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(54) **Sheet metal forming apparatus**

Vorrichtung zum Umformen von Blechen

Appareil de formage de tôles

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a forming apparatus, and more particularly to a sheet metal forming apparatus, according to the preamble of claim 1.

2. Description of the Related Art

[0002] FIG. 1 is a schematic view of a sheet metal formed according to prior art. As shown in FIG. 1, in prior art, a uniform electromagnetic force F1 is applied to drive a sheet metal 1 to impact and fit a forming surface of a mold 2. The forming surface has a plurality of projections 21 and a plurality of recesses 22. In the forming process, the sheet metal 1 first contacts the projections 21, which generates a counter force F2 of the same magnitude as F1. Then, a portion of the sheet metal 1 is deformed to extend to the recesses 22. However, since all the regions of the sheet metal 1 are under the uniform electromagnetic force F1, the portion of the sheet metal 1, when extending to the recesses 22, is subject to the electromagnetic force F1 and the counter force F2 at the positions of the projections 21, resulting in a severe lateral constraining force F3. Therefore, a pattern structure with a high aspect ratio cannot be formed.

[0003] US Patent No. 7076981 discloses a method of forming a bipolar plate by an electromagnetic formation process. In this patent, the blank is a sheet of material. Therefore, the sheet of material and the conductive frame need to be made to contact each other by an external force, so as to generate an inductive eddy current return path. During the pulse current induction, the problem of spark discharge may occur, which makes mass production almost impossible. Furthermore, since the two ends of the blank are restricted, the pulsing of the blank is constrained in the forming process, resulting in breakage of the blank and occurrence of an electric arc.

[0004] US Patent No. 7178374 discloses a method of manufacturing a bipolar plate by a press forming process. In this patent, the stress distribution of the sheet is controlled in the forming process according to the structural design of the die, thereby enhancing the overall forming effect. However, the method disclosed in this patent has the disadvantages of high local thickness reduction rate of the formed bipolar plate, and poor dimensional accuracy of the flow passages due to the incomplete bonding of the blank to the die.

[0005] Consequently, there is an existing need for a sheet metal forming apparatus to solve the above-mentioned problems.

SUMMARY OF THE INVENTION

[0006] The present invention provides a sheet metal forming apparatus according to claim 1 which includes a mold and an electromagnetic field generating device. The mold has a forming surface. The forming surface has a pattern structure. The pattern structure includes at least one high portion and at least one low portion. The electromagnetic field generating device has a plate-like electromagnetic actuator for generating a magnetic field. The plate-like electromagnetic actuator is spaced from the mold by a gap. The gap is used to accommodate a sheet metal. The plate-like electromagnetic actuator has a forming region. The forming region has a featured geometry corresponding to the pattern structure, so that a small repulsive electromagnetic force is generated between the sheet metal at positions opposite the at least one high portion and the plate-like electromagnetic actuator, and a large repulsive electromagnetic force is generated between the sheet metal at positions opposite the at least one low portion and the plate-like electromagnetic actuator.

[0007] The sheet metal forming apparatus of the present invention has the following advantages.

1. Since the design of the plate-like electromagnetic actuator depends on the geometrical shape of the pattern structure of the forming surface, electromagnetic forces of different magnitudes can be generated at predetermined positions, so as to reduce the lateral constraining force on the blank (the sheet metal) in the forming process, thereby manufacturing a predefined pattern with a high aspect ratio.

2. Since a high-speed and quasi-hydrostatic forming pressure is generated by the electromagnetic field generating device, the formability of the blank can be improved, the thickness reduction rate of the blank can be reduced, and warpage caused by residual stresses can also be reduced.

3. The plate-like electromagnetic actuator has a simple geometry, has low resistance and low inductance, and therefore can generate a higher primary current with the same pulse energy.

4. Since the plate-like electromagnetic actuator does not need to be closely pressed against the blank, the problem of spark discharge can be completely avoided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

FIG. 1 is a schematic view of a sheet metal formed according to prior art;

FIG. 2 is a schematic view of a sheet metal forming apparatus according to a first embodiment of the present invention;

FIG. 3 is a schematic view of a plate-like electromagnetic actuator which can be used in the apparatus according to the first embodiment of the present invention;

FIG. 4 is a schematic view of another aspect of the plate-like electromagnetic actuator which can be used in the apparatus according to the present invention;

FIGs. 5A and 5B are schematic views of predefined patterns formed on the sheet metal by an apparatus according to the present invention;

FIG. 6 is a schematic view of formation of a sheet metal obtained by an apparatus according to the present invention; and

FIG. 7 is a schematic view of a sheet metal forming apparatus according to a second embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0009] FIG. 2 is a schematic view of a sheet metal forming apparatus according to a first embodiment of the present invention; and FIG. 3 is a schematic view of a plate-like electromagnetic actuator according to the first embodiment of the present invention. As shown in FIGs. 2 and 3, the sheet metal forming apparatus 3 includes a mold 30 and an electromagnetic field generating device 40. The mold 30 has a forming surface 31, the forming surface 31 has a pattern structure 311, and the pattern structure 311 includes at least one high portion 312 and at least one low portion 313. In this embodiment, the pattern structure 311 includes a plurality of high portions (raised structures) 312 and a plurality of low portions (recessed structures) 313, so as to form a convex-concave structure.

