



(10) International Publication Number
WO 2009/108208 A1

(43) International Publication Date
3 September 2009 (03.09.2009)

PCT

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| <p>(51) International Patent Classification:
 <i>H04R 7/04</i> (2006.01) <i>H04R 9/02</i> (2006.01)</p> | <p>[US/US]; 814 Livingston Court, Marietta, GA 30067 (US).</p> |
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| <p>(22) International Filing Date:
 5 March 2008 (05.03.2008)</p> | |
| <p>(25) Filing Language: English</p> | |
| <p>(26) Publication Language: English</p> | <p>(74) Agent: ISAF, Louis T.; Womble Carlyle Sandrige & Rice, PLLC, P.o.box 7037, Atlanta, GA 30357-0037 (US).</p> |
| <p>(30) Priority Data:
 61/032,131 28 February 2008 (28.02.2008) US</p> | <p>(81) Designated States (<i>unless otherwise indicated, for every kind of national protection available</i>): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR,</p> |
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(54) Title: PLANAR LOUDSPEAKERS, OR THE LIKE, AND ASSOCIATED METHODS

(57) Abstract: Electromechanical transducers, such as loudspeakers and speaker systems, are described herein. In particular, planar speaker systems and methods of manufacturing planar speaker systems are described. In one embodiment, among others, an electromechanical transducer comprises a substantially planar substrate and a frame adapted to support the substrate. Also, a plurality of electrically conductive circuits are formed on the substantially planar substrate.

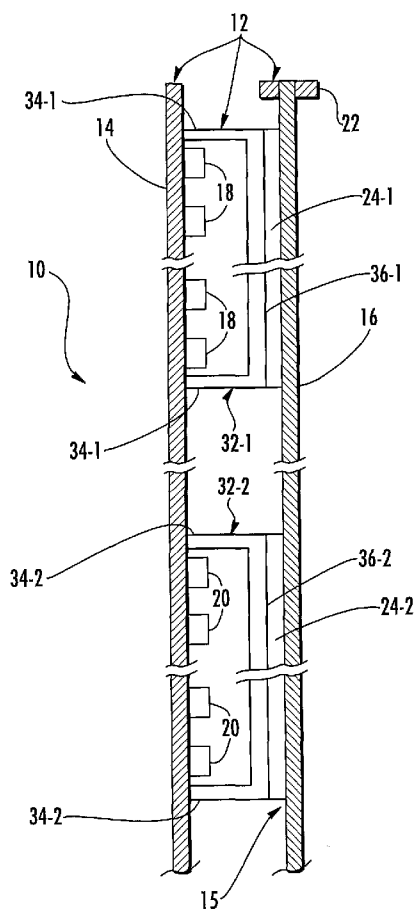


FIG. 1



KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *with international search report (Art. 21(3))*

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI

PLANAR LOUDSPEAKERS, OR THE LIKE, AND ASSOCIATED METHODS

TECHNICAL FIELD

5 The present disclosure generally relates to electromechanical transducers and, more particularly, to planar speaker systems and methods for manufacturing webs for use therein.

BACKGROUND

10 For many years, speaker systems with loudspeakers have been used in various applications for conveying audio signals to listeners. Many loudspeakers in use are referred to as “cone” speakers because of their cone-shaped design. Cone speakers use a magnet and moving coil arrangement to convert incoming electrical signals to vibrations of the cone, and the vibrations produce sound waves.

15 Another type of loudspeaker is the planar speaker, which has a substantially planar shape. A portion of the structure of a planar speaker typically includes an arrangement of magnets that create a standing magnetic field. The planar speaker also includes, within the magnetic field, a flexible substrate upon which a speaker circuit is formed. In response to electrical signals propagating through the speaker circuit,
20 which consequently alters its magnetic properties, the speaker circuit experiences a force of attraction to one magnetic pole while experiencing a repelling force from the other pole. In this way, the substrate vibrates in response to the electrical audio signals, thus creating sound waves. As examples, each of U.S. Patent Application Publication No. 2004/0200801, U.S. Patent No. 6,492,009 and U.S. Patent No.
25 6,645,389 disclose some aspects of planar speakers, and the entire disclosure of each of the above-referenced documents is incorporated herein by reference.

 Many speaker systems include multiple loudspeakers. In order to sufficiently produce a wide range of audible frequencies, different types of loudspeakers can be used. For example, a relatively large loudspeaker, referred to as a “woofer”, is
30 typically able to accurately produce sounds within a relatively lower frequency range. A relatively small loudspeaker, referred to as a “tweeter”, is typically able to accurately produce sounds within a relatively higher frequency range. In addition,

speaker systems typically use a “midrange” loudspeaker to produce sounds within a relatively intermediate frequency range that is between the relatively lower and higher frequency ranges. In many systems, a crossover circuit is used to filter out certain out-of-range frequencies for each respective loudspeaker. In this way, each speaker is
5 supplied with a range of frequencies that it can properly handle.

In the field of speaker system design, there is always a desire for a new balance of properties, for example with respect to simplifying the manufacturing process for creating speaker systems, particularly planar speaker systems.

