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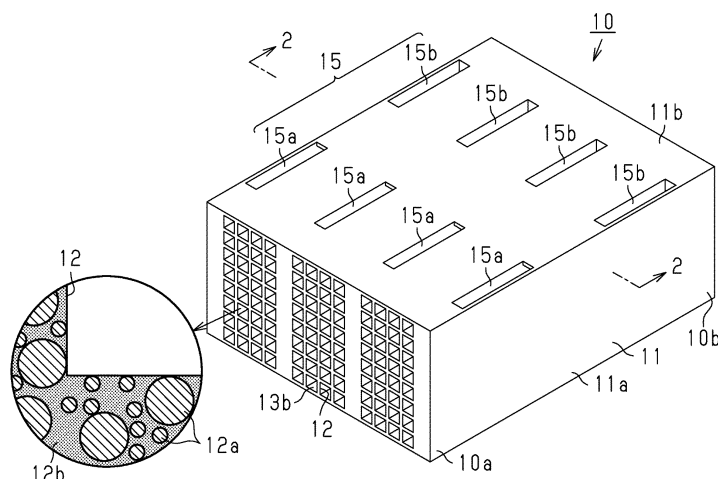
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(54) **HEAT EXCHANGER AND PRODUCTION METHOD FOR HEAT EXCHANGER**

(57) A heat exchanger 10 comprising first cells that cause a first fluid to flow therethrough, second cells that cause a second fluid to flow therethrough, and partitioning walls 12 that partition the first cells and the second cells. The partitioning walls 12 comprise: skeleton sections 12a having silicon carbide as the main component

thereof; and filled sections 12b that comprise metal filled between the gaps of the skeleton sections 12a and covering the surface of the skeleton sections 12a. The partitioning walls 12 have a surface roughness Ra of at least 1.0 μm .

Fig.1



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a heat exchanger and a method for manufacturing a heat exchanger.

BACKGROUND ART

10 **[0002]** A known heat exchanger mounted, for example, on a vehicle includes a plurality of first passages and second passages partitioned by partition walls. The heat exchanger exchanges heat through the partition walls between a first fluid flowing through the first passages and a second fluid flowing through the second passages. It is preferred that the partition walls of the heat exchanger are formed from a material having high thermal conductivity. For example, Patent Document 1 discloses a technique in which a porous body of silicon carbide is impregnated with metal silicon to form partition walls having a dense structure so as to increase the thermal conductivity of the partition walls. The partition walls having the dense structure are formed by placing a porous body of silicon carbide in a metal silicon atmosphere and vapor-depositing the metal silicon.

PRIOR ART LITERATURE

20 **PATENT LITERATURE**

[0003] Patent Document 1: Japanese Laid-Open Patent Publication No. 2010-271031

SUMMARY OF THE INVENTION

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PROBLEMS THAT THE INVENTION IS TO SOLVE

30 **[0004]** The partition walls formed by impregnating a porous body of silicon carbide with a metal such as metal silicon have a dense structure. Thus, the surfaces of the partition walls tend to be smooth and have few asperities. In particular, as Patent Document 1 discloses, when the partition walls are formed by placing a porous body of silicon carbide in a metal silicon atmosphere and vapor-depositing metal silicon, the partition walls are likely to have smooth surfaces. This is because metal silicon exists in extremely small units and hinders the formation of asperities after vapor-deposition. This decreases the area of contact between the partition walls and the fluid flowing through the passages and lowers the heat exchange efficiency. One objective of the present invention is to increase the heat exchange efficiency of a heat exchanger including partition walls formed by impregnating a porous body of silicon carbide with a metal such as metal silicon.

MEANS FOR SOLVING THE PROBLEMS

40 **[0005]** A heat exchanger that solves the above problems includes first cells, second cells, and partition walls. A first fluid flows through the first cells, and a second fluid flows through the second cells. The partition walls partition the first cells and the second cells. The heat exchanger exchanges heat between the first fluid and the second fluid. The partition walls include a frame portion and a filling portion. The frame portion has silicon carbide as a main component. The filling portion covers a surface of the frame portion and is formed from a metal that fills a void in the frame portion. The partition walls have a surface roughness Ra of 1.0 μm or greater.

[0006] When the partition walls have the surface roughness Ra of 1.0 μm or greater, the area of contact between the fluids and the partition walls is increased. This increases the heat exchange efficiency.

50 **[0007]** With the heat exchanger of the present invention, it is preferred that the metal is metal silicon. The metal silicon increases the thermal conductivity of the partition walls and increases the heat exchange efficiency. Further, the difference in coefficient of thermal expansion is small between metal silicon and silicon carbide, which forms the frame portion. This prevents damages caused by thermal shocks during use.

[0008] With the heat exchanger of the present invention, it is preferred that the surface roughness Ra of the partition walls is 5.0 μm or less. This structure decreases the flow resistance of the fluids.

55 **[0009]** A method for manufacturing a heat exchanger that solves the above problems is a method for manufacturing a heat exchanger that includes first cells through which a first fluid flows, second cells through which a second fluid flows, and partition walls that partition the first cells and the second cells. The heat exchanger exchanges heat between the first fluid and the second fluid. The method includes a molding step, a degreasing step, and an impregnation step. In the molding step, a molded body is molded from a mixture including silicon carbide particles, an organic binder, and

a dispersion medium. In the degreasing step, the organic binder included in the molded body is removed to obtain a porous degreased body. In the impregnation step, an inner side of the degreased body is impregnated with a metal. The impregnation step includes heating the degreased body in a state contacting a cluster of metal to a melting point of the metal or higher for impregnation of the metal of an amount equivalent to 1.01 to 1.1 times a pore volume of the degreased body.

[0010] The surface roughness of the partition walls can be increased by adjusting a condition for impregnating a porous body of silicon carbide with metal, specifically, by heating a porous degreased body in a state contacting a cluster of metal to a melting point of the metal or higher for impregnation and setting the amount of the metal for impregnation to a predetermined amount. As a result, the heat exchange efficiency between the fluid and the partition walls is increased. This consequently increases the heat exchange efficiency of the heat exchanger.

[0011] With the method for manufacturing a heat exchanger of the present invention, it is preferred that the metal is metal silicon. Metal silicon has an acceptable wettability for silicon carbide that forms the frame portion. This allows metal silicon to fill the voids between the silicon carbide particles without gaps.

EFFECT OF THE INVENTION

[0012] The present invention succeeds in increasing the heat exchange efficiency of a heat exchanger including partition walls formed by impregnating a porous body of silicon carbide with a metal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013]

Fig. 1 is a perspective view of a heat exchanger.