[0010] The electromagnetic field generating device 40 includes a fixing base 41 and a plate-like electromagnetic actuator 42 for generating a magnetic field. In this embodiment, the plate-like electromagnetic actuator 42 may be made of gold, silver, copper, aluminum, or an alloy thereof; a composite material containing gold, silver, copper, or aluminum; or a superconductor material. The fixing base 41 is used to fix the plate-like electromagnetic actuator 42 and bear a reaction force of the plate-like electromagnetic actuator 42. The fixing base 41 is made of an insulating material, and preferably is made of, but is not limited to, an engineering plastic or a glass fiber resin. The fixing base 41 has a recess 411, and the recess 411 has a shape matching the shape of the plate-like electromagnetic actuator 42, so as to accommodate the plate-like electromagnetic actuator 42.

[0011] The plate-like electromagnetic actuator 42 is spaced from the mold 30 by a gap, and the gap is used to accommodate a sheet metal 5. The plate-like electromagnetic actuator 42 has a forming region 421. In this embodiment, the plate-like electromagnetic actuator 42 is an E-shaped plate-like actuator, and the forming region 421 is located at a central plate of the E-shaped plate-like actuator. The forming region 421 has a featured geometry 422 corresponding to the pattern structure 311, so that a small repulsive electromagnetic force is generated between the sheet metal 5 at positions opposite the at least one high portion 312 and the plate-like electromagnetic actuator 42, and a large repulsive electromagnetic force is generated between the sheet metal 5 at positions opposite the at least one low portion 313 and the plate-like electromagnetic actuator 42.

[0012] In this embodiment, the featured geometry 422 includes a first portion 423 and a second portion 424. The first portion 423 is a plurality of elongated through holes (is a plurality of through slots in this embodiment) passing through the plate-like electromagnetic actuator 42, the second portion 424 is a plurality of flat-plate structures, and the through holes are located between the flat-plate structures. FIG. 2 shows only two through holes (the first portion 423) and three flat-plate structures (the second portion 424). Furthermore, in this embodiment, the current direction of the central plate of the plate-like electromagnetic actuator 42 is in the direction away from the paper, and the current direction of two side plates of the plate-like electromagnetic actuator 42 is in the direction toward the paper. Each through hole corresponds to each high portion 312 of the pattern structure 311, and each flat-plate structure corresponds to each low portion 313 of the pattern structure 311.

[0013] It should be noted that, in other applications, the first portion 423 of the forming region 421 of the plate-like electromagnetic actuator 42 may be at least one elongated notch not passing through the plate-like electromagnetic actuator 42. and the second portion 424 of the forming region 421 is a flat-plate structure, as shown in FIG. 4.

[0014] When a pulse current flows through the plate-like electromagnetic actuator 42, a repulsive electromagnetic force is generated between the plate-like electromagnetic actuator 42 and the sheet metal 5, and drives the sheet metal 5 to fit the pattern structure 311, so as to form a predefined pattern 51 corresponding to the pattern structure 311 on the sheet metal 5. According to different patterns of the pattern structure 311, different predefined patterns can be formed (such as straight flow passages and zigzag flow passages as shown in FIGs. 5A and 5B).

[0015] As shown in FIGs. 2 and 6, a small repulsive electromagnetic force is generated between the plate-like electromagnetic actuator 42 and the sheet metal 5 at the positions opposite the through holes (the first portion 423), and a large repulsive electromagnetic force is generated between the plate-like electromagnetic actuator 42 and the sheet metal 5 at the positions opposite the flat-plate structures (the second portion 424). That is to say, when the repulsive electromagnetic force drives

thesheet metal 5 to fit the pattern structure 311, the sheet metal 5 has a small forming force at the positions opposite the high portions 312, and the sheet metal 5 has a large forming force at the positions opposite the low portions 313.

[0016] As the sheet metal 5 has a small forming force at the positions opposite to the high portions 312 (i.e., the positions opposite to the first portions 423), when the sheet metal 5 is deformed under stress to fit the pattern structure 311, the sheet metal 5 at the positions opposite the low portions 313 suffers a small lateral constraining force, so the sheet metal 5 is not easily broken, has a low local thickness reduction rate, and can be completely bonded to the pattern structure 311, thereby achieving a high dimensional accuracy. Furthermore, the predefined pattern 51 (as shown in FIGs. 5A and 5B) after the sheet metal 5 is formed has a high aspect ratio.

