettability and facilitate the processes of sintering and impregnation.

#### Cooling.

[0030] In order to obtain the blanks with fine structure, impregnated Cu-Cr blanks were cooled from the impregnation temperature to the crystallization temperature at

a rate of 20-28 degrees/min.

[0031] To relieve internal stresses, the structure was annealed in inert medium at  $650-670^{\circ}\text{C}$  for 120 minutes.

[0032] Thus, the proposed invention has enabled to achieve the goal: to provide such method of manufacturing a copper-based composite material for electrical contacts, with the cost of manufacturing of such electrical contacts lower than the cost of manufacturing contacts made of material obtained according to prototype process due to creation of conditions allowing to reduce the number of loadings and unloadings of a vacuum chamber to perform three separate technological operations with one vacuum chamber loading, i.e. heating blanks in inert gas or hydrogen atmosphere to a temperature of alloying of interphase border of chromium-copper powder components by a surface-active agent, impregnation of a blank made of copper and chromium powder mixture with alloying components to produce copper layer over blank made of copper and chromium powder mixture, cooling the obtained blank and annealing the blank.

[0033] The resulting composite material for contacts was tested in contactors operating in power circuits of the rolling stock of Ukrainian railways. The service life of contacts made of the proposed composite contact material was 50-60% longer than the service life of conventional contacts.

#### Claims

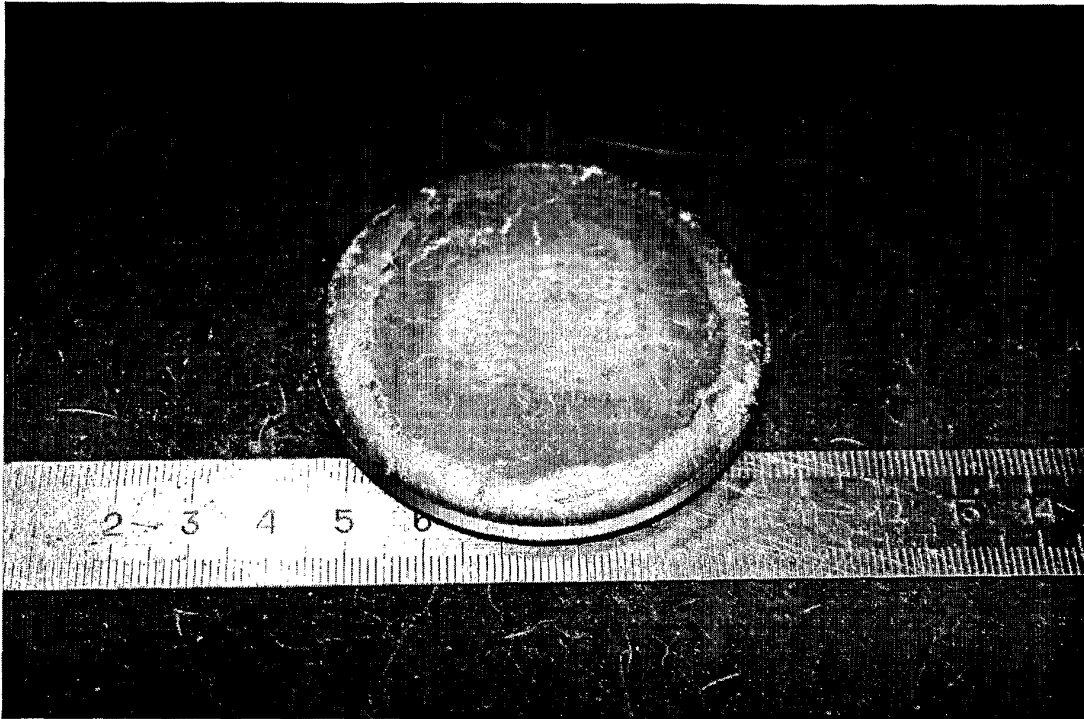
1. A method of manufacturing a copper-based composite material for electrical contacts comprising preparation of a powder mixture of at least two powder components - conductive and heat resistant components, pressing powder mixture and obtaining a blank, which is sintered to obtain a copper-based composite material for electrical contacts, **characterized in that** copper and chromium powders are preliminarily mixed in a high-power mill to obtain a fine homogenized copper and chromium powder mixture, the obtained powders are pressed to produce two compression-molded briquettes: one of copper and chromium powder mixture and another from copper powder, a source of alloying components is arranged between said compression-molded briquettes, the mixture is heated up to a temperature of  $700-900^{\circ}\text{C}$  in a vacuum chamber under vacuum of  $10^{-3} - 10^{-5}$  Torr and is kept under these conditions for 30-60 minutes to remove unwanted impurities and/or admixtures, which is followed by alloying of interphase border of chromium-copper powder components by surface-active agent in inert gas atmosphere or in hydrogen obtained from metal hydride at a temperature of  $1085-1150^{\circ}\text{C}$  with simultaneous impregnation of compression-molded briquettes of copper and chromium powders with alloying components until a copper layer of a thickness of 2.5-5.0 mm is formed above the compression-