Fig. 2 is a cross-sectional view taken along line 2-2 in Fig. 1.

Fig. 3 is a cross-sectional view taken along line 3-3 in Fig. 2.

Fig. 4 is a cross-sectional view taken along line 4-4 in Fig. 2.

Fig. 5 is a diagram illustrating a molding step.

Fig. 6 is a diagram illustrating a processing step (a diagram illustrating a state in which a processing jig for a first process is stuck in a molded body).

Fig. 7 is a diagram illustrating the processing step (a diagram illustrating a state in which the processing jig for the first process is stuck in and then pulled out of the molded body).

Fig. 8 is a diagram illustrating the processing step (a diagram illustrating a second process).

Fig. 9 is a diagram illustrating a degreasing step.

Fig. 10 is a diagram illustrating an impregnation step.

MODES FOR CARRYING OUT THE INVENTION

[0014] One embodiment of a heat exchanger will now be described.

[0015] As shown in Figs. 1 and 2, a heat exchanger 10 of the present embodiment includes an outer wall 11 and partition walls 12. The outer wall 11 has the form of a rectangular tube. The partition walls 12 partition the inner side of the outer wall 11 into a plurality of first cells 13a and a plurality of second cells 13b extending in an axial direction of the outer wall 11. The outer wall 11, which has the form of a rectangular tube, includes two opposing vertical side walls 11a and two opposing lateral side walls 11b. The outer wall 11 is configured so that its cross section orthogonal to the axial direction is rectangular and laterally elongated.

[0016] As shown in Fig. 2, in a cross section orthogonal to the axial direction of the outer wall 11, the partition walls 12 form a grid-like cell structure and include partition walls 12 parallel to the vertical side walls 11a and partition walls 12 parallel to the lateral side walls 11b. The cell structure of the partition walls 12 is not particularly limited. For example, the cell structure may be configured so that the partition walls 12 have a thickness of 0.1 to 0.5 mm and a cell density of 15 to 93 cells per 1 cm² in a cross section orthogonal to the axial direction of the outer wall 11.

[0017] As shown in Fig. 3, the first cells 13a, through which a first fluid flows, each include two ends that are sealed by a sealed portion 22. As shown in Fig. 4, each second cell 13b, through which a second fluid flows, includes two open ends.

[0018] The first fluid is not particularly limited and a known heat medium may be used. Examples of known heat medium include a coolant (long life coolant (LLC)) and an organic solvent, such as ethylene glycol. The second fluid is not particularly limited, and exhaust gas of an internal combustion engine may be used.

[0019] As shown in Fig. 2, in a cross section orthogonal to the axial direction of the outer wall 11, each first cell 13a has the same cross-sectional shape as the second cells 13b.

[0020] As shown in Fig. 2, the heat exchanger 10 includes a plurality of first cell lines 14a and a plurality of second cell lines 14b. The first cell lines 14a include only the first cells 13a arranged parallel to the vertical side walls 11a of the outer wall 11, and the second cell lines 14b include only the second cells 13b arranged parallel to the vertical side walls 11a. In the present embodiment, four second cell lines 14b are arranged between two adjacent first cell lines 14a. This arrangement is repeated to form a pattern.

[0021] As shown in Figs. 1 and 3, in the heat exchanger 10, the first cell lines 14a each include a connection portion 15 extending in a vertical direction, which extends along the vertical side walls 11a. The connection portion 15 extends through the partition walls 12 between adjacent first cells 13a in the vertical direction and connects the cells of the first cell lines 14a. The connection portion 15 has an end at one side in the vertical direction (upper side in Fig. 3) that opens in the outer wall 11 (lateral side wall 11b) and an end at the other side in the vertical direction (lower side in Fig. 3) reaching the first cell 13a that is the farthest from the opening of the connection portion 15. In other words, each connection portion 15 opens in one side of the outer wall 11 and extends to the first cell 13a that is the farthest from the opening of the connection portion 15. The connection portion 15 of the heat exchanger 10 includes a first connection portion 15a and a second connection portion 15b. The first connection portion 15a is arranged closer to a first end 10a, which is located at one side in the axial direction of the heat exchanger 10, and the second connection portion 15b is arranged closer to a second end 10b, which is located at the other side in the axial direction of the heat exchanger 10.

[0022] As shown in Fig. 3, a first passage 16 is formed inside the heat exchanger 10 by the first cells 13a, the first connection portion 15a, and the second connection portion 15b. The opening of the first connection portion 15a and the opening of the second connection portion 15b in the outer wall 11 of the heat exchanger function as an inlet or an outlet of the first passage 16. Further, as shown in Fig. 4, a second passage 17 is formed inside the heat exchanger 10 by each second cell 13b with the first end 10a and the second end 10b of the outer wall 11 functioning as an inlet or an outlet of the second passage 17. The heat exchanger 10 exchanges heat through the partition walls 12 between the first fluid flowing through the first passages 16 and the second fluid flowing through the second passages 17.

[0023] The material of the outer wall 11 and the partition walls 12 of the heat exchanger 10 and a surface shape of the outer wall 11 and the partition walls 12 will now be described. In the present embodiment, the outer wall 11 and the partition walls 12 are formed from the same material and have the same surface shape. Thus, hereinafter, the partition walls 12 will be described in detail and the outer wall 11 will not be described.

[0024] As shown in Fig. 1, the partition walls 12 include a frame portion 12a having a porous structure and a filling portion 12b. The filling portion 12b covers the surface of the frame portion 12a and is formed from a metal that fills the voids in the frame portion 12a. The frame portion 12a includes silicon carbide as a main component. Here, "main component" refers to a component that is greater than or equal to 50% by mass. The frame portion 12a may include a component other than silicon carbide. An example of a component other than silicon carbide may be a ceramic material including a carbide, such as tantalum carbide and tungsten carbide, or a nitride, such as silicon nitride and boron nitride. When a component other than silicon carbide is included, the component may be of a single type or two or more types.

[0025] The metal forming the filling portion 12b may be, for example, metal silicon, aluminum, iron, or copper. Among these substances, metal silicon is particularly preferred. The metal forming the filling portion 12b may be of a single type or two or more types.

[0026] Preferably, a volume ratio of the frame portion 12a to the filling portion 12b (frame portion : filling portion) in the partition walls 12 is, for example, 60:40 to 40:60. Preferably, the volume of the metal forming the filling portion 12b is greater than the pore volume and, more preferably, 1.01 to 1.1 times the pore volume. When the volume of the metal is 1.01 times or greater than the pore volume, the surface roughness of the partition walls is increased. When the volume of the metal is less than or equal to 1.1 times the pore volume, metal is prevented from being deposited on the surfaces of the partition walls and the outer wall.