[0017] FIG. 7 is a schematic view of a sheet metal forming apparatus according to a second embodiment of the present invention. The sheet metal forming apparatus 6 in this embodiment is substantially the same as the sheet metal forming apparatus 3 (FIG. 2) in the first embodiment, and the difference lies in the geometry of the forming region of the plate-like electromagnetic actuator 62. In this embodiment, the first portion 622 of the forming region 621 of the plate-like electromagnetic actuator 62 is at least one recessed structure, and the second portion 623 is at least one raised structure. Other portions that are the same as those of the sheet metal forming apparatus 3 in the first embodiment are represented by the same reference numerals, and will not be described herein again.

[0018] In this embodiment, when the repulsive electromagnetic force drives the sheet metal 5 to fit the pattern structure 311, the sheet metal 5 has a small forming force at the positions opposite the high portions 312 (i.e., the positions opposite the recessed structures), and the sheet metal 5 has a large forming force at the positions opposite the low portions 313 (i.e., positions opposite the raised structures).

[0019] As the sheet metal 5 has a small forming force at the positions opposite to the high portions 312, when the sheet metal 5 is deformed under stress to fit the pattern structure 311, the sheet metal 5 at the positions opposite the low portions 313 suffers a small lateral constraining force, so the sheet metal 5 is not easily broken, has a low local thickness reduction rate, and can be completely bonded to the pattern structure 311, thereby achieving a high dimensional accuracy. Furthermore, the predefined pattern 51 (as shown in FIGs. 5A and 5B) after the sheet metal 5 is formed has a high aspect ratio.

[0020] The sheet metal forming apparatus of the present invention has the following advantages.

1. Since the design of the plate-like electromagnetic actuator depends on the geometrical shape of the pattern structure of the forming surface, electromagnetic forces of different magnitudes can be generated at predetermined positions, so as to reduce the lateral constraining force exerted on the blank (the sheet metal) in the forming process, thereby manufacturing a predefined pattern with a high aspect ratio.

2. Since a high-speed and quasi-hydrostatic forming pressure is generated by the electromagnetic field generating device, the formability of the blank can be improved, the thickness reduction rate of the blank can be reduced, and warpage caused by residual stresses can also be reduced.

3. The plate-like electromagnetic actuator has a simple geometry, has low resistance and low inductance, and therefore can generate a higher primary current with the same pulse energy.

4. Since the plate-like electromagnetic actuator does not need to be closely pressed against the blank, the problem of spark discharge can be completely avoided.

[0021] While the embodiments of the present invention have been illustrated and described, various modifications and improvements can be made by those skilled in the art. The embodiments of the present invention are therefore described in an illustrative but not restrictive sense. Therefore it is intended that the present invention is not limited to the particular forms as illustrated, but it covers all modifications within the scope of the present invention as defined by the appended claims.

Claims

1. A sheet metal forming apparatus (3, 6), **characterized in** comprising:

   a mold (30), having a forming surface (31), wherein the forming surface (31) has a pattern structure (311), and the pattern structure (311) comprises at least one high portion (312) and at least one low portion (313); and

   an electromagnetic field generating device (40), having a plate-like electromagnetic actuator (42, 62) for generating a magnetic field, wherein the plate-like electromagnetic actuator (42, 62) is spaced from the mold (30) by a gap, the gap is used to accommodate a sheet metal (5), the plate-like electromagnetic actuator (42, 62) has a forming region (421, 621), **characterized in that** the forming region (421, 621) has a featured geometry (422) corresponding to the pattern structure (311), so that a small repulsive electromagnetic force is generated between the sheet metal (5) at positions opposite the at least one high portion (312) and the plate-like elec-

tromagnetic actuator (42, 62), and a large repulsive electromagnetic force is generated between the sheet metal (5) at positions opposite the at least one low portion (313) and the plate-like electromagnetic actuator (42, 62).

2. The forming apparatus (3, 6) according to Claim 1, wherein the featured geometry (422) comprises a first portion (423, 622) and a second portion (424, 623), the first portion (423, 622) corresponding to the at least one high portion (312) of the pattern structure (311), and the second portion (424, 623) corresponding to the at least one low portion (313) of the pattern structure (311).

3. The forming apparatus (3, 6) according to Claim 2, wherein the first portion (423, 622) is at least one notch not passing through the plate-like electromagnetic actuator (42, 62).

4. The forming apparatus (3, 6) according to Claim 2, wherein the first portion (423, 622) is at least one through hole passing through the plate-like electromagnetic actuator (42, 62).

5. The forming apparatus (3, 6) according to Claim 2, wherein the first portion (423, 622) is at least one recessed structure, and the second portion (424, 623) is at least one raised structure.

6. The forming apparatus (3, 6) according to any of the preceding claims, wherein the plate-like electromagnetic actuator (42, 62) is an E-shaped plate-like actuator, and the forming region (421, 621) is located at a central plate of the E-shaped plate-like actuator.

7. The forming apparatus according to any of the preceding claims, wherein the plate-like electromagnetic actuator (42, 62) is made of gold, silver, copper, aluminum, or an alloy thereof.

