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(71) Applicant: **MITSUBISHI ELECTRIC CORPORATION**
Chiyoda-ku
Tokyo 100-8310 (JP)

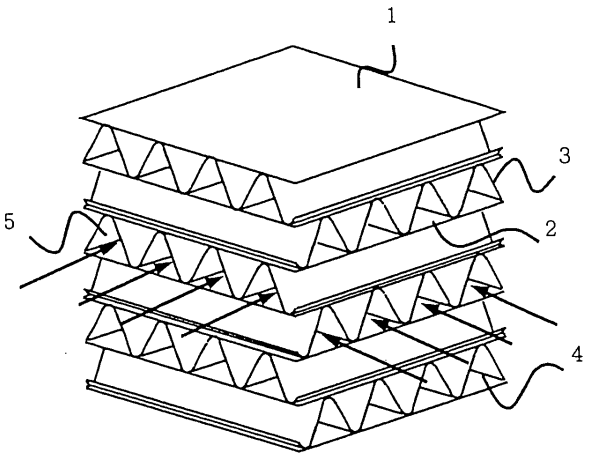
(72) Inventors:
- **TAKADA, Masaru,**
  c/o MITSUBISHI Electric Corporation
  Tokyo 100-8310 (JP)
- **ARAI, Hidemoto,**
  c/o MITSUBISHI Electric Corporation
  Tokyo 100-8310 (JP)
- **YAMAWAKI, Terufumi,**
  c/o MITSUBISHI Electric Corporation
  Tokyo 100-8310 (JP)
- **YAMADA, Yasuo,**
  c/o MITSUBISHI Electric Corporation
  Tokyo 100-8310 (JP)
- **SUGIYAMA, Youichi,**
  c/o MITSUBISHI Electric Corporation
  Tokyo 100-8310 (JP)

(74) Representative: **Pfenning, Meinig & Partner GbR**
Patent- und Rechtsanwälte
Theresienhöhe 13
80339 München (DE)

(54) HEAT EXCHANGE DEVICE AND HEAT EXCHANGER VENTILATOR LOADED WITH THE SAME

(57) A heat exchange element in which heat is exchanged between two flows respectively passing through spaces 4 and 5 for air supply and exhaust, partitioned with a plurality of members 2 and 3. The members 2 and 3 are bonded with a bonding agent which contains a volatile organic compound or a carbonyl compound but from which the total emission of such a chemical substance is 100 μg/hr or less per gram.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to a heat exchange element for exchanging heat between two flows supplying and exhausting air for ventilation, used for air-conditioning in, for example, buildings and motor vehicles, and to a heat exchange ventilator including the same.

Background Art

[0002] Heat exchange ventilators generally used in the field of air conditioning use a variety of heat exchange elements. There is a static type among the heat exchange elements. The static heat exchange element, which itself does not operate, basically includes partition members whose front and rear surfaces are in contact with respective two air flows to exchange heat, and moisture (in total heat exchange ventilators), from one air flow to the other, and spacing members for forming paths through which the two air flows pass the front and rear surfaces of the partition members. Many of these members are bonded with an adhesive or a pressure-sensitive adhesive and then stacked. Such heat exchange elements include a cross-flow type as disclosed in Patent Document 1 and a counterflow type as disclosed in Patent Document 2.

[0003] Two blowers are installed in the paths for the two air flows of the heat exchange element: one introduces air from the outdoors to one of the flow paths of the element; the other introduces air from an indoor living space to the other flow path. When the air flows pass through the heat exchange element, the heat and moisture in the flows are exchanged in such a structure. Consequently, outdoor fresh air is introduced with its temperature and moisture close to those of the air in the indoor living space, and ventilation thus can be performed without impairing amenity.