[0027] The filling portion 12b forms the surfaces of the partition walls 12. Preferably, the partition walls 12 have a surface roughness (arithmetic mean surface roughness: Ra) that is greater than or equal to 1.0 μm and less than or equal to 1.2 μm . Further, it is preferred that the surface roughness of the partition walls 12 is 5.0 μm or less. The surface roughness of the partition walls 12 can be adjusted by changing a condition for forming the filling portion 12b by impregnating the porous frame portion 12a with metal.

[0028] A method for measuring the surface roughness Ra will now be described.

[0029] Samples that are 10 mm $\times$ 10 mm plates are cut out from the partition walls of the heat exchanger. The surface roughness Ra of the sample is measured by a roughness measurement instrument (e.g., Surfcom1400d, manufactured by TOKYO SEIMITSU) over a measurement span of 2 mm in a longitudinal direction of the passage. The same measurement is performed three times to obtain the mean value of the measurements.

[0030] A method for manufacturing the heat exchanger of the present embodiment will now be described with reference to Figs. 5 to 10. The heat exchanger is manufactured by sequentially performing a molding step, a processing step, a degreasing step, and an impregnation step as described below.

Molding Step

[0031] As a raw material for molding the heat exchanger, silicon carbide particles, an organic binder, and a dispersion medium are mixed to prepare a clay-like mixture. In this case, particles of a component other than silicon carbide, such as ceramic particles, may be mixed if necessary.

[0032] Preferably, the silicon carbide particles and the particles of components other than silicon carbide have an average particle size (50% particle diameter) of, for example, 0.5 to 50 μm .

[0033] Examples of the organic binder include, for example, polyvinyl alcohol, methyl cellulose, ethyl cellulose, and carboxymethyl cellulose. Among these organic binders, methyl cellulose and carboxymethyl cellulose are particularly preferred. The organic binder may be of a single type or a combination of two or more types of the above.

[0034] Examples of the dispersion medium include water and an organic solvent. The organic solvent is, for example, ethanol. The dispersion medium may be of a single type or a combination of two or more types of the above.

[0035] Another component may further be included in the mixture. The other component may be, for example, a plasticizer or a lubricant. Examples of the plasticizer include a polyoxyalkylene compound, such as polyoxyethylene alkyl ether and polyoxypropylene alkyl ether. The lubricant is, for example, glycerol.

[0036] A molded body 20 shown in Fig. 5 is molded from the clay-like mixture. The molded body 20 includes the outer wall 11, which has the form of a rectangular tube, and the partition walls 12, which partition the inner side of the outer wall 11 into a plurality of cells 13 extending in the axial direction of the outer wall 11. The cells 13 in the molded body 20 each have two open ends. The molded body 20 can be molded, for example, by extrusion molding. A drying process is performed on the obtained molded body 20 to dry the molded body 20.

Processing Step

[0037] In the processing step, a first process and a second process are performed. The first process is performed to form first connection portions and second connection portions in the molded body. The second process is performed to seal the two ends in some of the cells of the molded body.

[0038] As shown in Fig. 6, in the first process, for example, the first connection portions 15a and the second connection portions 15b are formed by a heated processing tool 21 that contacts the molded body and removes parts of the outer wall 11 and the partition walls 12 of the molded body 20.

[0039] Specifically, as shown in Fig. 6, a blade having a contour that corresponds to the first connection portion 15a and the second connection portion 15b is prepared as the processing tool 21. The blade is formed from a heat resistant metal (e.g., stainless steel) and has a thickness that is set so as not to exceed the width of the first cell 13a. Subsequently, the blade is heated to a temperature that burns and removes the organic binder included in the molded body 20. For example, when the organic binder is methyl cellulose, the blade is heated to 400°C or higher.

[0040] As shown in Fig. 7, the heated blade is stuck into the molded body 20 from an outer side and then pulled out to form the first connection portions 15a and the second connection portions 15b. In this case, when the heated blade contacts the molded body 20, the organic binder included in the molded body 20 is burned and removed at the contact portion. Thus, the insertion resistance of the molded body 20 against the blade is extremely small. This limits deformation and breakage around the portion where the blade is stuck. Further, the burned and removed organic binder reduces the amount of processing waste.

[0041] As shown in Fig. 8, in the second process, among the cells 13 of the molded body 20, two ends of each cell 13 defining a first cell 13a are sealed with the clay-like mixture used in the molding step. This forms the sealed portions 22 that seal the two ends of the cell 13. Then, a drying process is performed on the molded body 20 to dry the sealed portions 22.

[0042] A processed molded body is obtained by performing the processing step including the first process and the second process. The order in which the first process and the second process are performed is not particularly limited. The first process may be performed after the second process.

Degreasing Step

[0043] In the degreasing step, the processed molded body is heated to burn and remove the organic binder included in the processed molded body. This removes the organic binder from the processed molded body and obtains a degreased body. As shown in Fig. 9, the degreased body 30, which is obtained by removing the organic binder from the processed molded body in the degreasing step, has a porous structure including voids between particles of silicon carbide. Preferably, a volume of the voids (pore volume) in the degreased body 30 is 40% to 60% by volume. The pore volume of the degreased body 30 can be adjusted by changing a content rate of the silicon carbide particles in the mixture used in the molding step.

Impregnation Step

[0044] In the impregnation step, the inner side of each wall forming the degreased body is impregnated with a metal, such as metal silicon. The impregnation step includes heating the degreased body in a state contacting a cluster of the metal to the melting point of the metal or higher (for example, when metal silicon is used, 1450°C or higher) in an inert gas atmosphere, such as argon or nitrogen, or in a vacuum. As shown in Fig. 10, molten metal enters the voids between particles forming the degreased body by a capillary action and impregnates the voids. The portion of the degreased body where the cluster of metal comes into contact is not particularly limited. From the viewpoint of the efficiency, it is preferred that the cluster of metal comes into contact with the upper part of the degreased body.

[0045] When metal silicon is used, it is preferred that metal silicon having a purity of less than 98% is used. The melting point of metal silicon (cluster of metal silicon) tends to be lower as the purity decreases. Thus, use of metal silicon having a low purity can lower the heating temperature required by the impregnation step. This decreases the manufacturing cost. The purity of metal silicon is, for example, 95% or higher.