8. The forming apparatus (3, 6) according to any of the preceding claims, wherein the plate-like electromagnetic actuator (42, 62) is made of a composite material containing gold, silver, copper, or aluminum.

9. The forming apparatus (3, 6) according to any of the preceding claims, wherein the plate-like electromagnetic actuator (42, 62) is made of a superconductor material.

10. The forming apparatus (3, 6) according to any of the preceding claims, wherein the electromagnetic field generating device (40) further comprises a fixing base (41) for fixing the plate-like electromagnetic actuator (42, 62).

11. The forming apparatus (3, 6) according to Claim 10, wherein the fixing base (41) is made of an insulating material.

12. The forming apparatus (3, 6) according to Claim 11, wherein the insulating material is an engineering plastic or a glass fiber resin.

Patentansprüche

1. Vorrichtung zur Umformung von Blechen (3, 6), umfassend:

eine Form (30) mit einer Formfläche (31), wobei die Formfläche (31) eine Musterstruktur (311) aufweist und wobei die Musterstruktur (311) mindestens einen hohen Abschnitt (312) und mindestens einen niedrigen Abschnitt (313) aufweist; und

eine Vorrichtung (40) zum Erzeugen eines elektromagnetischen Feldes, mit einem plattenförmigen elektromagnetischen Aktuator (42, 62) zum Erzeugen eines Magnetfeldes, wobei der plattenförmige elektromagnetische Aktuator (42, 62) über einen Spalt beabstandet zu der Form (30) ist, wobei der Spalt zur Aufnahrne eines Blechs (5) verwendet wird, und wobei der plattenförmige elektromagnetische Aktuator (42, 62) einen Umformbereich (421, 621) aufweist,

dadurch gekennzeichnet, dass der Umformbereich (421, 621) ein Merkmalsgebilde (422) entsprechend der Musterstruktur (311) aufweist, so dass eine kleine abstoßende elektromagnetische Kraft zwischen dem Metallblech (5) und dem plattenförmigen elektromagnetischen Aktuator (42, 62) an Positionen gegenüber dem mindestens einen hohen Abschnitt (312) erzeugt wird, und sodass eine große abstoßende elektromagnetische Kraft zwischen dem Metallblech (5) und dem plattenförmigen elektromagnetischen Aktuator (42, 62) an Positionen gegenüber dem mindestens einen niedrigen Abschnitt (313) erzeugt wird.

2. Umformvorrichtung (3, 6) nach Anspruch 1, wobei das Merkmalsgebilde (422) einen ersten Abschnitt (423, 622) und einen zweiten Abschnitt (424, 623) umfasst, wobei der erste Abschnitt (423, 622) entsprechend dem mindestens einen hohen Abschnitt (312) der Musterstruktur (311) ausgebildet ist und der zweite Abschnitt (424, 623) entsprechend dem wenigstens einen niedrigen Abschnitt (313) der Musterstruktur (311) ausgebildet ist.

3. Umformvorrichtung (3, 6) nach Anspruch 2, wobei der erste Abschnitt (423, 622) wenigstens eine Kerbe ist, die sich nicht durch den plattenförmigen elek-

tromagnetischen Aktuator (42, 62) erstreckt.

4. Umformvorrichtung (3, 6) nach Anspruch 2, wobei der erste Abschnitt (423, 622) mindestens eine Durchgangsbohrung ist, die sich durch den plattenförmigen elektromagnetischen Aktuator (42, 62) erstreckt.

5. Umformvorrichtung (3, 6) nach Anspruch 2, wobei der erste Abschnitt (423, 622) mindestens eine vertiefte bzw. ausgesparte Struktur ist und der zweite Abschnitt (424, 623) mindestens eine erhabene Struktur.

6. Umformvorrichtung (3, 6) nach einem der vorhergehenden Ansprüche, wobei der plattenförmige elektromagnetische Aktuator (42, 62) ein E-förmiger plattenförmiger Aktuator ist und der Umformungsbereich (421, 621) sich an einer zentralen Platte des E-förmigen plattenförmigen Aktuators befindet.

7. Umformvorrichtung (3, 6) nach einem der vorhergehenden Ansprüche, wobei der plattenförmige elektromagnetische Aktuator (42, 62) aus Gold, Silber, Kupfer, Aluminium oder einer Legierung davon hergestellt ist.

8. Umformvorrichtung (3, 6) nach einem der vorhergehenden Ansprüche, wobei der plattenförmige elektromagnetische Aktuator (42, 62) aus einem Verbundmaterial hergestellt ist, das Gold, Silber, Kupfer oder Aluminium enthält.

9. Umformvorrichtung (3, 6) nach einem der vorhergehenden Ansprüche, wobei der plattenförmige elektromagnetische Aktuator (42, 62) aus einem supraleitenden Material hergestellt ist.