Patent Document 1: Japanese Unexamined Patent Application Publication No. 2004-190921
Patent Document 2: Japanese Unexamined Patent Application Publication No. 2004-003824

[0004] Recently, living spaces in, for example, buildings have been made highly airtight in order to save energy and increase the lifetime of the buildings, and chemical substance are used more for the buildings and the equipment in the buildings. Accordingly, the concentration of organic compounds (volatile organic compounds (VOC)) vaporizing from the buildings and the equipment is an issue. The Ministry of Health, Labour and Welfare of Japan specifies guideline values of concentrations in indoor air for 13 compounds that are considered to be harmful to the human body. In order to reduce the concentration of indoor chemicals including the 13 compounds, mechanical ventilation for clearing indoor air becomes more important. A heat exchange ventilator is advantageous which performs ventilation to introduce fresh air into a living space while heat is exchanged between intake air and exhaust air, in view of minimizing the energy loss resulting from the mechanical ventilation. Since the heat exchange ventilator can reduce the concentration of volatile organic compounds in the air of the living space while ensuring energy saving, harmful effects of the chemical compounds in question to the human body can be reduced advantageously.

Disclosure of Invention

Problems to be Solved by the Invention

[0005] The heat exchange element contained in the heat exchange ventilator is intended to exchange heat and moisture and generally designed so as to have an extremely large contact area with air flow passing through it. Accordingly, even if a very small amount of chemical substances, such as volatile organic compounds, are emitted from a component of the heat exchange element, the total chemical concentration in the air flowing into the living space is disadvantageously increased after ventilation.

[0006] For example, a heat exchange element of a heat exchanger uses a bonding agent (adhesive or pressure-sensitive adhesive), and the bonding agent is generally of an emulsion type using water as a principal solvent. Some of the emulsion-type bonding agents emit a large amount of volatile organic compounds, such as the residue (unreacted monomer) of the base resin, after drying. Part of the volatile organic compounds adheres to the heat exchange element or the ventilator during manufacture and may be reemitted from the element or the heat exchange ventilator in use. Some of the adhesives and pressure-sensitive adhesives contain a plasticizer for ensuring that the resin has film formability at low temperatures or flexibility after curing, or an organic solvent for adjusting the viscosity. The plasticizer and the solvent are also emitted after curing, consequently increasing the chemical emission from the heat exchanger.

[0007] In order to overcome these disadvantages, a device for removing or decomposing chemical substances (for example, an activated carbon filter, a decomposition catalyst, a decomposition device using electric discharge, etc.) can

be provided downstream from the heat exchange element, upstream from the outlet to the living space. Such a device must be large in order to reduce the chemical substances in the air of the living space to a very low concentration. Accordingly, a larger space is required and a higher energy must be consumed. This is disadvantageous to the heat exchange ventilator intended for energy saving ventilation.

[0008] It is therefore preferable that the reduction of indoor chemicals be performed by introducing fresh air from the outdoors while the emission of chemical substances from the heat exchange ventilator is minimized.

[0009] In view of the above-described disadvantages, the object of the present invention is to provide a heat exchange element that minimizes the emission of chemical substances whose presence in space, particularly in the living space of human beings and other organisms, is unfavorable, and a heat exchange ventilator that is provided with the heat exchange element to reduce the chemical emission, and thus to enhance the effect of reducing the concentration of the chemical substances in the space equipped with the ventilator.

Means for Solving the Problems

[0010] A heat exchange element of the present invention exchanges heat between two flows passing through an air supply space and an exhaust space partitioned with a plurality of members. The plurality of members are bonded with a bonding agent (adhesive or pressure-sensitive adhesive) which contains a volatile organic compound (VOC) or a carbonyl compound but from which the total emission of such a chemical substance is 100 μg/hr or less per gram. For the measurement, a bonding agent to be tested is dried in a clean container with a cross section of about 2 to 3 cm^2 (for example, at 100°C for about 5 minutes), and then air over the bonding agent is sampled. The chemical emission is then measured as the emission rate of total volatile organic compounds collected and analyzed by the method specified in JIS A 1901 (Determination method of the emission of volatile organic compounds (VOC), form aldehydes and other carbonyl compounds for building products -- Small chamber method).