10

SUMMARY

The present disclosure describes electromechanical transducers, such as planar speakers of audio systems. In one embodiment, among others, an electromechanical transducer comprises a frame adapted to support a substrate having a plurality of electrically conductive circuits formed thereon. The substrate, or at least a portion
15 thereof, may be substantially planar, and the circuits may be formed by selective demetalization with an etchant. In one example, at least first and second speaker circuits are provided on the same substrate. The first speaker circuit may be subjected to a first magnetic field, and the second speaker circuit may be subjected to a second magnetic field, or both speaker circuits may be subjected to the same magnetic field.
20 A first force (e.g., related to the first magnetic field) acts upon the first speaker circuit, such as when electrical current flows through the first speaker circuit. Also, a second force (e.g., related to the second magnetic field) acts upon the second speaker circuit, such as when electrical current flows through the second speaker circuit. These forces cause vibrations that produce audible noise.

25 The present disclosure also describes methods of manufacturing planar speaker systems. In one implementation, a method comprises the step of forming multiple planar speaker circuits on a single substrate. The method also includes the step of supporting the single substrate (e.g., the web that includes the substrate and speaker circuits) using a frame.

30 Other features, advantages, and implementations of the present invention will be apparent to one of ordinary skill in the art upon examination of the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The following figures are schematic, and the components shown in the figures are not necessarily drawn to scale. Instead, emphasis is placed upon clearly illustrating the general principles of the present disclosure. Reference characters designating corresponding components are repeated as necessary throughout the figures for the sake of consistency and clarity.

Fig. 1 is a side cross-sectional view of portions of a planar speaker system, in accordance with a first embodiment of the present invention.

10 Fig. 2 is front view of a representative speaker subcomponent exploded away from an associated subframe, in accordance with the first embodiment of the present invention.

Fig. 3 is an exploded front view of a web and portions of a frame of a planar speaker system, in accordance with a second embodiment of the present invention.

15 Fig. 4 is an exploded front view of a web and portions of a frame of a planar speaker system, in accordance with a third embodiment of the present invention.

Fig. 5 is an exploded front view of a web and portions of a frame of a planar speaker system, in accordance with a fourth embodiment of the present invention.

20 Fig. 6 is an isolated view of a web of a planar speaker system, wherein the web is shown in a flat configuration, although the web includes regions for respectively extending in different planes, in accordance with a fifth embodiment of the present invention.

25 Fig. 7A is an isolated view of a web of a planar speaker system, wherein the web is shown in a flat configuration, although the web includes regions for respectively extending in different planes, in accordance with a sixth embodiment of the present invention.

Fig. 7B is an exploded view of portions of the planar speaker system of the sixth embodiment of the present invention.

30 Fig. 8A is an isolated view of a web of a planar speaker system, wherein the web is shown in a flat configuration, although the web includes regions for respectively extending in different planes, in accordance with a seventh embodiment of the present invention.

Fig. 8B shows the web of Fig. 8A formed into a three-dimensional shape, in accordance with a version of the seventh embodiment of the present invention.

Fig. 9 is a flow chart illustrating an embodiment of a method for manufacturing a speaker system.

5 Fig. 10 is a flow chart illustrating an embodiment of a method for forming a web of a planar speaker system.

DETAILED DESCRIPTION

In the following, a brief discussion of one aspect of a first embodiment of the present invention is followed by a more detailed discussion. As described in greater detail below, a single web can include multiple speaker circuits formed on a flexible substrate. The web, which includes the multiple speaker circuits, can be mounted on a frame in a manner such that at least some of the multiple speaker circuits are substantially simultaneously aligned with respective features (e.g., subframes) of the frame and/or respective features (e.g., magnets) carried by the frame.

15 Fig. 1 is a schematic cross-sectional view of portions of an electromechanical transducer, which is described in the following in accordance with the first embodiment of the present invention. The electromechanical transducer may be configured as a planar speaker system 10 that includes, among other things, a frame 12 (e.g., an enclosure and/or cabinet-like frame) that includes a fixed support 14. The planar speaker system 10 also includes a web 15, and the web includes a flexible substrate 16. At least portions of the substrate 16 are for being vibrated to create sound waves, and the substrate may be any suitable material, as will be discussed in greater detail below. The flexible substrate 16 includes edge portions that are typically held stationary by the frame 12. If desired, the web 15 may be covered with a fabric cover (not shown) or any other suitable cover for the purpose of decoration and/or protection. Typically any such cover will be spaced apart from the portions of the substrate 16 / web 15 that vibrate, so as not to interfere with the vibrating of the substrate 16.

30 In some embodiments, the planar speaker system 10 includes a second web positioned on an opposite side of the fixed support 14 from the web 15. The second flexible substrate can be configured to include substantially the same structure and

functions as mentioned herein with respect to the web 15. Thus, multiple webs may be used in the planar speaker system 10.

Residing on the fixed support 14 are one or more magnets, or sets of magnets (e.g., permanent magnets) for creating standing magnetic fields. As shown in Fig. 1, the fixed support 14 includes a first set of magnets 18, which creates a first magnetic field pattern, and a second set of magnets 20, which creates a second magnetic field pattern. Depending on the design of the planar speaker system 10, the fixed support 14 can include additional sets of magnets positioned thereon to create additional magnetic field patterns. The number of corresponding sets of magnets typically depends primarily on the number of speakers or speaker circuits included in the planar speaker system 10. Alternatively, multiple speaker circuits may be associated with a single set of magnets, or the like.