10. Umformvorrichtung (3, 6) nach einem der vorhergehenden Ansprüche, wobei die Vorrichtung (40) zum Erzeugen des elektromagnetischen Feldes ferner eine Befestigungsbasis (41) zur Fixierung des plattenförmigen elektromagnetischen Aktuators (42, 62) aufweist.

11. Umformvorrichtung (3, 6) nach Anspruch 10, wobei die Befestigungsbasis (41) aus einem isolierenden Material hergestellt ist.

12. Umformvorrichtung (3, 6) nach Anspruch 11, wobei das isolierende Material ein technischer Kunststoff oder ein Glasfaser-Harz ist.

Revendications

1. Un appareil de formage de tôles (3, 6), **caractérisé en ce qu'**il comporte:

un moule (30), ayant une surface de formage (31), dans lequel la surface de formage (31) présente une structure à motifs (311), et la structure à motif (311) comporte au moins une partie haute (312) et une partie basse (313); et
un dispositif générateur de champ électromagnétique (40), ayant un actionneur électromagnétique en forme de plaque (42, 62) pour la génération d'un champ magnétique, dans lequel l'actionneur électromagnétique en forme de plaque (42, 62) est espacé du moule (30) par un vide, le vide étant utilisé pour recevoir une tôle (5), l'actionneur électromagnétique en forme de plaque (42, 62) ayant une zone de formage (421, 621), **caractérisé en ce que** la zone de formage (421, 621) a une géométrie définie (422) correspondant à la structure à motifs (311), de telle manière qu'une légère force électromagnétique répulsive est générée entre la tôle (5) à des positions opposées la dite partie haute au moins (312) et l'actionneur électromagnétique en forme de plaque (42, 62), et une forte force électromagnétique répulsive est générée entre la tôle (5) à des positions opposées à la partie basse au moins (313) et l'actionneur électromagnétique en forme de plaque (42, 62).

2. L'appareil de formage (3, 6) selon la revendication 1, dans lequel la géométrie définie (422) comporte une première partie (423, 622) et une seconde partie (424, 623), la première partie (423, 622) correspondant à la partie haute au moins (312) de la structure à motifs (311), et la seconde partie (424, 623) correspondant à la partie basse au moins (313) de la structure à motifs.

3. L'appareil de formage (3, 6) selon la revendication 2, dans lequel la première partie (423, 622) est au moins une encoche ne passant pas au travers de l'actionneur électromagnétique en forme de plaque (42, 62).

4. L'appareil de formage (3, 6) selon la revendication 2, dans lequel la première partie (423, 622) est au moins un trou passant au travers l'actionneur électromagnétique en forme de plaque (42, 62).

5. L'appareil de formage (3, 6) selon la revendication 2, dans lequel la première partie (423, 622) est au moins une structure en creux, et la seconde partie (424, 623) est au moins une structure en élevation.

6. L'appareil de formage (3, 6) selon l'une quelconque des revendications précédentes, dans lequel l'actionneur électromagnétique en forme de plaque (42, 62) est un actionneur en forme de plaque présentant la forme d'un E, et la zone de formage (421, 621) est située dans une paque centrale de l'actionneur

en forme de plaque en forme de E.

7. L'appareil de formage (3, 6) selon l'une quelconque des revendications précédentes, dans lequel l'actionneur électromagnétique en forme de plaque (42, 62) est réalisé en or, en argent, en cuivre, en aluminium ou un de leurs alliages.

8. L'appareil de formage (3, 6) selon l'une quelconque des revendications précédentes, dans lequel l'actionneur électromagnétique en forme de plaque (42, 62) est réalisé à partir d'un composé comportant de l'or, de l'argent, du cuivre, de l'aluminium.

9. L'appareil de formage (3, 6) selon l'une quelconque des revendications précédentes, dans lequel l'actionneur électromagnétique en forme de plaque (42, 62) est réalisé en un matériau superconducteur.

10. L'appareil de formage (3, 6) selon l'une quelconque des revendications précédentes, dans lequel le dispositif générateur de champ électromagnétique (40) comporte en outre une base de fixation (41) pour la fixation de l'actionneur électromagnétique en forme de plaque (42, 62).

11. L'appareil de formage (3, 6) selon la revendication 10, dans lequel la base de fixation (41) est réalisé en un matériau isolant.

12. L'appareil de formage (3, 6) selon la revendication 11, dans lequel le matériau isolant est du plastique manufacturé ou de la résine de fibre de verre.