Advantages

[0011] In the heat exchange element of the present invention, the members constituting the heat exchange element are bonded with a bonding agent from which the emission of volatile organic compounds is reduced to a rate of 100 μg/hr or less per gram. Consequently, the amount of chemical substances emitted from the heat exchange element and the heat exchange ventilator including the heat exchange element can be reduced. Accordingly, ventilation using the heat exchange ventilator of the present invention can reduce the concentration of chemical substances in the living space effectively.

[0012] In the present invention, furthermore, by using a bonding agent from which the emission of volatile organic compounds is low after drying and which contains no plasticizer or organic solvent, for bonding the members constituting the heat exchange element, the chemical emission from the heat exchange element and the heat exchange ventilator including the heat exchange element can be greatly reduced.

Brief Description of the Drawings

[0013]

[Fig. 1] Fig. 1 is a perspective view of a heat exchange element according to Embodiment 1 of the present invention.
[Fig. 2] Fig. 2 is a perspective view of a unit component constituting the heat exchange element shown in Fig. 1.

Reference Numerals

[0014]

1: heat exchange element
2: partition member
3: spacing member
4, 5: flow path

Best Mode for Carrying Out the Invention

Embodiment 1

[0015] Fig. 1 is a perspective view of a heat exchange element 1 having a cross-flow stack structure, contained in a

heat exchange ventilator of the present invention. For producing the heat exchange element 1, a unit component is first prepared by bonding a planar partition member 2 to a waved spacing member 3 as shown in Fig. 2, and then unit components are stacked in the direction in which the partition member 2 is stacked on the spacing member 3. In this instance, the unit components are stacked in such a manner as to be turned 90 degree with respect to one another so that the spacing members 3 form two gas flow paths 4 and 5 perpendicular to each other.

[0016] When the unit component shown in Fig. 2 is formed or stacked, a bonding agent (adhesive or pressure-sensitive adhesive) is used and mainly applied to the ridge lines at the summits of the spacing member 3. The application of the bonding agent, the formation of the unit components, and the stacking for the heat exchange element can be performed according to known methods.

[0017] In the present embodiment, an example of the heat exchange element 1 using an adhesive is explained as a case where the unit component is formed with a machine (corrugator) for manufacturing single-faced corrugated paper for packaging. In the corrugator, material sheets for the partition member 2 and the spacing member 3 are used as the liner and the corrugated portion, respectively, and a desired bonding agent, whose viscosity may have been adjusted, is placed in the glue feeder of the corrugator. Thus unit component is continuously formed. Then, a bonding agent is further applied to the ridges at the summits of the resulting unit component using, for example, a roll coater, and unit components are stacked while being turned 90 degree with respect to one another. The heat exchange element 1 is thus produced.

[0018] The bonding agent for bonding the partition member 2 and the spacing member 3 used in the manufacture of the heat exchange element 1 is often of a resin emulsion type containing water as a principal solvent. For example, this type of adhesive contains a base resin that is dispersed in particle form in water. The resin particles are aggregated and cured to form film by drying to remove the water. At the same time, the resin of the adhesive permeates into the asperities on the surfaces of the members in contact with each other and hardens to exhibit an effect of adhesion. The adhesive is selected from various types, depending on the compatibility with the materials to be bonded, the presence or absence of water resistance, the degree of viscosity, and other desired physical properties. Generally used adhesives include vinyl acetate resin emulsion adhesives, acrylic resin emulsion adhesives, vinyl acetate-acrylic ester copolymer resin emulsion adhesives, and ethylene-vinyl acetate copolymer resin (EVA) emulsion adhesives. In addition, combined adhesives containing some of these different types may be used.

Many pressure-sensitive adhesives are of an emulsion type containing water as a principal solvent, as with the above-described adhesives. Generally used emulsion types include epoxy, synthetic rubber, polyurethane, acrylic, ethylene-vinyl acetate copolymer (EVA), and silicone pressure-sensitive adhesives.