[0046] The amount of metal cluster that contacts the degreased body (preparation amount of metal filling degreased body) is set to be greater than the amount corresponding to the pore volume of the degreased body 30, or less than the amount corresponding to the pore volume of the degreased body 30. Specifically, the preparation amount of metal is set to an amount corresponding to 1.01 to 1.1 times the pore volume of the degreased body 30.

[0047] When the preparation amount of metal is set to be greater than the amount corresponding to the pore volume of the degreased body 30, part of the impregnating metal will overflow the pores in the degreased body 30 and form projections on the surface. This increases the surface roughness of the formed outer wall and partition walls. When the preparation amount of metal is set to be less than the amount corresponding to the pore volume of the degreased body 30, irregularities resulting from the pores of the degreased body 30 will be produced in the surface of the formed outer wall and partition walls. This increases the surface roughness of the formed outer wall and partition walls.

[0048] The heating process in the impregnation step may be performed successively with the heating process of the degreasing step. For example, in a state contacting a cluster of metal silicon, the processed molded body may be heated at a temperature lower than the melting point of metal silicon to remove the organic binder and obtain the degreased body. Then, the heating temperature may be raised to the melting point of the metal silicon or higher to impregnate the degreased body with the molten metal silicon.

[0049] The heat exchanger is obtained by performing the impregnation step.

[0050] In the present embodiment, special temperature management is performed in the steps from the degreasing step. Specifically, the steps from the degreasing step are performed at a lower temperature than a sintering temperature of the silicon carbide included in the mixture used in the molding step so that the processed molded body and the degreased body are not exposed to a temperature higher than or equal to the sintering temperature. Therefore, in the degreasing step, heating is performed at a temperature that is higher than or equal to a temperature that burns and removes the organic binder and lower than the sintering temperature. In the same manner, in the impregnation step, heating is performed at a temperature higher than or equal to the melting point of the metal and lower than the sintering temperature.

[0051] The operation and advantages of the present embodiment will now be described.

(1) The heat exchanger includes the first cells through which the first fluid flows, the second cells through which the second fluid flows, and the partition walls that partition the first cells and the second cells. The partition walls include the frame portion, which has silicon carbide as a main component, and the filling portion, which covers the surface of the frame portion and is formed from a metal that fills the voids in the frame portion. The partition walls have the surface roughness Ra of 1.0 μm or greater.

The above structure increases the area of contact between fluid and the partition walls when the first fluid and the second fluid are flowing. This increases the heat exchange efficiency between the fluids and the partition walls and increases the heat exchange efficiency of the heat exchanger.

(2) The filling portion is formed from metal silicon.

The filling portion, which is formed from metal silicon, increases the thermal conductivity of the partition walls and increases the heat exchange efficiency. Further, the difference in coefficient of thermal expansion is small between metal silicon and silicon carbide, which forms the frame portion. This prevents damages caused by thermal shocks during use.

(3) The surface roughness Ra of the partition walls is 5.0 μm or less.

The above structure avoids a situation in which the surface shape of the partition walls causes the first fluid and the second fluid flowing along the partition walls to become turbulent flows and limits increases in the flow resistance.

(4) The method for manufacturing a heat exchanger that includes the first cells through which the first fluid flows, the second cells through which the second fluid flows, and the partition walls that partition the first cells and the second cells includes the molding step, the degreasing step, and the impregnation step. The molding step molds a

molded body from a mixture of silicon carbide particles, an organic binder, and a dispersion medium. The degreasing step removes the organic binder included in the molding body to obtain a porous degreased body. The impregnation step impregnates the inner side of the degreased body with a metal. In the impregnation step, the degreased body is heated in a state contacting a cluster of metal to a melting point of the metal or higher for impregnation of the metal of an amount equivalent to 1.01 to 1.1 times the pore volume of the degreased body.

Generally, partition walls formed by impregnating a porous body of silicon carbide with a metal such as metal silicon have a dense structure. Thus, the surfaces of the partition walls tend to be smooth and have few asperities. In particular, as Patent Document 1 discloses, when the partition walls are formed by placing a porous body of silicon carbide in a metal silicon atmosphere and vapor-depositing metal silicon, the partition walls are likely to have smooth surfaces. This is because metal silicon exists in extremely small units and hinders the formation of asperities after vapor-deposition. In this respect, the above-described structure increases the surface roughness of the partition walls even when the partition walls are formed by impregnating a porous body of silicon carbide with a metal.

(5) The metal that impregnates the inner side of the degreased body is metal silicon.

Metal silicon has an acceptable wettability for silicon carbide that forms the frame portion. This allows metal silicon to fill the voids between the silicon carbide particles without gaps.

(6) In the impregnation step, the degreased body is heated in a state in which a cluster of metal is placed on the degreased body.

The above structure allows for effective impregnation of a metal by using the effect in which the molten metal flows down the walls of the degreased body.

(7) The heat exchanger of the present embodiment is manufactured by performing temperature management as described above. The frame portion is formed in a state in which the silicon carbide particles are in contact with one another, and the shape of the frame portion is held with the voids filled with the silicon carbide. In other words, the silicon carbide particles do not include connected portions (necks), which result from sintering. This prevents cracking of necks between the silicon carbide particles even when internal temperature differences cause distortion in the partition walls during use of the heat exchanger. This further prevents cracks from spreading through necks.

[0052] The present embodiment may be modified as described below. Also, the configuration of the above embodiment and following modifications may be combined.

- The shape of the heat exchanger (for example, outer shape of heat exchanger or cell shape) is not limited to that of the above embodiment and may be changed.
- In the above embodiment, the partition walls and the outer wall include the frame portion and the filling portion and the surface roughness Ra is configured to be 1.0 μm or greater. However, this does not limit the material of the outer wall or the surface shape of the outer wall.
- Part of or all of the processing step may be omitted from the method for manufacturing the heat exchanger. The processing step is performed so that the shape of the molded body, which is obtained in the molding step, becomes close to the shape of the manufactured heat exchanger. Thus, the processing step may include only the processes that are necessary for shaping the manufactured heat exchanger and the molded body. Further, the processing step may include a process other than the first process and the second process as long as the process for removing part of the molded body is performed by a processing tool, which is heated to a temperature that burns and removes the organic binder and contacts the molded body.
- The method for manufacturing the heat exchanger may further include a step other than the molding step, the processing step, the degreasing step, and the impregnation step. For example, a surface machining, such as polishing, may be performed after the impregnation step. Preferably, a process after the degreasing step is performed in the same manner as the impregnation step at a temperature lower than or equal to a predetermined temperature.