The flexible substrate 16 is positioned near the fixed support 14. The peripheral edges of the flexible substrate 16 are typically respectively supported by fixed edge supports 22. The fixed edge supports 22 form part of the structure of the frame 12. The fixed edge supports 22 are positioned to support at least two edges (e.g., the fixed edge supports 22 may respectively support all of the peripheral edges) of the flexible substrate 16 in a fixed relationship with the fixed support 14 and the corresponding sets of magnets. The peripheral edges of the flexible substrate 16 may be fixedly mounted to the edge supports 22 by way of adhesive material, clips, or by way of any other suitable material, devices or mounting method.

In accordance with the first embodiment and as best understood with reference to Fig. 1, the web 15 includes at least two composite components (e.g., loudspeaker subcomponents 24-1 and 24-2) formed on one side or both sides of the flexible substrate 16. Fig. 2 is a schematic front view that illustrates a speaker subcomponent 24 that is representative of each of the speaker subcomponents 24-1 and 24-2 shown in Fig. 1, and Fig. 2 shows the representative speaker subcomponent 24 exploded away from a representative subframe 32, as will be discussed in greater detail below. As will also be discussed in greater detail below, features of the representative speaker subcomponent 24 may be formed, for example, by selective demetalization with an etchant. In accordance with the first embodiment, the representative speaker

subcomponent 24 includes a speaker circuit 25 and a border 30 that are formed (e.g., by selective demetalization with an etchant) on the flexible substrate 16.

As best understood with reference to Fig. 2, the speaker circuit 25 of the representative speaker subcomponent 24 includes a serpentine electrically conductive path 26 formed on the flexible substrate 16. The ends of conductive path 26 typically terminate at terminal pads 28, which can be connected to electrical conductors that supply audio signals in electrical form. In some embodiments, the terminal pads 28 may be connected to terminal pads of other speaker circuits formed on the same flexible substrate 16. As a result, the electrical signals can be applied to the different speaker circuits in parallel. The conductive path 26 can be configured as illustrated in Fig. 2 or in any other suitable configuration.

The border 30 of the representative speaker subcomponent 24 is typically included, but in some situations it is optional and may be omitted. The border 30, when present, typically extends at least substantially all the way around the speaker circuit 25, and the border is shown as extending all the way around the speaker circuit 25 in Fig. 2. As will be discussed in greater detail below, the border 30 may be fixedly mounted in a manner that isolates the portion of the flexible substrate 16 that is bounded by the border from those portions of the flexible substrate that are exterior to the border, so that from a functional standpoint the representative speaker subcomponent 24 may be characterized as including (e.g., consisting essentially of) the speaker circuit 25, border 30, and the portion of the flexible substrate 16 that is bounded by (e.g., substantially surrounded by) the border.

In accordance with the first embodiment and as best understood with reference to Fig. 1, the frame 12 includes subframes 32-1 and 32-2 respectively for the speaker subcomponents 24-1 and 24-2. In accordance with the first embodiment, each subframe 32-1, 32-2 includes a base 34-1, 34-2 mounted to the fixed support 14, and a face 36-1, 36-2 fixedly mounted to the border 30 (see Fig. 2) of the respective speaker subcomponent 24-1, 24-2. The bases 34-1, 34-2 may be mounted to the fixed support 14 by way of adhesive material, clips, or by way of any other suitable material, devices or mounting method.

Fig. 2 shows the representative speaker subcomponent 24, which is representative of each of the speaker subcomponents 24-1, 24-2 of Fig. 1, exploded

away from a subframe 32, which is representative of each of the subframes 32-1, 32-2 of Fig. 1. The border 30 of the representative speaker subcomponent 24 may be fixedly mounted to the face 36 of the representative subframe 32 by way of adhesive material, or by way of any other suitable material, device or mounting method. In accordance with the first embodiment, the face 36 of the representative subframe 32 is shaped and sized substantially the same as the border 30 of the representative speaker subcomponent 24, and the face 36 extends around and defines an opening 38. Accordingly, the border 30 of the representative speaker subcomponent 24 can be characterized as extending substantially around the opening 38. While they are vibrating, the speaker circuit 25 of the representative speaker subcomponent 24 and the speaker subcomponent's portion of the flexible substrate 16 may extend into the subframe's opening 38.

In accordance with the first embodiment, the border 30 of the representative speaker subcomponent 24 and the face 36 of the representative subframe 32 are oriented toward one another (e.g., if it weren't for the adhesive material interposed between them, the border 30 of the representative speaker subcomponent 24 and the face 36 of the representative subframe 32 would be in opposing face-to-face configuration with respect to one another, although other arrangements may be suitable. Accordingly and as an example of the schematic nature of some of the figures of this disclosure, Fig. 2 may appear to be schematic with respect to a version of the first embodiment in which the border 30 and the speaker circuit 25 are formed on only the back side of the flexible substrate 16 (e.g., the border 30 and the speaker circuit 25 may appear to be on the front side of the flexible substrate 16 in Fig. 2). However, the border 30 and the speaker circuit 25 may be on either or both sides of the flexible substrate 16, and the flexible substrate 16 may be transparent to light, so that the border 30 and the speaker circuit 25 may be seen through the flexible substrate 16. For example, Fig. 2 can be characterized as being illustrative of an embodiment in which the flexible substrate 16 is substantially transparent, such that the speaker circuit 25 and the border 30 are seen through the flexible substrate. It is also within the scope of the present invention for the substrate 16 not to be transparent.