[0019] However, these bonding agents may contain an unintended residue of the base resin. The residue may be a unreacted residual monomer or a decomposition product produced at the time of polymerization of monomers to prepare a polymer of the resin (for example, a vinyl acetate monomer being a residual monomer, or acetic acid or acetaldehyde being a decomposition product, in the preparation of vinyl acetate resin or ethylene-vinyl acetate copolymer (EVA) resin)). The residual monomer and decomposition product contain volatile organic compounds (defined as organic compounds generally having boiling points in the range of 50 to 260°C, or defined in JIS A 1901 as organic compounds having gas chromatographic peaks in the range between n-hexane and n-hexadecane) or components having lower boiling points than the volatile organic compounds. JIS A 1901 specifies an example of a method for collecting and measuring these components in detail.

[0020] In order to help the film formation by curing, or in order to maintain the flexibility of the resin after curing, the emulsion-dispersed adhesive and pressure-sensitive adhesive may contain a phthalate ester as a plasticizer, such as n-butyl phthalate (DBP) or di-2-ethylhexyl phthalate (DOP). While some of the phthalate esters have relatively high melting points and are not classified as volatile organic compounds, the above-mentioned DBP and DOP in the phthalate ester are particularly designated as compounds whose indoor concentration should be reduced and the Ministry of Health, Labour and Welfare specifies guideline values for their indoor concentrations.

[0021] Some of the emulsion-dispersed adhesives containing water as a principal solvent contain an organic solvent, such as toluene, xylene, ethylbenzene, or styrene, for the purpose of, for example, adjusting the viscosity. After all, a major part of the chemical substances emitted from adhesives at the time of drying results from the chemical substances contained in aqueous emulsion adhesives, such as plasticizers and organic solvents. It is therefore preferable to use adhesives not containing those chemical substances. The above organic solvents have relatively low boiling points, and accordingly almost all the organic solvent in an adhesive is emitted when the adhesive is cured to form a film. However, part of the organic solvent remains in the resin.

[0022] Some of the heat exchange ventilators are used under high-humidity conditions. The heat exchange element used under these conditions requires that the partition members 2 and the spacing members 3 be water-resistant so as to prevent damage resulting from water absorption, and that the bonding agent be also water-resistant so as to ensure reliability for a long time. In order to enhance the water resistance, some of the bonding agents contain formaldehyde or the like as a crosslinking agent for crosslinking molecular chains during curing, in addition to a plasticizer which is generally contained in bonding agents. Although formaldehyde has a very low boiling point (boiling point: about -19

degree) and is not classified into the group of volatile organic compounds, it is suspected to be a causative agent of the sick building syndrome or the like. The Ministry of Health, Labour and Welfare specifies a guideline value for its concentration in indoor air, as well as that for acetaldehyde.

[0023] The above solvent and chemical inclusions are not only left in the bonding agent and emitted after curing and film formation, but also are emitted during drying or curing in the preparation of the heat exchange element. The emitted chemical compounds are absorbed by the partition members 2 and the spacing members 3 and, thus, contained in the resulting product. When the product is used, the chemical compounds may be reemitted by airflow passing through the element. It is therefore preferable to use a bonding agent which does not include such chemical substances as far as possible.

[0024] Recently developed aqueous emulsion-dispersed adhesives include adhesives using a resin whose residual monomer is reduced, adhesives containing no plasticizer or any other chemical substance, but functioning in the same manner as known adhesives, and adhesives containing no organic solvent. Examples of these adhesives are disclosed in Japanese Patent No. 3299920 and Japanese Unexamined Patent Application Publication Nos. 2004-155997, 2001-152116, 2002-179719, and 2003-171639. These adhesives do not contain chemical substances likely to be emitted as main constituents, and consequently they hardly emit the chemical substances during and after drying.