EXAMPLES

[0053] Specific examples of the above described embodiment will now be described.

Example 1

[0054] First, a mixture having the composition described below was prepared.

[0055] Silicon carbide particles with average particle size of 15 μm (large particles): 52.5 parts by mass

Silicon carbide particles with average particle size of 0.5 μm (small particles): 23.6 parts by mass

Methyl cellulose (organic binder): 5.4 parts by mass

Glycerol (lubricant): 1.1 parts by mass

Polyoxyalkylene compound (plasticizer): 3.2 parts by mass

Water (dispersion medium): 11.5 parts by mass

With this mixture, a molded body was molded to have the same shape as one shown in Fig. 5, in which the height was 50 mm, the width was 100 mm, the length was 100 mm, the thickness of the outer wall was 0.3 mm, the thickness of the partition walls was 0.25 mm, and the cell width was 1.2 mm.

[0056] Next, a plate-like jig heated to 400°C was stuck into the outer wall of the molded body to form the first connection portions and the second connection portions. Then, predetermined cells were sealed with a clay-like mixture having the same composition as the above mixture to form the processed molded body including first cells and second cells. Subsequently, the processed molded body was heated at 450°C for five hours to remove the organic binder and obtain the degreased body. Then, the degreased body was heated at 1550°C for seven hours in a vacuum in a state in which 153 g (preparation amount: amount corresponding to 1.05 times pore volume of degreased body) of metal silicon plate is placed on the degreased body to impregnate the degreased body with metal silicon and obtain a heat exchanger of example 1.

Example 2

[0057] A heat exchanger of example 2 was obtained in the same manner as example 1 except in that the amount (preparation amount) of metal silicon plate was set to 147.2 g (amount corresponding to 1.01 times pore volume of degreased body).

Example 3

[0058] A heat exchanger of example 3 was obtained in the same manner as example 1 except in that the amount (preparation amount) of metal silicon plate was set to 160.3 g (amount corresponding to 1.1 times pore volume of degreased body).

Comparative Example

[0059] A heat exchanger of a comparative example was obtained in the same manner as example 1 except in that the amount (preparation amount) of metal silicon plate was set to 145.7 g (amount corresponding to 1.0 times pore volume of degreased body).

Measurement of Surface Roughness

[0060] The partition wall was cut out as a measurement sample over width 10 mm × length 10 mm from each example and the comparative example of the heat exchanger. The surface roughness (arithmetic mean surface roughness: Ra) of the measurement samples were measured using a surface roughness measurement instrument. As the surface roughness measurement instrument, Surfcom1400d, manufactured by TOKYO SEIMITSU, was used. The results are shown in Table 1.

Measurement of Exhaust Heat Recovery Amount

[0061] With each example and the comparative example of the heat exchanger, a coolant, which was 40°C, was charged through the inlet into the first cells at a flow rate of 10 L/min and a high temperature gas, which was 400°C, was charged through the inlet into the second cells at a flow rate of 10 g/sec. Then, the temperature difference in the coolant at the inlet and the outlet was measured to obtain the exhaust heat recovery amount for each heat exchanger. The results are shown in Table 1.

Table 1

	Preparation Amount of Metal Silicon (Volume Ratio to Pore Volume of Degreased Body)	Surface Roughness Ra	Exhaust Heat Recovery Amount
Example 1	1.05×	2.0 μm	3.4 kW
Example 2	1.01×	1.0 μm	3.1 kW
Example 3	1.1x	4.5 μm	3.3 kW

(continued)

	Preparation Amount of Metal Silicon (Volume Ratio to Pore Volume of Degreased Body)	Surface Roughness Ra	Exhaust Heat Recovery Amount
Comparative Example	1.0×	0.5 μm	2.9 kW

[0062] As shown in Table 1, in the comparative example in which the preparation amount of the metal silicon in the impregnation step corresponded to 1.0 times the pore volume of the degreased body, the surface roughness of the partition walls was 0.5 μm . In contrast, in examples 1 to 3, in which the preparation amount of the metal silicon in the impregnation step was set to be greater than the pore volume of the degreased body, the surface roughness of the partition walls was 1.0 to 4.5 μm . From the results, it is indicated that the surface roughness of the partition walls can be increased by increasing the preparation amount of metal silicon from the pore volume of the degreased body.

[0063] Also, from the results of examples 1 to 3, it can be confirmed that when the surface roughness Ra of the partition walls is increased, the area of contact between the fluids and the partition walls is increased thereby increasing the exhaust heat recovery amount. This indicates that the heat exchange efficiency can be increased by increasing the surface roughness Ra of the partition walls.

DESCRIPTION OF THE REFERENCE NUMERALS

[0064] 10) heat exchanger, 11) outer wall, 12) partition wall, 12a) frame portion, 12b) filling portion, 13a) first cell, 13b) second cell, 20) molded body, 30) degreased body.

Claims

1. A heat exchanger, comprising:

first cells through which a first fluid flows;
 second cells through which a second fluid flows; and
 partition walls that partition the first cells and the second cells, wherein
 the heat exchanger exchanges heat between the first fluid and the second fluid,
 the partition walls include a frame portion having silicon carbide as a main component and a filling portion that
 covers a surface of the frame portion and is formed from a metal that fills a void in the frame portion, and
 the partition walls have a surface roughness Ra of 1.0 μm or greater.

2. The heat exchanger according to claim 1, wherein the metal is metal silicon.

3. The heat exchanger according to claim 1 or 2, wherein the surface roughness Ra of the partition walls is 5.0 μm or less.

4. A method for manufacturing a heat exchanger, wherein the heat exchanger includes first cells through which a first fluid flows, second cells through which a second fluid flows, and partition walls that partition the first cells and the second cells and exchanges heat between the first fluid and the second fluid, the method comprising:

a molding step for molding a molded body from a mixture including silicon carbide particles, an organic binder, and a dispersion medium;
 a degreasing step for removing the organic binder included in the molded body to obtain a porous degreased body; and
 an impregnation step for impregnating an inner side of the degreased body with a metal,
 wherein the impregnation step includes heating the degreased body in a state contacting a cluster of metal to a melting point of the metal or higher for impregnation of the metal of an amount equivalent to 1.01 to 1.1 times a pore volume of the degreased body.

