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(54) **Method of manufacturing composite material**

(57) A method of manufacturing metal matrix composite with ceramic particles as a disperse phase includes the steps of holding the single metal matrix com-

posite or the plurality of layered metal matrix composites between a pair of pressing dies, pressing the metal matrix composite by the pressing dies, and heating the metal matrix composite.

FIG. 1A

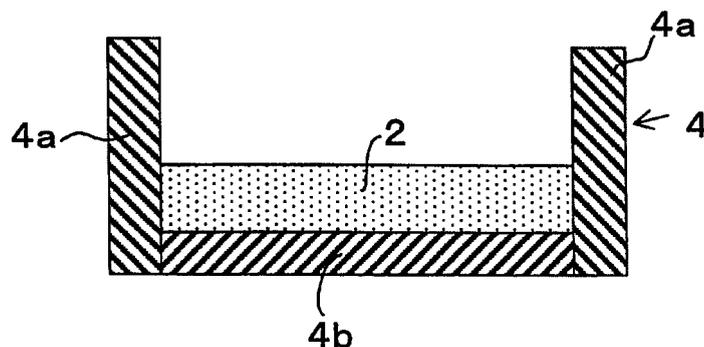


FIG. 1B

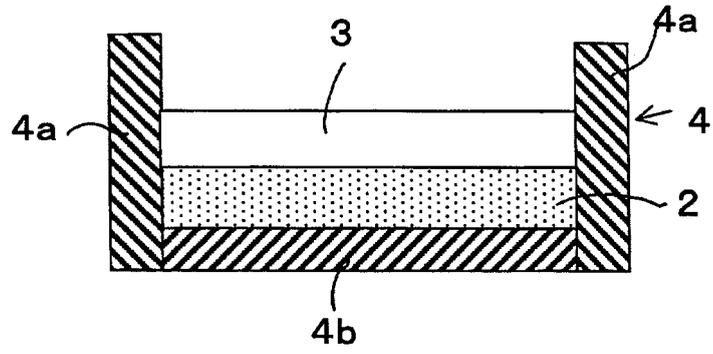


FIG. 1C



Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a method of manufacturing composite material and more particularly to a method of manufacturing metal matrix composite with ceramic particles as a disperse phase.

[0002] Metal matrix composites with ceramic particles as a disperse phase can be manufactured by squeeze casting. Squeeze casting is heating a matrix metal up to its melting point or above and injecting the pressurized molten metal into the cavity of a die with a disperse phase preplaced therein.

[0003] Unexamined Japanese patent application publication No. 2002-226925 has disclosed a method of manufacturing metal matrix composite with ceramic particles as a disperse phase, in which the composite has two different coefficients of expansion in the width direction. In the above manufacturing method, pressurized molten metal is injected into a die.

[0004] Unexamined Japanese patent application publication No. 2002-322531 has disclosed an aluminum matrix composite with ceramic particles as a disperse phase and a manufacturing method thereof. In the above manufacturing method, molten aluminum or aluminum alloy of 690 to 700 °C is injected into the cavity of a die to fill any gaps among ceramic particles preplaced therein with vacuum suction.

[0005] These squeeze castings are to inject pressurized molten metal or to inject with vacuum suction into any gaps among ceramic particles preplaced in the forming die, so that some composite materials have a distortion due to bias of ceramic particles and/or matrix metal, die deformation, desired shape of compact, conditions of temperature, or the like.

[0006] To reduce distortion, various casting methods have been studied so far, however, there has been no practical casting method to completely eliminate such distortion. This distortion, for example, causes some composite materials manufactured in a single casting to be defective, with a consequence of low yield of raw material. In addition, composite materials incorporating a large amount of ceramics are very brittle, so that distortions are not plastically deformed easily. For the above reasons, it has been a difficult task to correct the distortion of composite materials.

[0007] The present invention is directed to providing a method of manufacturing metal matrix composite with ceramic particles as a disperse phase, including a method of easily correcting the distortion of the composite with no cracks produced therein.

SUMMARY OF THE INVENTION

[0008] In accordance with the present invention, a method of manufacturing metal matrix composite with ceramic particles as a disperse phase includes the steps

of holding the single metal matrix composite or the plurality of layered metal matrix composites between a pair of pressing dies, pressing the metal matrix composite by the pressing dies, and heating the metal matrix composite.