As best understood with reference to Fig. 1, when electrical current flows through the speaker circuits 25 (Fig. 2) of the speaker subcomponents 24-1, 24-2, the magnetic properties of the speaker circuits change. Since the web 15 is subjected to magnetic fields from one or more sets of magnets 18, 20, etc., changes in the magnetic properties causes magnetic forces on the speaker circuits 25. The magnetic forces can attract the speaker circuits 25 toward the fixed support 14 or repel the speaker circuits 25 away from the fixed support 14. Typically, the flexible substrate 16 remains fixed, except for those portions of the flexible substrate that are respectively bounded by the borders 30. That is, the portions of the flexible substrate 16 that are bounded by the borders 30 flex with the respective movement of the speaker circuits 25. Stated differently, portions of the flexible substrate 16 that are respectively bounded by the borders 30 can oscillate toward and away from the fixed support 14 in response to the electrical current flowing through respective speaker circuits 25. In effect, the side to side motion of the respective portions of the flexible substrate 16 are vibrations that create sound waves.

As shown in Fig. 1, the web 15 includes at least two speaker subcomponents 24-1, 24-2. The first speaker subcomponent 24-1 is positioned in the vicinity of the first set of magnets 18 such that the first speaker subcomponent 24-1 experiences the effects of the magnetic field created by this set of magnets. More specifically, the first speaker subcomponent 24-1 may be formed so as to be adjacent to or near the first set of magnets 18. Similarly, the second speaker subcomponent 24-2 is located at a position proximate the second set of magnets 20. Any desirable number N of speaker subcomponents 24-1 to 24-N can be included in the web 15. In variations of the first embodiment in which the web 15 includes more than two speaker subcomponents 24, the design of the web 15 and frame 12 typically includes additional speaker subcomponents respectively associated with additional sets of magnets and subframes.

The speaker subcomponents 24-1 to 24-N can be configured to be different types of speaker subcomponents. More specifically and for example, each of the speaker subcomponents 24-1 to 24-N may be any one of a woofer speaker subcomponent having a substantially level frequency response within a range of relatively low audible frequencies, a tweeter speaker subcomponent having a

substantially level frequency response within a range of relatively high audible frequencies, and a midrange speaker subcomponent having a substantially level frequency response within a range of frequencies including frequencies between the relatively low audible frequencies and the relatively high audible frequencies.

- 5 Alternatively, the planar speaker system 10 may include other types of speakers (e.g., subwoofers and super-tweeters).

The differences between the woofer, midrange and tweeter speakers described in the present disclosure may be related to the size of the conductive paths 26 (Fig. 2) and/or borders 30 (Fig. 2) of each speaker subcomponent. For example, a woofer
10 speaker subcomponent may have a relatively large border 30 that is about six inches by twenty-four inches, a midrange speaker subcomponent may have a relatively mid-sized border 30 that is about four inches by eight inches, and a tweeter speaker subcomponent may have a relatively small border 30 that is about two inches by four inches. However, other sizes and other features and/or characteristics for providing
15 specific frequency ranges are within the scope of the present invention. In addition, the different speakers may have different frequency response. For example, the woofer speakers may have a relatively flat frequency response within a range of about 40Hz to about 1kHz; the midrange speakers may have a relatively flat frequency response within a range of about 300 Hz to about 5kHz; and the tweeter speakers may
20 have a relatively flat frequency response within a range of about 2kHz to about 20kHz. Although similar electrically conductive path configurations for the speaker circuits are illustrated in the figures herewith, the speaker circuits may include any suitable path configuration as desired and the speakers may have any suitable size and frequency response.

- 25 In accordance with one acceptable method of the first embodiment, the single web 15 of the first embodiment includes all of the speaker subcomponents 24-1 to 24-N of the first embodiment, and the following occurs substantially simultaneously: the mounting of the edges of the flexible substrate 16 to the edge supports 22 and/or the mounting of the borders 30 to the faces 36 of the subframes 32. As best understood
30 with reference to Fig. 1 and in accordance with the first embodiment: all of the borders 30 (Fig. 2) extend (e.g., substantially extend) in a common first plane; all of the subframe's faces 36 extend (e.g., substantially extend) in a common second plane

that is parallel to and closely adjacent to the first plane; and, while the planar speaker system 10 is not operating, all of the speaker circuits 25 extend (e.g., substantially extend) in the first plane with the borders 30, whereas at least the portions of the substrate 16 that are portions of the speaker subcomponents 24-1 to 24-N extend in a common third plane that is parallel to and closely adjacent to the second plane. The second plane is between the first and third planes. However, different configurations are within the scope of the present invention, and some examples of possible different configurations are described in the following.

Fig. 3 is an exploded, schematic front view of portions of a planar speaker system 110, in accordance with a second embodiment of the present invention. More specifically, Fig. 3 illustrates a substantially planar web 115, which includes speaker subcomponents 124-1, 124-2, 124-3, exploded away from a frame 112, which includes edge supports 122 and subframes 132-1, 132-2, 132-3. Fig. 3 and similar figures are schematic, for example, because the frame's fixed support (e.g., see the fixed support 14 in Fig. 1) and the magnets (e.g., see the magnets 18, 20 shown in Fig. 1) are not shown in Fig. 3. The second embodiment of the present invention is like the first embodiment, except for variations noted and variations that will be apparent to one of ordinary skill in the art. Accordingly, reference numerals for features of the second embodiment that are like corresponding features of the first embodiment are incremented by 100.