5. The method for manufacturing a heat exchanger according to claim 4, wherein the metal is metal silicon.

Fig.1

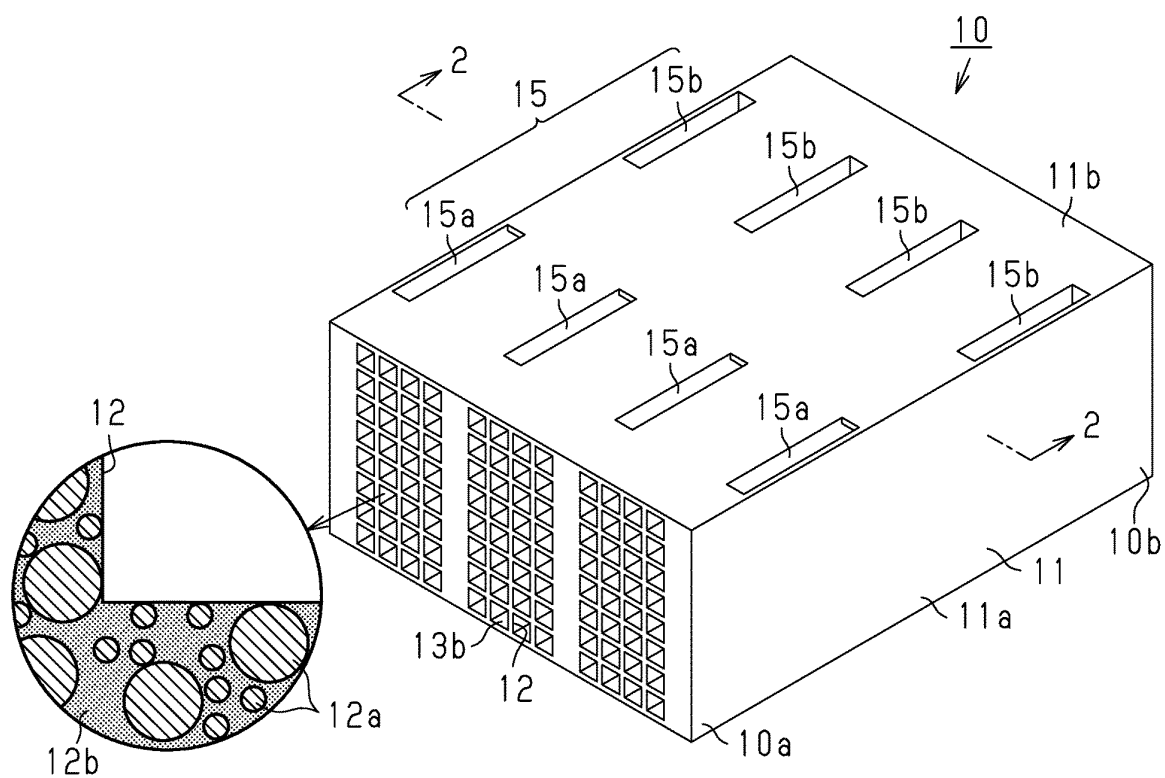


Fig.2

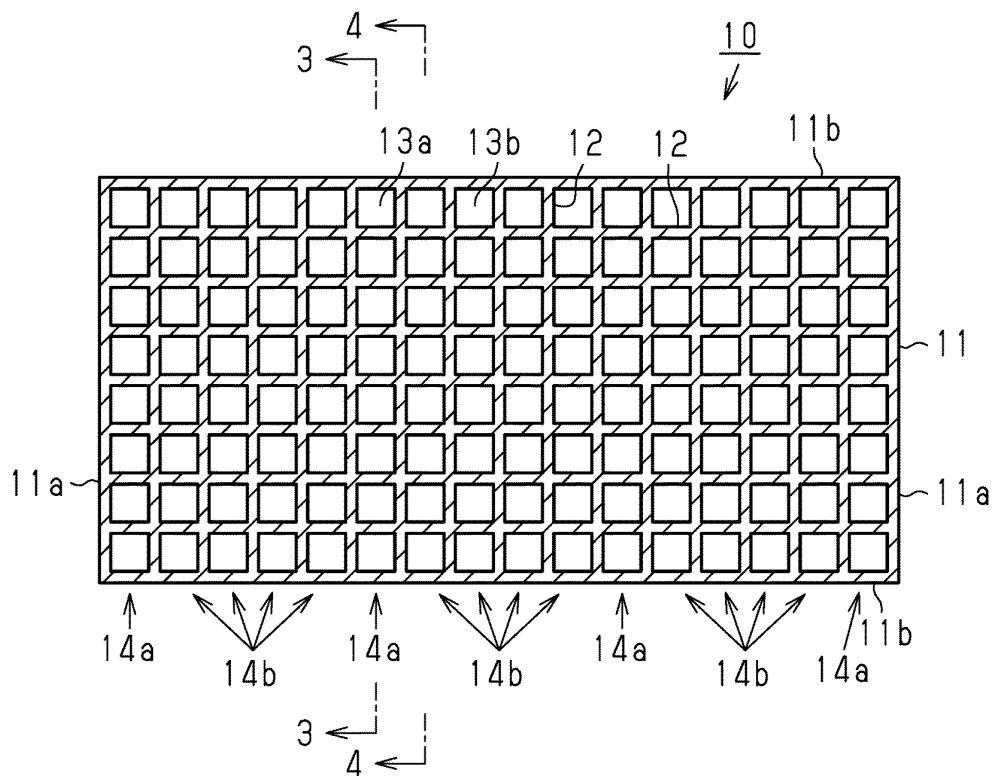


Fig.3

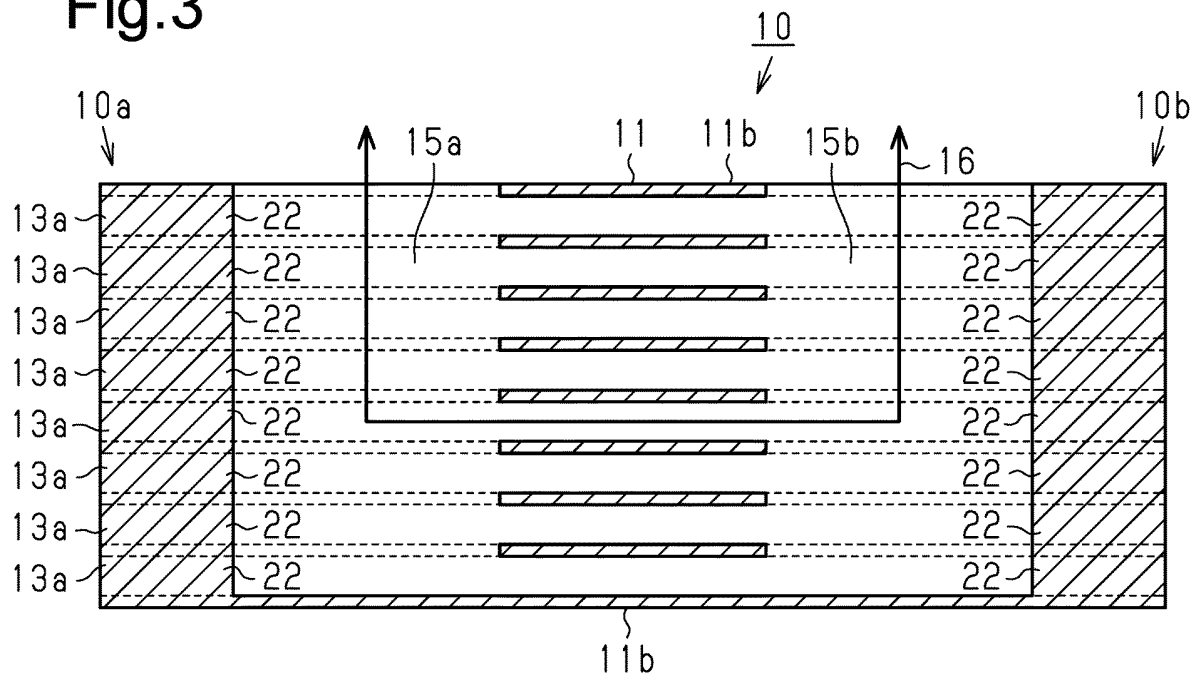


Fig.4

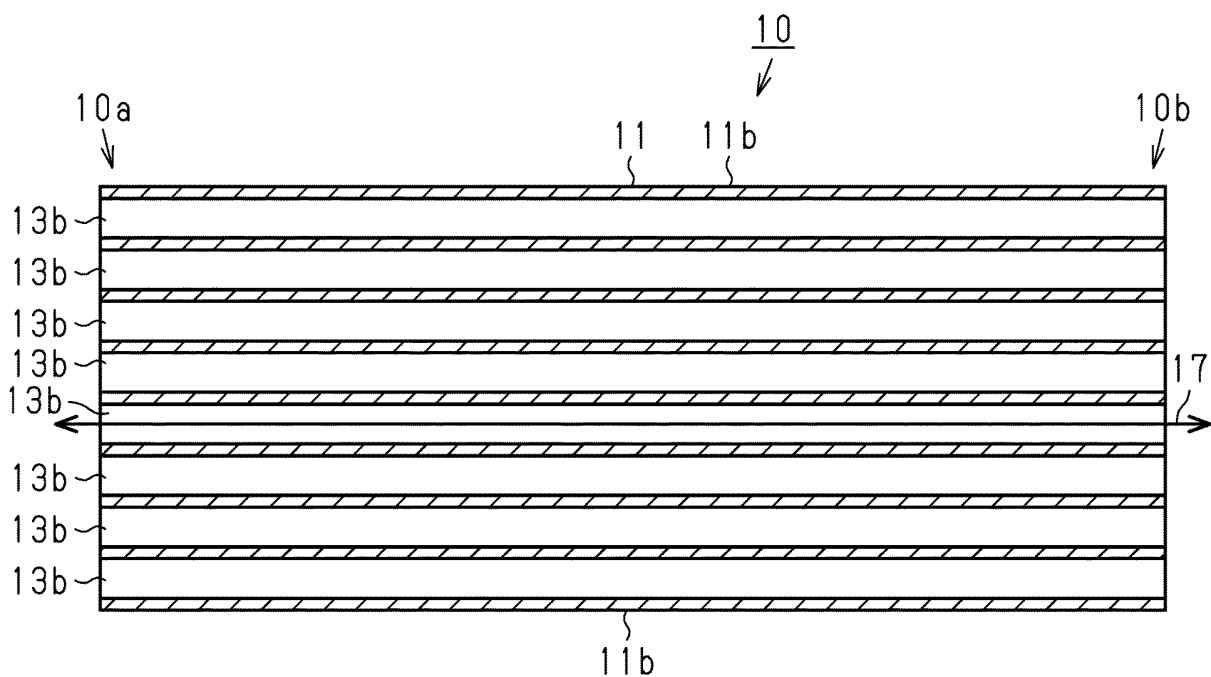


Fig.5

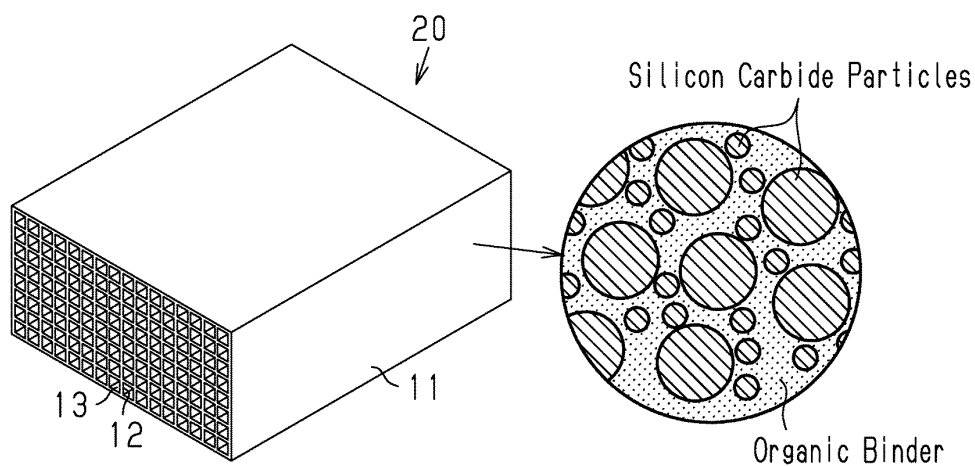


Fig.6

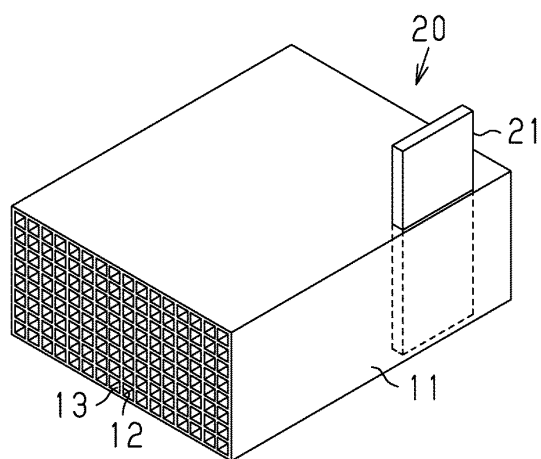


Fig.7

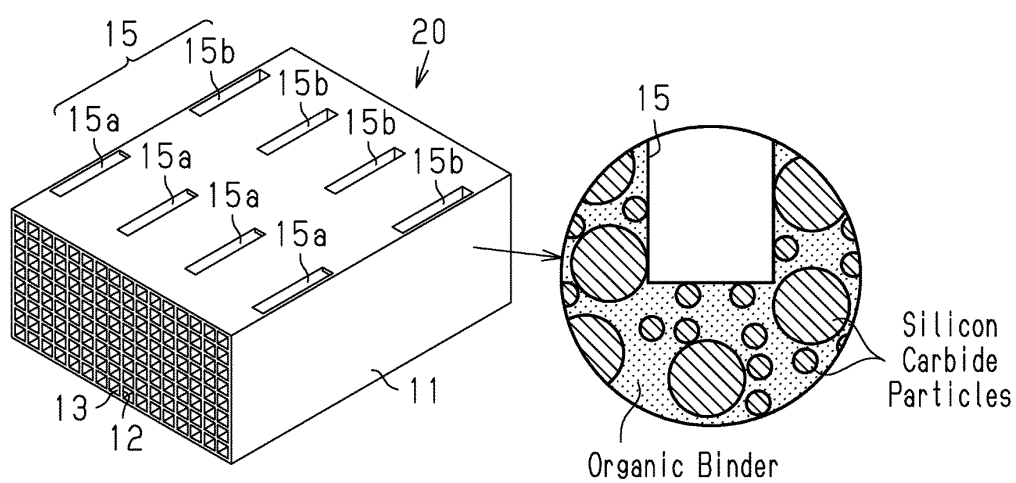


Fig.8

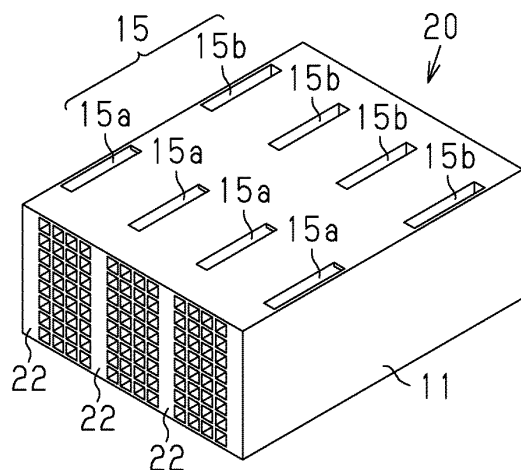