[0025] By using the above-described adhesive as the bonding agent of the heat exchange element to bond the members constituting the heat exchange element, chemical substances, such as volatile organic compounds, plasticizers, and organic solvents, which are likely to remain in and be emitted from the bonding agent or likely to be absorbed by and emitted from the heat exchange element can be extremely reduced. Accordingly, the heat exchange ventilator including the heat exchange element can further reduce the chemical emission to fresh air introduced from the outdoors; hence, the heat exchange ventilator can more enhance the effect of reducing the indoor concentration of the chemical substances than the known products. In addition, since the volatile organic compounds, plasticizers and organic solvents usually have foul odors, the effect of reducing the foul odors emitted from the ventilator can be subsidiarily expected by reducing emitted volume of such chemical substances.

[0026] When the bonding agent used in the present invention is used in the above-described manufacturing process, the following should be noted. If a bonding agent not satisfying the requirements for the bonding agent used in the present invention (adhesive or pressure-sensitive adhesive emitting a large amount of volatile organic compounds, or containing a plasticizer, an organic solvent, or the like) has been used in the corrugator or the roll coater before feeding the bonding agent of the present invention into the equipment, the chemical substances may be mixed with the bonding agent of the present invention and contaminate it, and consequently the chemical emission from the resulting heat exchange element may be extremely increased. In order to prevent the contamination, the portion in the equipment coming into contact with the bonding agent should be sufficiently cleaned before using the bonding agent.

[0027] The partition member 2 and the spacing member 3 are made of a variety of materials according to the intended use or application of the heat exchange element 1. For example, a total heat exchange element require that the partition member 2 has moisture permeability. Accordingly, the partition member 2 is generally made of a specially-treated paper prepared by applying a special treatment for improving the moisture permeability or the elasticity to paper with various resins or chemical solutions, a resin having an improved moisture permeability, or a sheet prepared by bonding or depositing the resin onto a nonwoven fabric or any other reinforcing substrate. Sensible heat exchange elements do not require such characteristics, and accordingly allow a wide range of choices in materials. For example, a resin film or a thin metal plate (metal film) can be used instead of paper. The spacing member 3, which maintains the space between the partition members 2, is made of a wide variety of materials, such as a paper subjected to a special treatment for reducing the elasticity with a resin, a resin film and a reinforced resin film prepared by bonding or depositing the resin film onto a nonwoven fabric or any other reinforcing substrate, a molded resin, a metal, and a metal thin film bonded to paper.

[0028] Preferably, the partition member 2 and the spacing member 3 constituting the heat exchange element 1 are preferably made of materials from which the emission of chemical substances is minimized because the partition member 2 and the spacing member 3 also have very large contact areas with air. However, natural materials, such as paper, may originally contain some of the volatile organic compounds. Thus, it may be difficult to prepare a material completely free from chemical substances. The materials of the partition member 2 and the spacing member 3 are formed into sheets and wound into rolls or cut into rectangular pieces. In this process, the sheets are often brought into sufficient contact with air at relatively high temperature. Consequently, chemical substances or the like may vaporize and completely dissipate or result in a similar state.

Example

[0029] A heat exchange element 1 was prepared as an example of the heat exchange element 1 of the present inversion by the above-described method. In the preparation, a specially treated paper with an inorganic agent was used for the partition members 2 and the spacing members 3, and an adhesive from which residual monomers were reduced

was used as the bonding agent. The adhesive was prepared by partially introducing ethylene-vinyl acetate polymer (EVA) resin emulsion to vinyl acetate resin aqueous emulsion, instead of adding the above-described plasticizer, so as to exhibit the same characteristics. On the other hand, another heat exchange element was prepared for a comparative example by the above-described method using the same partition members and spacing members as in the example. Only the adhesive was replaced with a vinyl acetate resin aqueous emulsion adhesive which contains a plasticizer and from which the emission of total volatile organic compounds defined by JIS A 1901 and measured in accordance with JIS A 1901 was about 500 μg/hr per gram of the adhesive. The heat exchange elements of the example and the comparative example were installed in the same type of heat exchange ventilators and the chemical emissions from the ventilators were measured and compared with each other. The results are shown in Table 1.