In accordance with the second embodiment, the web 115 includes three differently sized speaker subcomponents 124-1, 124-2, 124-3, and the frame 112 includes three differently sized subframes 132-1, 132-2, 133-3 / subframe faces 136-1, 136-2, 136-3 that are respectively aligned with and mounted to the borders (e.g., see border 30 in Fig. 2) of the speaker subcomponents 124-1, 124-2, 124-3. The periphery of the web 115 is sized for being mounted to / is mounted to the frame's peripheral edge supports 122.

The relatively large speaker subcomponent 124-1 is a subcomponent of a woofer speaker, which is better able to handle relatively lower frequency signals. The woofer speaker subcomponent 124-1 can thus produce low frequency oscillation of the respective portion of the flexible substrate 116 to create relatively low frequency sound waves. The relatively medium-sized speaker subcomponent 124-2 is a

component of a midrange speaker, which is better able to handle frequency signals within a relatively middle range between the woofer and tweeter speakers. The medium speaker subcomponent 124-2 can thus produce oscillations in the respective portion of the flexible substrate 116 at these relatively middle frequencies for creating sound waves in the relatively intermediate audible range. The relatively small speaker subcomponent 124-3 represents a subcomponent of a tweeter speaker, which is better able to handle higher frequency signals. The small speaker subcomponent 124-3 can thus produce relatively high frequency oscillation of the respective portion of the flexible substrate 116 to create high frequency sound waves.

10 Fig. 4 is a schematic front view of a substantially planar web 215, which includes speaker subcomponents 224-1, 224-2, 224-3, exploded away from a frame 212, which includes edge supports 222 and subframes 232-1, 232-2, 232-3, in accordance with a third embodiment of the present invention. The third embodiment of the present invention is like the second embodiment, except for variations noted and variations that will be apparent to one of ordinary skill in the art. Accordingly, reference numerals for features of the third embodiment that are like corresponding features of the second embodiment are incremented by 100. Unlike the embodiment of Fig. 3, the embodiment of Fig. 4 includes, for example, multiple tweeters / tweeter speaker subcomponents 224-3 and multiple midrange speakers / midrange speaker subcomponents 224-2. In some embodiments, there can be multiple woofers / woofer speaker subcomponents 224-1. As illustrated in Fig. 4, the tweeter speaker subcomponents 224-3 are positioned proximate the four corners of the flexible substrate 216.

25 Fig. 5 is a schematic front view of a substantially planar web 315, which includes speaker subcomponents 324-1, 324-2, 324-3, exploded away from a frame 312, which includes edge supports 322 and subframes 332-1, 332-2, 332-3, in accordance with a fourth embodiment of the present invention. The fourth embodiment of the present invention is like the third embodiment, except for variations noted and variations that will be apparent to one of ordinary skill in the art. Accordingly, reference numerals for features of the fourth embodiment that are like corresponding features of the third embodiment are incremented by 100. The arrangement of Fig. 5 is different from that of Fig. 4 in that, for example, the tweeter

speaker subcomponents 324-3 are positioned at a top portion of the flexible substrate 316, the midrange speaker subcomponents 324-2 are positioned at a middle portion of the flexible substrate 316, and the woofer speaker subcomponent 324-1 is positioned at a lower portion of the flexible substrate 316. A variety of arrangements are within
5 the scope of the present invention.

Fig. 6 is a schematic isolated view of a web 415 of a planar speaker system in a flat configuration, in accordance with a fifth embodiment of the present invention. The fifth embodiment of the present invention is like the fourth embodiment, except for variations noted and variations that will be apparent to one of ordinary skill in the
10 art. Accordingly, reference numerals for features of the fifth embodiment that are like corresponding features of the fourth embodiment are incremented by 100.

In accordance with the fifth embodiment, the web 415 is segregated into regions 50, 52, 54 that respectively include the woofer, midrange and tweeter speaker subcomponents 424-1, 424-2, 424-3. The regions 50, 52, 54 may be respectively
15 defined, at least in part, by lines of disruption 46, 48 formed in or on the flexible substrate. Each of the lines of disruption 46, 48 may, for example, be a fold line (e.g., a score line for facilitating at least partial folding there along) a line formed by the application of a marking agent or the like (e.g., a line formed by the application of ink), or any other type of line of disruption which is visually apparent, facilitates
20 folding therealong, and/or helps to facilitate mounting to a frame (e.g., see the frame 12 of Fig. 1), as will be discussed in greater detail below. As another specific example, the lines of disruption 46, 48 may be formed at the same time as the speaker subcomponents 424-1, 424-2, 424-3 by selective demetalization with an etchant, as will be discussed in greater detail below.