[0009] Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

FIG. 1A is a schematic sectional view illustrating a manufacturing process, in which ceramic particles are placed in a forming die according to a first preferred embodiment of the present invention;

FIG. 1B is a schematic sectional view illustrating a manufacturing process, in which molten metal is injected into the forming die according to the first preferred embodiment of the present invention;

FIG. 1C is a schematic sectional view of a composite material according to the first preferred embodiment of the present invention;

FIG. 2A is a schematic view illustrating a distortion correction process, in which a composite material is held between a pair of pressing dies according to the first preferred embodiment of the present invention;

FIG. 2B is a schematic view illustrating a distortion correction process, in which the composite material is pressed by the pressing dies according to the first preferred embodiment of the present invention;

FIG. 2C is a schematic view illustrating a distortion correction process, in which the pressing dies are fastened by die clampers according to the first preferred embodiment of the present invention;

FIG. 3A is a schematic view illustrating a distortion correction process, in which a plurality of composite materials are held between a set of pressing dies and intervening dies each having the same shape as the pressing die as seen in the pressing direction according to a second preferred embodiment of the present invention;

FIG. 3B is a schematic view illustrating a distortion correction process, in which a plurality of composite materials are held between a set of pressing dies and intervening dies each having a larger shape than the pressing die as seen in the pressing direction according to a third preferred embodiment of the present invention; and

FIG. 3C is a schematic view illustrating a distortion correction process, in which a plurality of composite materials are held between a set of pressing dies and intervening dies each having a larger shape than the pressing die as seen in the pressing direction and each having fins for heat sink and radiation, provided at the ends according to a fourth preferred embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0011] The following will describe a method of manufacturing composite material according to the first through fourth preferred embodiments of the present invention with reference to FIGS. 1A through 3C.

[0012] The manufacturing method according to the present invention is directed to manufacturing metal matrix composite with ceramic particles as a disperse phase, including a distortion correction process. Furthermore, the manufacturing method according to the present invention is directed to manufacturing metal matrix composite with ceramic particles as a disperse phase, including a manufacturing process and a distortion correction process.

[0013] Matrix metal is not limited if the metal is usable for molten metal casting in forming composite material. The matrix metal may be pure aluminum, aluminum alloy including Mg, Cu, Zn, Si, Mn, or the like, pure copper, copper alloy including Ni, Sn, Zn, Al, Pb, P, or the like, pure magnesium, and magnesium alloy including Al, Zn, Mn, Zr, or the like. Especially, in terms of thermal conductivity, aluminum, aluminum alloy, copper and copper alloy are preferable.

[0014] Ceramic particles as a disperse phase are not limited if the ceramic has a low thermal expansion. The ceramic of composite material may be a single substance or a mixture of various kinds of ceramics depending on application. The ceramic may be, for example, silicon carbide, aluminum nitride, boron nitride, carbon and zirconia, either alone or in mixture. In terms of thermal conductivity, silicon carbide is preferable. The grain size of ceramic particle is determined on properties required for composite material. For example, a mixture of coarse particles and fine particles may be used for tight filling. For example, coarse particles having approximately 100 μm in diameter and fine particles having approximately 10 μm in diameter may be used.

[0015] The manufacturing process includes placing ceramic particles in the forming die, injecting pressurized

molten matrix metal into the forming die and solidifying the matrix metal, thus manufacturing a plate-like composite material. The term "plate-like" not only includes the shape of a plate but also other plate-like shapes that allow lamination thereof, such as tray-like shape.

[0016] FIGS. 1A through 1C illustrate the above manufacturing process. FIG. 1A is a schematic sectional view illustrating a manufacturing process, in which ceramic particles are placed in a forming die. FIG. 1B is a schematic sectional view illustrating a manufacturing process, in which molten metal is injected into the forming die. FIG. 1C is a schematic sectional view of a composite material.

[0017] The following will describe the manufacturing process in detail with reference to FIGS. 1A through 1C.

[0018] A die 4 which serves as a forming die is open top box-shaped, having a plurality of disassemblable die components 4a, 4b fastened by bolts and nuts (not shown). The die 4 is made of a material having a higher melting point than a matrix metal. For example, the die 4 may be made of iron.