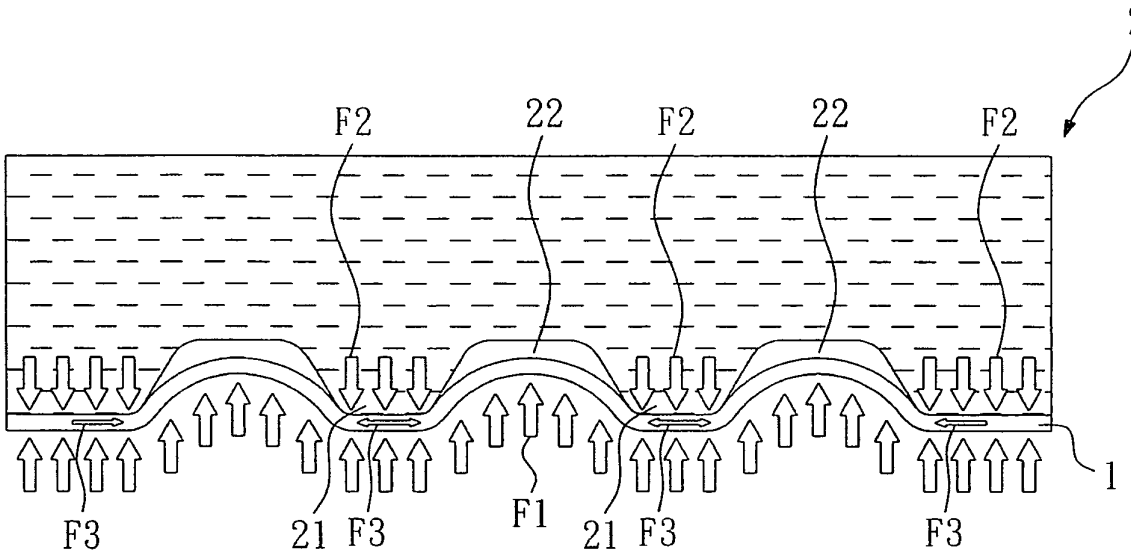

FIG. 1 (Prior Art)