25 As shown in Fig. 6, the lines of disruption 46, 48 are parallel (e.g., substantially parallel) to one another. However, in other embodiments, the lines of disruption 46, 48 may be oblique with respect to one another or in other arrangements depending on the particular design. More specifically regarding the regions 50, 52, 54 into which the web 415 is segregated, the flexible substrate 416 includes a first region
30 50, a second region 52, and a third region 54. As shown in Fig. 6, the periphery of each region 50, 52, 54 is at least partially defined by the lines of disruption 46, 48, although there may be other arrangements. The regions 50, 52, 54 may accommodate

different types of speaker subcomponents if desired. For example, as illustrated, the tweeter speaker subcomponents 424-3 are positioned in the first region 50, the midrange speaker subcomponents 424-2 are positioned in the second region 52, and the woofer speaker subcomponent 424-1 is positioned in the third region 54.

5 Alternatively, the different regions 50, 52, 54 may include different types and combinations of speaker subcomponents to meet particular design parameters. From the arrangement shown in Fig. 6, the flexible substrate 416 can be folded (e.g., partially folded) along the respective lines of disruption 46, 48 to direct groups of speakers within the respective regions 50, 52, 54 in different directions.

10 The frame of the fifth embodiment (not shown, but for example see frame 12 of Fig. 1) is configured to properly support the flexible substrate 416 in its folded state. Further, the fifth embodiment's fixed support (not shown, but for example see fixed support 14 of Fig. 1) and magnets (not shown, but for example see magnets 18, 20 of Fig. 1) are configured to respectively correspond to the location of the speaker subcomponents 424-1, 424-2, 424-3 with the flexible substrate 416 in its folded state. In this respect, the frame of the fifth embodiment may be designed with additional supports for holding the edges of each region 50, 52, 54. These additional supports of the frame can also help to orient the regions 50, 52, 54 in specific directions according to the design. For each of the regions 50, 52, 54 of the fully assembled and not
20 operating speaker system, the region's borders 30 and speaker circuits 25 typically extend in a common plane.

In some embodiments, the flexible substrate can include one line of disruption to create two regions. Or, the flexible substrate can include any number of lines of disruption to create as many regions as needed to create a specific sound distribution
25 according to a particular design. As explained in more detail below, the flexible substrate can be trimmed or cut to allow the typically single piece of flexible substrate to be formed (e.g., folded) into any desirable shape or configuration.

Fig. 7A is a schematic isolated view of a web 515 of a planar speaker system in a flat configuration, in accordance with a sixth embodiment of the present
30 invention. The sixth embodiment of the present invention is like the fifth embodiment, except for variations noted and variations that will be apparent to one of ordinary skill in the art. Accordingly, reference numerals for features of the sixth

embodiment that are like corresponding features of the fifth embodiment are incremented by 100 or 500.

In accordance with the sixth embodiment, the lines of disruption 546, 548 are not parallel. Rather, the lines of disruption 546, 548 are perpendicular (e.g.,
5 substantially perpendicular) to one another, although they can be oriented at any desirable angle with respect to each other. The lines of disruption 556, 558 divide the flexible substrate 516 into a first region 550, a second region 552, and a third region 554. When the flexible substrate 516 is folded about the lines of disruption 556, 558, an edge 66 of the first region 550 can be aligned to abut an edge 68 of the third region
10 554. In some embodiments, the flexible substrate 516 may include one or more tabs (not shown) along one or both of the edges 66, 68 to facilitate attachment (e.g., adhesion) of the edges 66, 68 together. Adhesive material may be used for adhering the tabs, or they may be attached by way of any suitable devices (e.g., clips), materials and/or methods.

15 Fig. 7B is an exploded schematic view of portions of a planar speaker system 510, in accordance with the sixth embodiment of the present invention. More specifically, Fig. 7B schematically shows the single web 515 of Fig. 7A folded along the lines of disruption 546, 548 into a three-dimensional shape and exploded away from a frame 512, which includes edge supports 522 and subframes 532-1, 532-2,
20 532-3, in accordance with the sixth embodiment. The three-dimensional shape may be formed by folding the flexible substrate 516 along the lines of disruption 546, 548 and optionally joining the edges 66, 68 together. As shown in Fig. 7B, the three regions 550, 552, 554 form a shape that appears to be three sides of a cube, where each side is adjacent to the other two sides.

25 In accordance with the sixth embodiment, the frame 512 is configured so that the subframe face 536-1 extends (e.g., substantially extends) in a first plane, the subframe faces 536-2 extend (e.g., substantially extend) in a common second plane that is not parallel to (e.g., is substantially perpendicular to) the first plane, and the subframe faces 536-3 extend (e.g., substantially extend) in a common third plane that
30 is not parallel to (e.g., is substantially perpendicular to) the first and second planes. When the speaker system 510 of the sixth embodiment is fully assembled, edges and corners of the folded substrate 516 are typically respectively adhered to (or otherwise

attached to in any suitable manner) the edge supports 522 of the frame 512. For example, the lines of disruption 546, 548 may be adhered to or otherwise attached to respective edge supports 522 of the frame. Also, the subframe faces 536-1, 536-2, 536-3 are respectively aligned with and mounted to the borders (e.g., see border 30 of Fig. 2) of the speaker subcomponents 524-1, 524-2, 524-3. Accordingly, the regions 550, 552, 554 extend in (e.g., substantially extend in) planes that are respectively parallel to and adjacent to the first, second and third planes that the subframe faces 536-1, 536-2, 536-3 extend in.