[0019] In the manufacturing process using the die 4, first, ceramic particles 2 as a disperse phase are placed in the die 4, as shown in FIG. 1A. Subsequently, pressurized molten matrix metal 3 is injected into the die 4, as shown in FIG. 1B. The molten matrix metal 3 is injected into the die 4 until it substantially fulfills any gap among the ceramic particles 2 and forms the layer of molten matrix metal with a specified amount to cover the ceramic particles 2 on the opening end of the die 4. Next, a head pressure approximately equivalent to a pressure for die-casting (for example, several dozen MPa to hundred MPa) is applied. The injected molten metal 3 penetrates into any gap among the ceramic particles 2 preplaced in the die 4. Then, the die 4 is cooled to solidify the molten metal 3. After the cooling, the die 4 is disassembled and the composite material is taken out.

[0020] In FIGS. 1A through 1C, the shape of composite material is plate-like, but it is not limited. Usage of a die having a cavity of desired shape helps form a composite material in the desired shape.

[0021] Molten metal may be premixed with other ceramic particles. Other ceramic particles may be the same as the ceramic particles preplaced in the die 4 or may be different therefrom. Premixed ceramic particles in a molten metal help change the volume fraction of disperse phase in the thickness direction of composite material.

[0022] The distortion correction process includes holding a single composite material or a plurality of layered composite materials between a pair of pressing dies and heating the composite materials under pressure.

[0023] FIGS. 2A through 2C illustrate the above distortion correction process. FIG. 2A is a schematic view illustrating a distortion correction process, in which a composite material having a distortion is held in between a pair of pressing dies. FIG. 2B is a schematic view illustrating a distortion correction process, in which the composite material is pressed by the pressing dies. FIG. 2C

is a schematic view illustrating a distortion correction process, in which the pressing dies are fastened by die clampers.

[0024] FIGS 3A through 3C illustrate other distortion correction processes using intervening dies for a plurality of composite materials each having a distortion. FIG. 3A is a schematic view illustrating a distortion correction process, in which a plurality of composite materials are held between a set of pressing dies and intervening dies each having the same shape as the pressing die as seen in the pressing direction. FIG. 3B is a schematic view illustrating a distortion correction process, in which a plurality of composite materials are held between a set of pressing dies and intervening dies each having a larger shape than the pressing die as seen in the pressing direction. FIG. 3C is a schematic view illustrating a distortion correction process, in which a plurality of composite materials are held between a set of pressing dies and intervening dies each having a larger shape than the pressing die as seen in the pressing direction and each having fins for heat sink and radiation, provided at the ends.

[0025] The following will describe a first preferred embodiment of the distortion correction process according to the present invention with reference to FIGS. 2A through 2C.

[0026] Referring to FIG. 2A, the composite material 1 having a distortion is held between the pair of pressing dies 5. The pressing dies 5 are made of a material having a higher melting point than a matrix metal. For example, the pressing dies 5 may be made of iron. Subsequently, as shown in FIG. 2B, the pressing dies 5 are pressurized toward each other in the thickness direction of the composite material 1. A pressure of 1.5 to 65 MPa is applied on the pressing dies 5. Next, as shown in FIG. 2C, the pressing dies 5 are fastened together by die clampers 6 at their peripheral portions. Thus, the distortion correction process is performed for a single composite material having a distortion.

[0027] FIGS 3A through 3C each illustrate a manner of clamping pressing dies in the distortion correction process for a plurality of composite materials 1 according to second through fourth preferred embodiments, respectively. As shown in FIGS. 3A through 3C, the composite materials 1 and the intervening dies 7 are alternately layered and held by the pair of pressing dies 5.

[0028] The intervening dies 7 may be formed in the same shape as the pressing die 5 as seen in the pressing direction or may be formed in a larger shape than the pressing die 5 as seen in the pressing direction. The intervening dies 7 are smaller than the pressing dies 5 as seen in the pressing direction and they are not smaller than the composite materials 1 as seen in the pressing direction.

[0029] It is generally difficult to heat or cool the inner portion between a pair of pressing dies, however, when the intervening dies 7 are larger than the pressing dies 5 as seen in the pressing direction, it helps heat or radiate

the inner portion. The intervening dies 7 can have a fin 8 at their ends to help absorb or radiate heat, as shown in FIG. 3C.

[0030] Now the clamped pressing dies 5 are directly put in a furnace for heating. Heating is preferably performed at a temperature of $((T_m + 273)/2 - 273)$ to $(T_m - 10)$ °C, where T_m is the melting point of the matrix metal. Specifically, the heating temperature is preferably 10 to 150 °C lower than the melting point of the matrix metal. The pressing dies 5 and/or the intervening dies 7 may include a built-in heater for heating. Heating time depends upon heating temperature, however, it preferably ranges from 30 minutes to 10 hours.