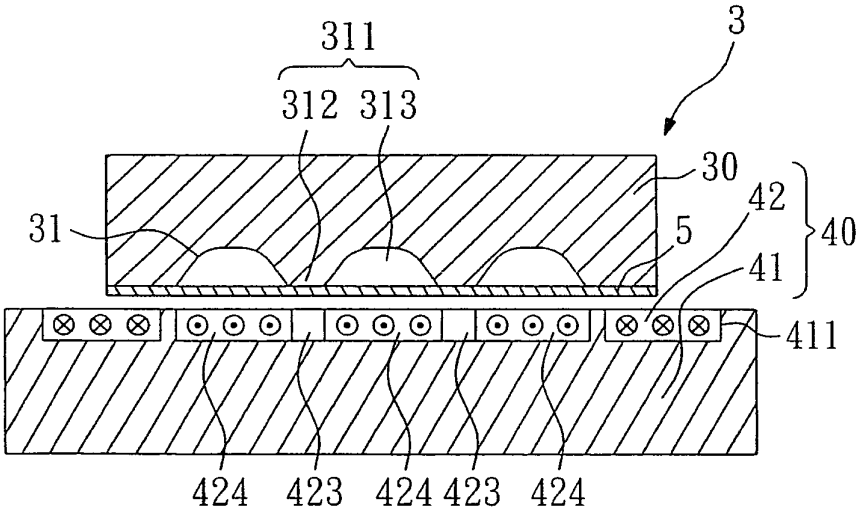

FIG. 2

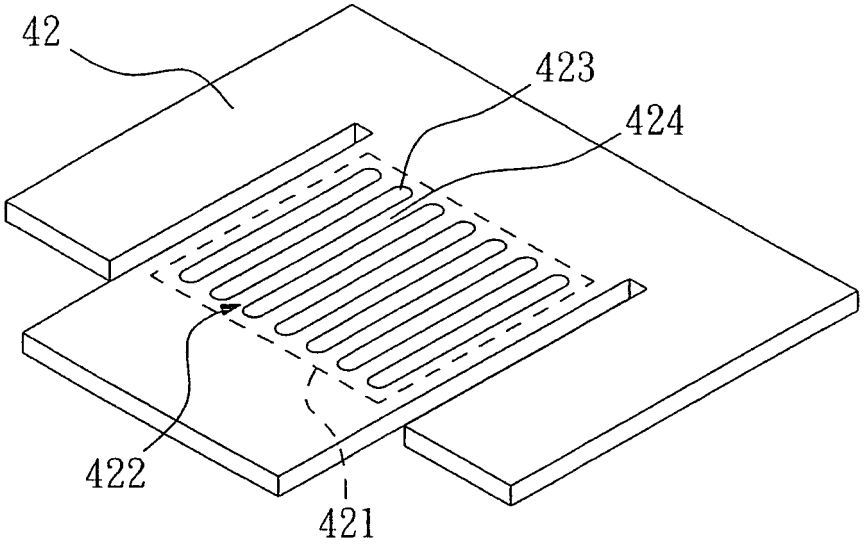

FIG. 3

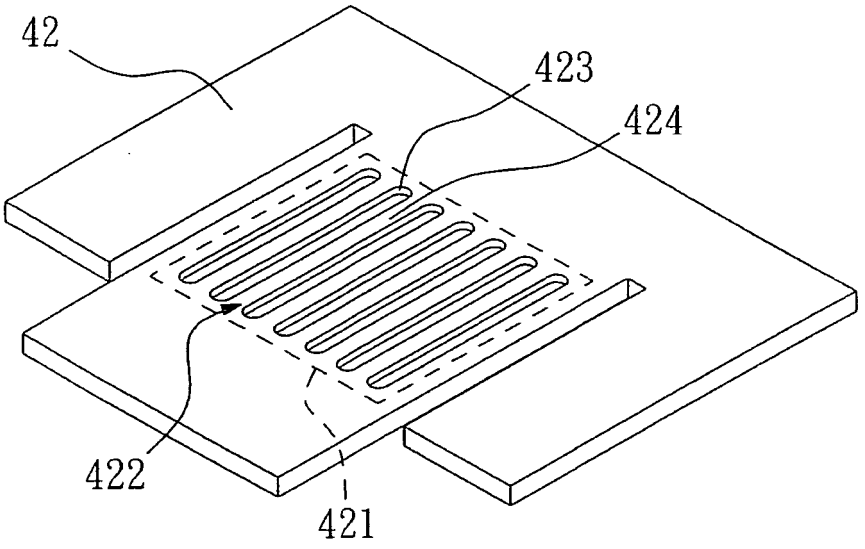

FIG. 4

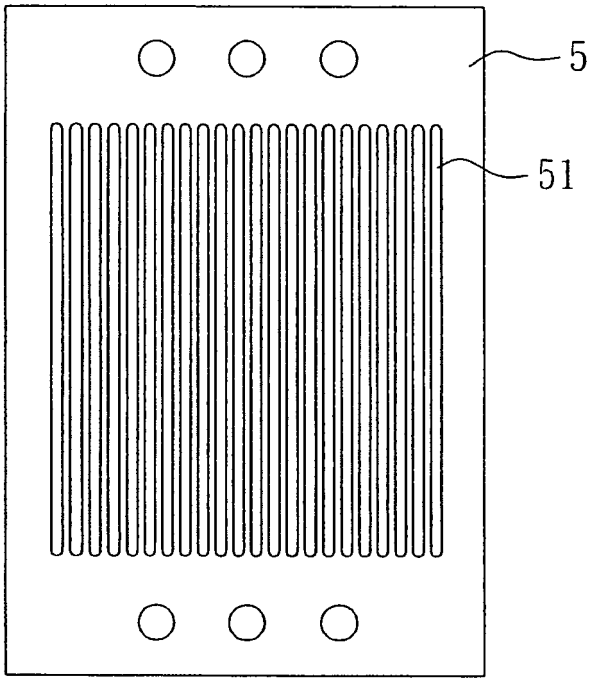

FIG. 5A

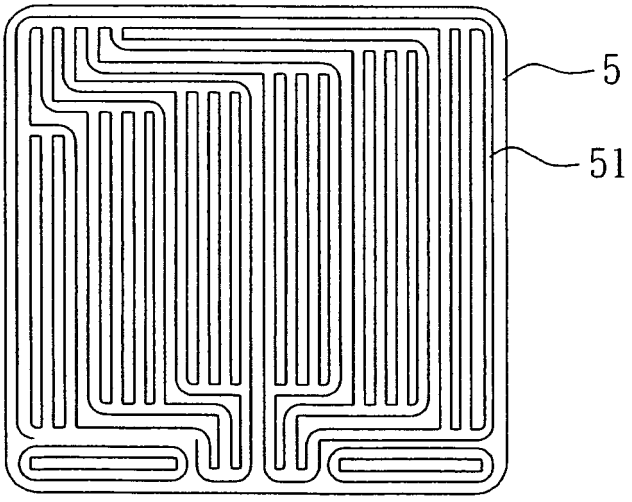