Fig. 8A is a schematic isolated view of a web 615 of a planar speaker system in a flat configuration, in accordance with a seventh embodiment of the present invention. The seventh embodiment of the present invention is like the sixth embodiment, except for variations noted and variations that will be apparent to one of ordinary skill in the art. Accordingly, reference numerals for features of the seventh embodiment that are like corresponding features of the sixth embodiment are incremented by 100.

As shown in Fig. 8A, the web 615 is somewhat circular except for a section or slice that is removed. The removed section in combination with the lines of disruption 646, 648 respectively partially define the generally pie-shaped regions 650, 652, 654. The regions 650, 652, 654 are configured to have substantially the same size and shape as one-another to provide at least some symmetry in a folded state. When the web 615 is folded along the lines of disruption 646, 648, an edge 80 of the first region 650 can be aligned to and abut with an edge 82 of the third region 654. In some embodiments, the flexible substrate 616 may include one or more tabs (not shown), such as adhesion tabs, along one or both of the edges 80, 82 to facilitate attachment of the edges 80, 82 together. This attachment between the edges 80, 82 may be made in any suitable manner, and in some situations these edges may not be directly attached to one another.

Fig. 8B illustrates the web 615 of Fig. 8A formed (e.g., folded) into a three-dimensional shape. The three-dimensional shape can be formed, for example, by folding the web 615 along the lines of disruption 646, 648 and optionally joining the edges 80, 82 together. Fig. 8B is a schematic pictorial view of the planar speaker system 610 of the seventh embodiment, with the three regions 650, 652, 654 together

forming a generally three-sided pyramidal shape with a substantially or somewhat circular base (e.g., substantially a cone). Nonetheless, at least portions of each of the three regions 650, 652, 654 (e.g., at least the speaker subcomponents 624-1, 624-2, 624-3) of the speaker system 610 can be characterized as being substantially planar.

- 5 The frame of the seventh embodiment (not shown, but for example see frame 12 of Fig. 1 and frame 512 of Fig. 7B) can be designed to have a three-dimensional shape that is sufficient to support the web 615 in its three-dimensional shape.

Fig. 9 is a flow chart illustrating an embodiment of a method that may be used, for example, for manufacturing the above-discussed speaker systems. The method of Fig. 9 can also be performed to manufacture other planar speaker systems according to other various design specifications that may be contemplated by one of ordinary skill in the art having an understanding of the present disclosure. Fig. 9 includes designing a planar speaker system, as indicated in block 86. The design of the speaker system can include a design layout of the speaker circuits on a substrate and a structural plan of the frame used for supporting the substrate. Block 86 may be optional and in some implementations may be omitted from the process flow. For instance, when a design is already planned, the method of Fig. 9 can begin with block 88.

In block 88, multiple speaker circuits (and optionally also multiple borders and/or lines of disruption) are formed on one or both sides of a single substrate according to the design of the particular planar speaker system. The multiple speaker circuits may include any size or type of speaker circuits for oscillating the substrate. Each of the speaker circuits / speaker subcomponents may have any suitable frequency response characteristics and may be classified as a tweeter subcomponent, midrange subcomponent, woofer subcomponent, or other frequency range responsive device. In block 90, the method includes coupling conductors, such as speaker wires, to termination pads of the speaker circuits. In some embodiments, the pads of all the speaker circuits on the substrate can be connected in parallel if no cross-over circuit is needed.

30 Block 92 includes the step of preparing the substrate to fit the corresponding frame. The preparing step can include folding along lines of disruption, cutting edges of the substrate, cutting and removing sections of the substrate, and/or other

preparation actions. In block 94, the substrate is attached to the frame according to the particular design. The substrate is supported by the frame in such a way that the substrate (e.g., respective portions of the substrate) can vibrate or oscillate without significant restriction to reproduce desired sound output. Also, the frame may include
5 magnets or other suitable apparatus for establishing a constant magnetic field pattern.

Fig. 10 is a flow chart illustrating an embodiment of a method that may be used for forming, or at least partially forming, any one of the above-discussed webs by forming multiple speaker subcomponents onto a substrate. As an example, the method of Fig. 10 may correspond to block 88 shown in Fig. 9 for forming multiple
10 speaker circuits (and optionally also multiple borders and/or line(s) of disruption) on a single substrate. In block 96 of Fig. 10, the method includes providing a plastic film base or any other suitable base as the substrate. The plastic film base can include any flexible material suitable for sound reproduction when oscillated. For example, the plastic film base may comprise polyester, such as polyethylene naphthalate (PEN).
15 The method further includes laminating the base with a foil layer, such as an aluminum foil layer, as indicated in block 98. In some embodiments, both sides of the base can be laminated with foil. In block 100, at least a design of the speaker subcomponents (e.g., the speaker circuits, and optionally also the multiple borders and/or line(s) of disruption) is printed onto the foil layer, such as with a protective ink
20 or another type of protective coating. The printed design may be for defining any size, shape, frequency response, type, etc., of a plurality of planar speaker circuits and optionally also multiple borders and/or line(s) of disruption. Printing the design typically also entails printing / defining termination pads for each speaker circuit for contact with external circuitry. In some embodiments, block 100 may also include
25 printing / defining conducting paths that connect the multiple speaker circuits in parallel. Block 102 includes the step of immersing the base into a caustic bath or otherwise suitably exposing the base to a suitable etchant to etch away the unprotected foil to form the resultant web. More specifically, typically a plurality of the webs are formed in series and subsequently separated from one another by cutting, such that
30 each resulting web includes at least two of the speaker subcomponents. Other post-production steps, such as adding protection layers, can be included in the method of Fig. 10 as well. The etching away of the unprotected foil can be generally referred to

as selective demetalizing with an etchant, and the demetalizing can be carried out in any suitable fashion.