[0031] After the heating is finished, the pressing dies 5 are left on an iron workbench or stool for cooling. Alternatively, the pressing dies 5 may be cooled in the furnace with a longer time. As may be necessary, it may be cooled rapidly. Finally, the pressing dies 5 are disassembled and the composite materials 1 are taken out.

[0032] The composite materials 1 as manufactured above may be used as a heat sink for semiconductor device. These preferred embodiments help correct the distortion of a composite material with no cracks produced thereon. Composite materials having a distortion were defective products so far, but they may be corrected according to the preferred embodiments, with a consequence of improved yield of raw material. These preferred embodiments also help correct a plurality of composite materials having a distortion at a time, so that it is efficient and cost-effective in manufacturing.

EXAMPLE

[0033] The following will describe an example of a method of manufacturing metal matrix composite material with ceramic particles as a disperse phase.

[0034] First, an iron die was prepared. The die was preheated at a temperature of 700 °C for an hour in the furnace. The preheated iron die had a temperature of approximately 280 to 300 °C. The punch was also preheated to a temperature of approximately 280 to 300 °C.

[0035] 120 g of silicon carbide particles as ceramic particles having a grain size of 100 μm were placed in the die. Subsequently, molten metal of foundry aluminum alloy AC4C having a temperature of 650 to 700 °C was injected into the die through the upper opening thereof so as to substantially fill any gaps among silicon carbide particles and cover the silicon carbide particles on the opening end of the die. The molten metal had a pressure of 100 MPa.

[0036] The injected molten metal penetrated into any gaps among the silicon carbide particles preplaced in the die, and the molten metal was then kept under a pressure of 100 MPa for three to six minutes. After that, the die was naturally cooled and disassembled. Thus, the plate-like composite materials having a 140-mm long and 100-mm wide rectangular broad surface were obtained. These composite materials each had a distortion in their

thickness direction. The shapes of the distortions were various such as convex, concave and waveform in the pressing direction.

[0037] The plate-like composite materials 1 having a convex distortion in the pressing direction as shown in FIG. 2A were placed on the upper surface of the stool parallel to the ground so that the convex surface is directed upward, and the distortions were measured by laser displacement gauge which is spaced upward from the composite materials 1. A distance from the fixed laser displacement gauge to the measured material was detected by laser beam while the material was moved laterally on the stool. Displacement detected while moving the material was measured as distortion. Distortions of the composite materials may be caused by uneven solidification, deformation due to preheated die, and deformation due to stress in die during casting.

[0038] Next, the composite material having a distortion was held between the pair of iron pressing dies, each having a 300-mm square quadrature broad surface by 100-mm thick in rectangular parallelepiped shape. In this example, the above-sized pressing dies were used, but pressing dies having a 160-mm or above square quadrature broad surface by 5-mm or above thick in rectangular parallelepiped shape are applicable for composite materials having the same size as the example.

[0039] The iron pressing dies were heated with the built-in heater. The pressing dies were heated to a temperature of 400 to 500 °C and pressurized to approximately 6.2 MPa with handpress with the composite material held therebetween. The pressing time was 30 minutes to 10 hours. The pressing time varies for different temperatures. For example, it took 7 hours at a temperature of 500 °C. The pressing dies were then naturally cooled to room temperature, and the composite material was taken out from the pressing dies.

[0040] The distortion of the composite material which had been 0.2 mm before distortion correction was 0.05 mm after distortion correction. It has been demonstrated that distortion correction is practicable.

[0041] The present examples and embodiments are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.

[0042] A method of manufacturing metal matrix composite with ceramic particles as a disperse phase includes the steps of holding the single metal matrix composite or the plurality of layered metal matrix composites between a pair of pressing dies, pressing the metal matrix composite by the pressing dies, and heating the metal matrix composite.

Claims

1. A method of manufacturing metal matrix composite with ceramic particles as a disperse phase, **charac-**

terized by:

holding a single metal matrix composite or a plurality of layered metal matrix composites, each having a distortion, between a pair of pressing dies;
pressing the metal matrix composite by the pressing dies; and
heating the metal matrix composite.

2. The method according to claim 1, further comprising the steps of:

placing ceramic particles in a forming die;
injecting pressurized molten matrix metal into the forming die; and
solidifying the matrix metal.