[0030] [Table 1]

Chemical emission from adhesive (per gram of adhesive)	Chemical emission from heat exchange ventilator
less than or equal to detection limit	$8.7x10^2$ μg/hr
about 500 μg/hr	$6.1xl0^4$ μg/hr

[0031] Table 1 shows that the chemical emission rates of the heat exchange element and the heat exchange ventilator depend on the chemical emissions from the adhesive. It has also been found from the data that in order to achieve, for example, a total volatile organic compound concentration of 400 μg/m3, which is the provisional target value for total volatile organic compounds in indoor air, currently specified by the Ministry of Health, Labour and Welfare, a preferred chemical emission from the adhesive in general cases is about 50 to 100 μg/hr or less per gram of the adhesive, though depending on the size of the heat exchange element, the volume of the space where the heat exchange ventilator is used, and other factors. Accordingly, by using an adhesive from which the chemical emission is in this range or below to bond the partition member 2 and the spacing member 3 constituting the heat exchange element 1, the heat exchange ventilator including the heat exchange element 1 can provide a good environment to the user.
In addition, it is preferable that the total emission of volatile organic compounds or carbonyl compounds from the entire heat exchange element 1 including the bonding agent bonding the partition member 2 and the spacing member 3 be 100 μg/hr or less per gram.

Industrial Applicability

[0032] The present invention can be applied to any heat exchange ventilator that uses a bonding agent for bonding its components, and can promise to produce an effect.
Also, the heat exchange ventilator of the present invention can be used not only for ventilation of rooms in buildings, but also for ventilation of various spaces, such as automobiles, trains, and other vehicles.

Claims

1. A heat exchange element in which heat is exchanged between two flows passing through an air supply space and an air exhaust space partitioned with a plurality of members,
wherein the plurality of members are bonded with a bonding agent which contains a volatile organic compound or a carbonyl compound but from which the total emission of such a chemical substance is 100 μg/hr or less per gram.

2. A heat exchange element in which heat is exchanged between two flows passing through an air supply space and an air exhaust space partitioned with a plurality of members,
wherein the plurality of members are bonded with a bonding agent which contains no plasticizer.

3. A heat exchange element in which heat is exchanged between two flows passing through an air supply space and an air exhaust space partitioned with a plurality of members,
wherein the plurality of members are bonded with a bonding agent which contains no organic solvent.

4. The heat exchange element according to Claim 1, wherein the bonding agent contains no plasticizer or organic solvent.

5. The heat exchange element according to any one of Claims 1 to 4, wherein the bonding agent is an resin emulsion-dispersed adhesive containing water as an principal solvent, selected from the group consisting of vinyl acetate

resin emulsion adhesives, acrylic resin emulsion adhesives, vinyl acetate-acrylic ester copolymer resin emulsion adhesives, ethylene-vinyl acetate copolymer resin (EVA) emulsion adhesives, and polyurethane adhesives, or prepared by mixing or further polymerizing a plurality of adhesives selected from the same group.

6. The heat exchange element according to any one of Claims 1 to 4, wherein the bonding agent is a resin emulsion pressure-sensitive adhesive containing water as a principal solvent, selected from the group consisting of epoxy resin pressure-sensitive adhesives, synthetic rubber pressure-sensitive adhesives, polyurethane pressure-sensitive adhesives, acrylic resin pressure-sensitive adhesives, ethylene-vinyl acetate copolymer resin (EVA) pressure-sensitive adhesives, and silicone pressure-sensitive adhesives, or prepared by mixing or further polymerizing a plurality of adhesives selected from the same group.

7. The heat exchange element according to any one of Claims 1 to 6, wherein the bonding agent is water-resistant.

8. The heat exchange element according to any one of Claims 1 to 7, wherein the total emission of volatile organic compounds or carbonyl compounds from the entire element including the members and the bonding agent is 100 μg/hr or less per gram.