FIG. 5B

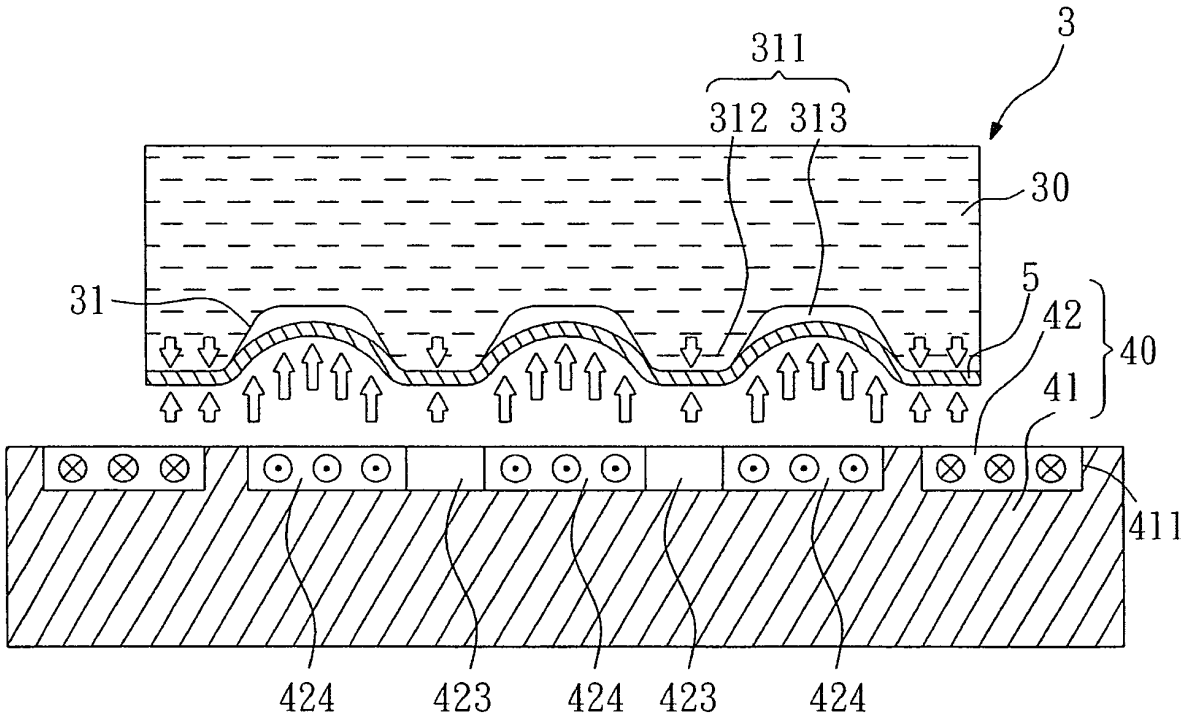

FIG. 6

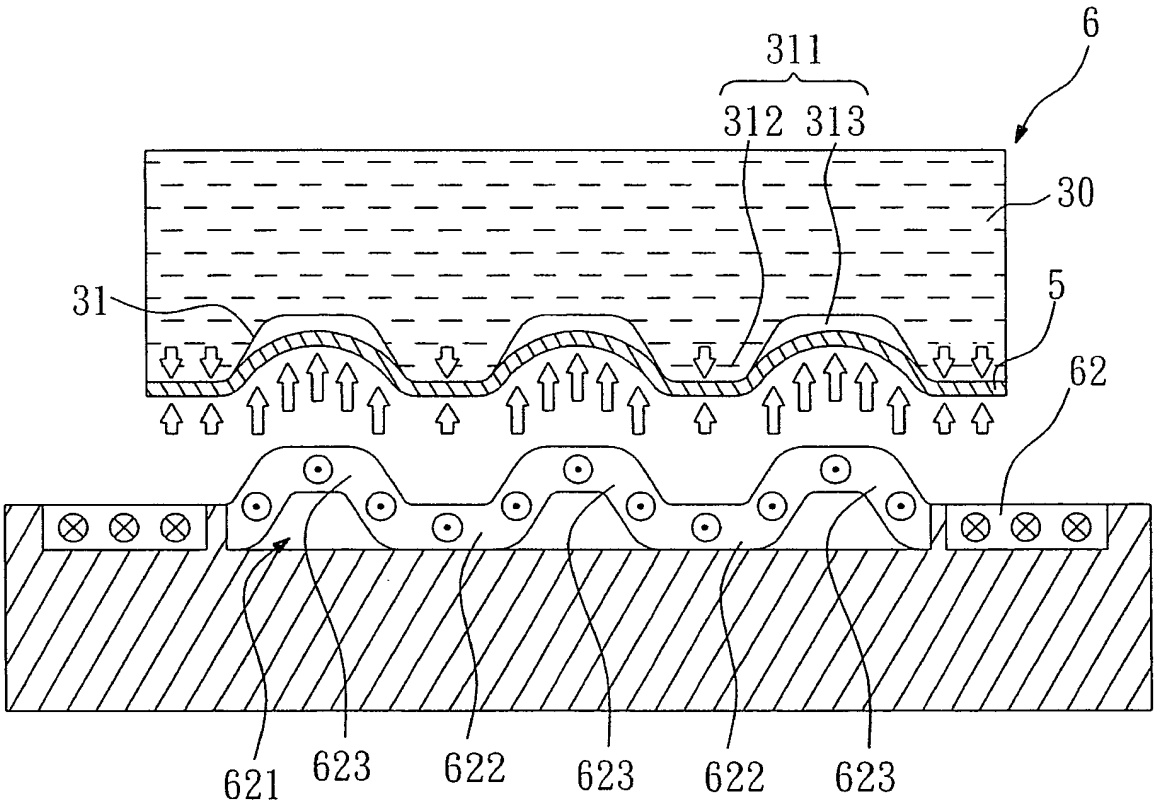

FIG. 7

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- US 7076981 B **[0003]**
- US 7178374 B **[0004]**