3. The method according to claim 2, wherein the molten metal matrix is premixed with other ceramic particles.

4. The method according to claim 3, wherein other ceramic particles are the same as the ceramic particles placed in the forming die.

5. The method according to claim 3, wherein other ceramic particles are different from the ceramic particles placed in the forming die.

6. The method according to any one of claims 1 through 5, wherein the holding step includes alternately layering an intervening die and the plurality of metal matrix composites.

7. The method according to claim 6, wherein the intervening die is formed in the same shape as the pressing die as seen in the pressing direction.

8. The method according to claim 6, wherein the intervening die is formed larger than the pressing die as seen in the pressing direction.

9. The method according to claim 6, wherein the intervening die is formed smaller than the pressing die as seen in the pressing direction and the intervening die is not smaller than the metal matrix composites as seen in the pressing direction.

10. The method according to any one of claims 6 through 9, wherein the intervening die has a fin at its end.

11. The method according to any one of claims 6 through 10, wherein the intervening die includes a built-in heater.

12. The method according to any one of claims 1 through 11, wherein the heating step is performed at a temperature of $((T_m + 273)/2 - 273)$ to $(T_m - 10)$ °C,

where T_m is the melting point of the matrix metal.

13. The method according to any one of claims 1 through 11, wherein the heating step is performed at a temperature of 10 to 150 °C lower than the melting point of the matrix metal. 5
14. The method according to any one of claims 1 through 13, wherein the pressing step includes applying a pressure of 1.5 to 65 MPa on the pressing dies. 10
15. The method according to any one of claims 1 through 14, wherein the matrix metal is selected from the group consisting of aluminum, aluminum alloy, copper, copper alloy, magnesium and magnesium alloy. 15
16. The method according to any one of claims 1 through 15, wherein the ceramic is selected from the group consisting of silicon carbide, aluminum nitride, boron nitride, carbon and zirconia, either alone or in mixture. 20
17. The method according to any one of claims 1 through 16, wherein the heating step includes putting the pressing dies that holds the metal matrix composite therebetween in a furnace for heating. 25
18. The method according to any one of claims 1 through 17, wherein the pressing die includes a built-in heater. 30
19. The method according to any one of claims 1 through 18, further comprising the step of cooling the pressing dies. 35
20. The method according to any one of claims 1 through 19, further comprising the step of fastening the pressing dies. 40
21. The method according to any one of claims 1 through 20, wherein the pressing die is made of iron. 45