9. A heat exchange ventilator including the heat exchange element according to any one of Claims 1 to 8.

FIG. 1

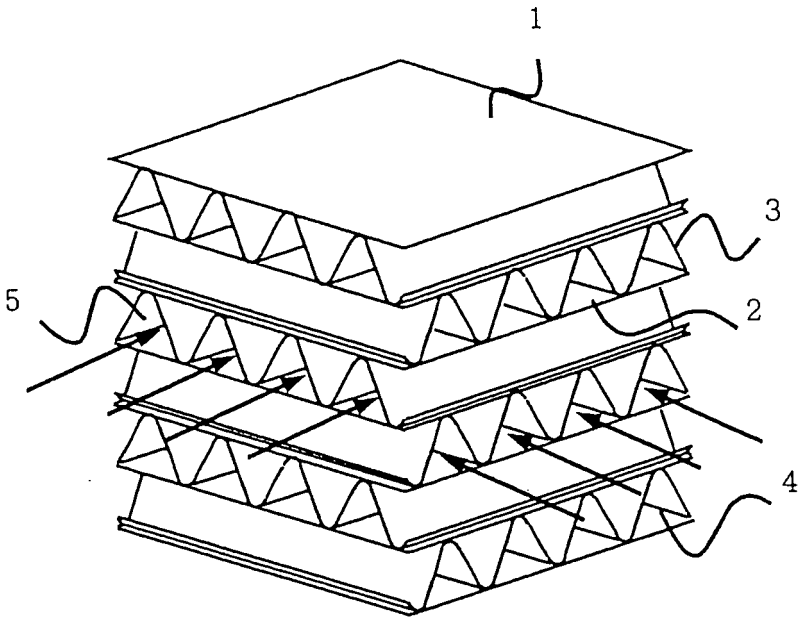
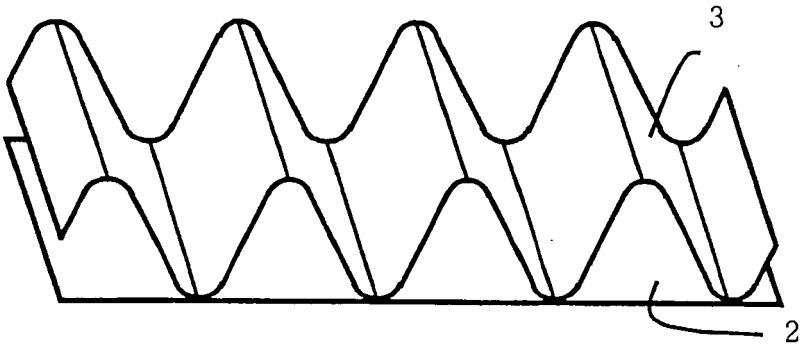


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/013756

A. CLASSIFICATION OF SUBJECT MATTER
F28F3/08(2006.01)

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)
F28F3/08(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2005
Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005

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.
Y	JP 2001-241867 A (Kabushiki Kaisha Seibu Giken), 07 September, 2001 (07.09.01), Par. No. [0024]; Fig. 1 (Family: none)	1-9
Y	JP 2000-502788 A (Lantec Products, Inc.), 07 March, 2000 (07.03.00), Page 9, lines 7 to 11; page 14, line 23 to page 15, line 1; Figs. 12 to 13 & US 5851636 A1 & EP 873491 A & WO 97/24572 A1 & DE 69628942 T & AU 1338497 A & CA 2239195 A & HK 1015026 A & CN 1206458 A & AT 244063 T & ES 2202494 T	1-9

☒ Further documents are listed in the continuation of Box C. ☐ 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
19 October, 2005 (19.10.05)	01 November, 2005 (01.11.05)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/013756

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2001-152116 A (Yayoi Kagaku Kogyo Kabushiki Kaisha), 05 June, 2001 (05.06.01), Par. Nos. [0025] to [0030]; Fig. 1 (Family: none)	1-9

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- JP 2004003824 A **[0003]**
- JP 3299920 B **[0024]**
- JP 2004155997 A **[0024]**
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- JP 2002179719 A **[0024]**
- JP 2003171639 A **[0024]**