Fig.9

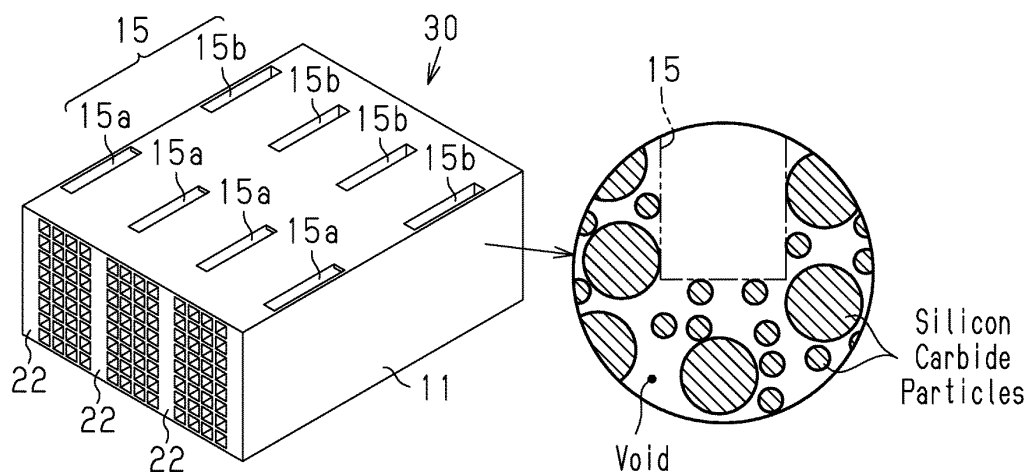
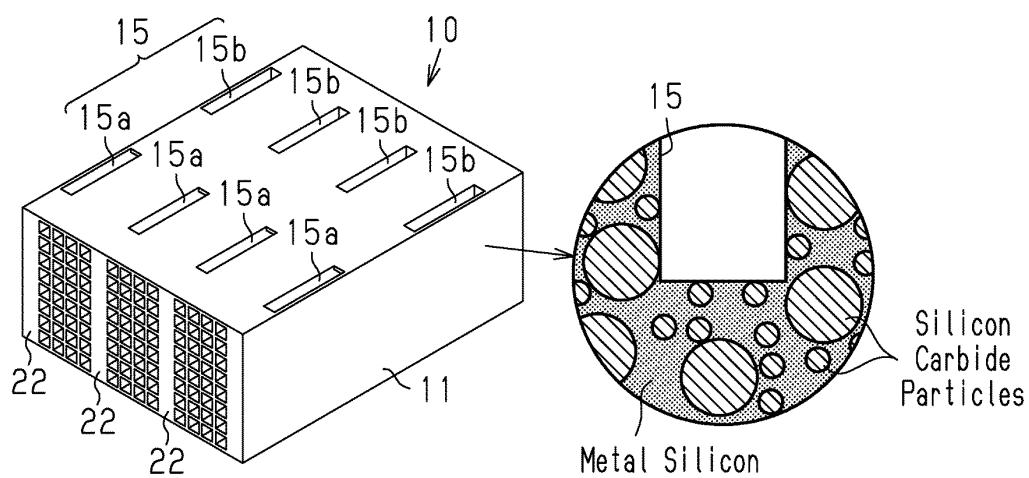


Fig.10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/038573

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. F28F21/04 (2006.01) i, C04B35/569 (2006.01) i, F28D7/00 (2006.01) i,
F28D21/00 (2006.01) i, F28F13/02 (2006.01) i, F28F21/08 (2006.01) i

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)

Int.Cl. F28F21/04, C04B35/569, F28D7/00, F28D21/00, F28F13/02, F28F21/08

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

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

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.
X	JP 2017-170645 A (IBIDEN CO., LTD.) 28 September 2017, paragraphs [0056]-[0087], fig. 1-5 & WO 2017/159306 A1	1-5



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
27 November 2018 (27.11.2018)

Date of mailing of the international search report
18 December 2018 (18.12.2018)

Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2010271031 A [0003]