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FIG. 1A

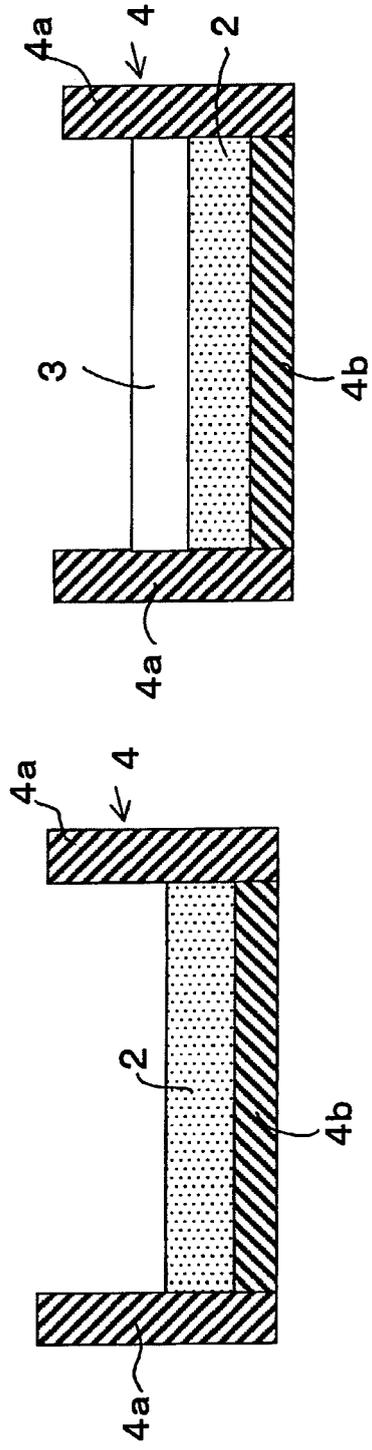


FIG. 1C



FIG. 2C

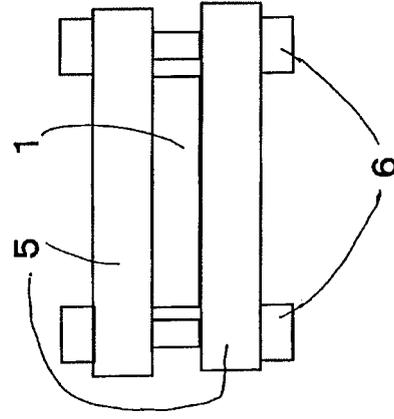


FIG. 2B

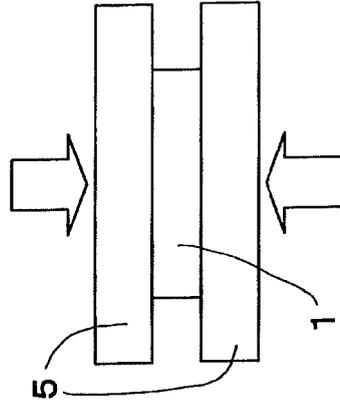


FIG. 2A

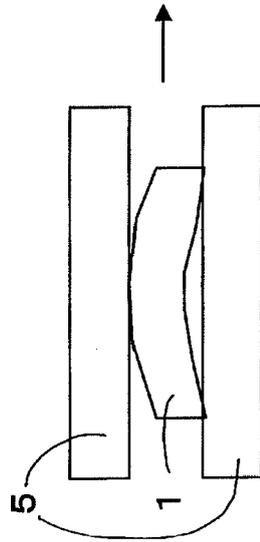


FIG. 3C

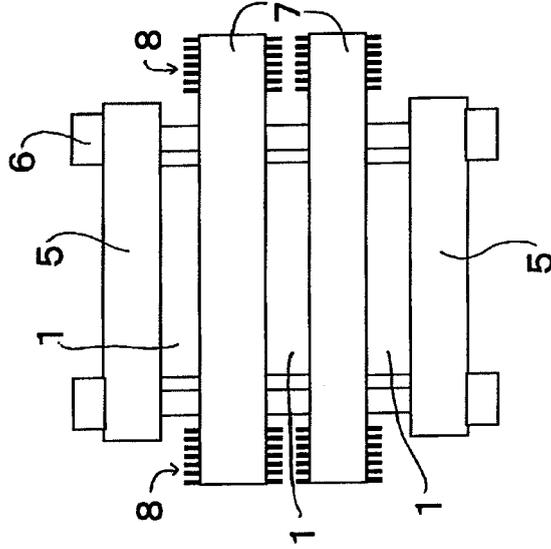


FIG. 3B

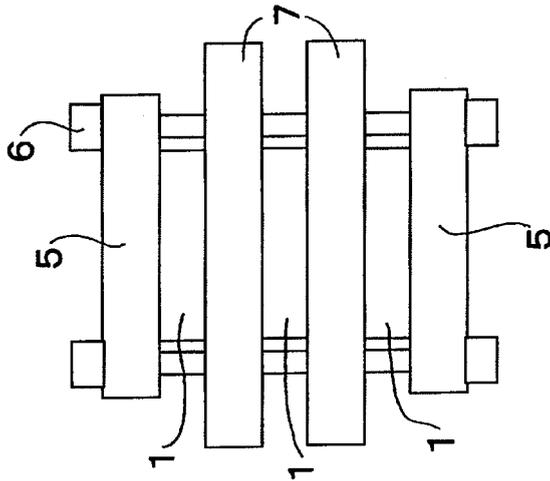
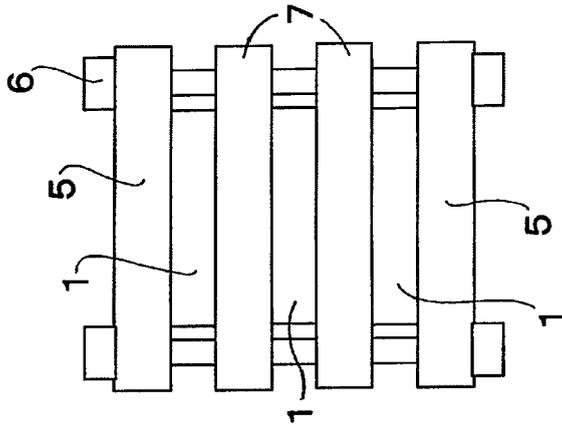


FIG. 3A





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