molded briquette from a mixture of copper and chromium powder, the obtained blank is cooled from impregnation temperature of 1085-1150°C to a temperature of 900-920°C at a rate equal to or exceeding 20°C/min, the cooled blank is annealed at a temperature of 500-700°C for 30-120 minutes, and a blank of copper-based composite material for producing electrical contacts is obtained. 5

2. A method according to claim 1, **characterized in that** after obtaining two compression-molded briquettes - from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between these briquettes, such source having a form of a grid. 10 15
3. A method according to claim 1, **characterized in that** after obtaining two compression-molded briquettes - from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between these briquettes, such source having a form of a foil. 20
4. A method according to claim 1, **characterized in that** after obtaining two compression-molded briquettes - from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between these briquettes, such source having a form of a coating applied onto the surface of one of the compression-molded briquettes. 25 30
5. A method according to claim 1, **characterized in that** after obtaining two compression-molded briquettes - from a mixture of copper and chromium powders and from copper powder, a source of alloying components is arranged between these briquettes, such source having a form of a vacuum coating deposited onto the surface of one of the compression-molded briquettes through mask. 35 40
6. A method according to claim 1, **characterized in that** alloying of interphase border of chromium-copper powder components is carried out using surface-active agent of the following composition (in wt.%): 45

carbon-0.10-0.12  
 silicon - 0.06 - 0.08  
 manganese - 1.80 - 2.00  
 chromium - 17.0 - 18.0 50  
 nickel - 8.90 - 9.00  
 titanium - 0.70 - 0.80  
 iron - the rest.

55



**Fig. 1**

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/UA 2009/000042

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| A. CLASSIFICATION OF SUBJECT MATTER                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                                                                              |                                                    |
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| 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)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                              |                                                    |
| H01H 33/66, 33/664, B22F 3/26, H01H 1/02, B22F 3/26, 3/14, 7/00, H01H 1/02                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                              |                                                    |
| 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)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                              |                                                    |
| C. DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                              |                                                    |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Citation of document, with indication, where appropriate, of the relevant passages                                           | Relevant to claim No.                              |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | RU 2063086 C1 (TOVARISCHESTVO S OGRANICHENNOI OTVETSTVENNOSTIJU "KANPAK") 27.06.1996, the abstract, cited in the description | 1-6                                                |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | JP 63096204 A (TOSHIBA CORP) 27.04.1988, the abstract, figure                                                                | 1-6                                                |
| A                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | WO 1990/015424 A1 (SIEMENS AKTIENGESELLSCHAFT) 13.12.1990, claims 10-12                                                      | 1-6                                                |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                              |                                                    |
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| Date of the actual completion of the international search                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                              | Date of mailing of the international search report |
| 22 April 2010                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                              | 29 April 2010                                      |
| Name and mailing address of the ISA/<br><br>RU                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                              | Authorized officer                                 |
| Facsimile No.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                                                                              | Telephone No.                                      |

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**Patent documents cited in the description**

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