The embodiments described herein merely represent exemplary implementations and are not intended to necessarily limit the present disclosure to any specific examples. Instead, various modifications can be made to these embodiments as would be understood by one of ordinary skill in the art. Any such modifications are intended to be included within the spirit and scope of the present disclosure and protected by the following claims. That is, it will be understood by those skilled in the art that while the present invention has been discussed above with reference to exemplary embodiments, various additions, modifications and changes can be made thereto without departing from the spirit and scope of the invention as set forth in the following claims.

CLAIMS

I claim:

- 5 1. An electromechanical transducer comprising:
 a web including a substrate and a plurality of circuits formed on the substrate
 by selective demetalization with an etchant, wherein at least a portion of the substrate
 is substantially planar, and the circuits are electrically conductive; and
 a frame to which the web is mounted.
- 10 2. The electromechanical transducer of claim 1, wherein the
 electromechanical transducer is a speaker system.
3. The electromechanical transducer of claim 1, wherein at least two of
15 the electrically conductive circuits are on the substantially planar portion of the
 flexible substrate.
4. The electromechanical transducer of claim 1, wherein:
 the substantially planar portion of the flexible substrate is a first substantially
20 planar portion of the flexible substrate;
 the flexible substrate includes a second substantially planar portion that
 extends nonparallel to the first substantially planar portion of the flexible substrate;
 at least a first of the electrically conductive circuits is on the first substantially
 planar portion of the flexible substrate; and
25 at least a second of the electrically conductive circuits is on the second
 substantially planar portion of the flexible substrate.
5. The electromechanical transducer of claim 1, wherein:
 the substrate together with the circuits at least partially forms a plurality of
30 electromechanical transducer components; and

each component of the plurality of electromechanical transducer components is configured to provide a substantially level frequency response within a particular frequency range.

5 6. The electromechanical transducer of claim 5, wherein the plurality of electromechanical transducer components comprises a tweeter speaker, a midrange speaker, and a woofer speaker.

10 7. The electromechanical transducer of claim 6, wherein the plurality of electromechanical transducer components further comprises multiple tweeter speakers.

 8. The electromechanical transducer of claim 1, wherein the substrate comprises at least one fold line.

15

 9. The electromechanical transducer of claim 8, wherein:
 the web is at least partially folded along the fold line so that the fold line at least partially defines regions of the web that face different directions; and
 the frame is configured for sufficiently supporting each of the regions of the
20 web.

 10. The electromechanical transducer of claim 1, wherein the plurality of electrically conductive circuits are connected in parallel.

25 11. A method of manufacturing a planar speaker system, the method comprising:
 providing a web that includes a plurality of speaker circuits; and
 then mounting the web, which includes the plurality of speaker circuits, to a
 frame.

30

12. The method of claim 11, wherein:
the providing step comprises forming the speaker circuits, and
the forming step comprises selectively demetalizing with an etchant.

5 13. The method of claim 11, wherein:
the web includes a plurality of borders;
the borders respectively extend substantially around the speaker circuits;
the mounting step comprises substantially simultaneously mounting the
borders to the frame.

10

14. The method of claim 13, wherein:
the frame includes a plurality of openings, and
the borders respectively extend substantially around the openings.

15 15. The method of claim 11, wherein the mounting step comprises at least
partially folding the web along the at least one fold line, the at least one fold line
divides the substrate into a plurality of regions, and each region contains at least one
of the speaker circuits.

20 16. The method of claim 15, wherein the folding step comprises orienting
the plurality of regions to face different directions.

17. The method of claim 15, further comprising:
before the folding step, cutting the web to form a first edge and a second edge;
25 and
aligning the first edge and the second edge with one another.

18. The method of claim 11, wherein the providing step comprises:
laminating a substrate with foil;
30 printing a design of at least the plurality of speaker circuits on the foil; and
removing the unprinted portions of the foil.

19. The method of claim 18, wherein the removing step comprises immersing the substrate in a caustic bath.

20. The method of claim 11, wherein the providing step comprises:
- 5 forming a first speaker subcomponent, wherein the first speaker subcomponent comprises a first speaker circuit of the plurality of speaker circuits, and the first speaker subcomponent is configured for having a substantially uniform frequency response within a range of relatively low audible frequencies;
- forming a second speaker subcomponent, wherein the second speaker
- 10 subcomponent comprises a second speaker circuit of the plurality of speaker circuits, and the second speaker subcomponent is configured for having a substantially uniform frequency response within a range of relatively high audible frequencies; and
- forming a third speaker subcomponent, wherein the third speaker
- subcomponent comprises a third speaker circuit of the plurality of speaker circuits,
- 15 and the third speaker subcomponent is configured for having a substantially uniform frequency response at least within a range of frequencies between the low audible frequencies and the high audible frequencies.

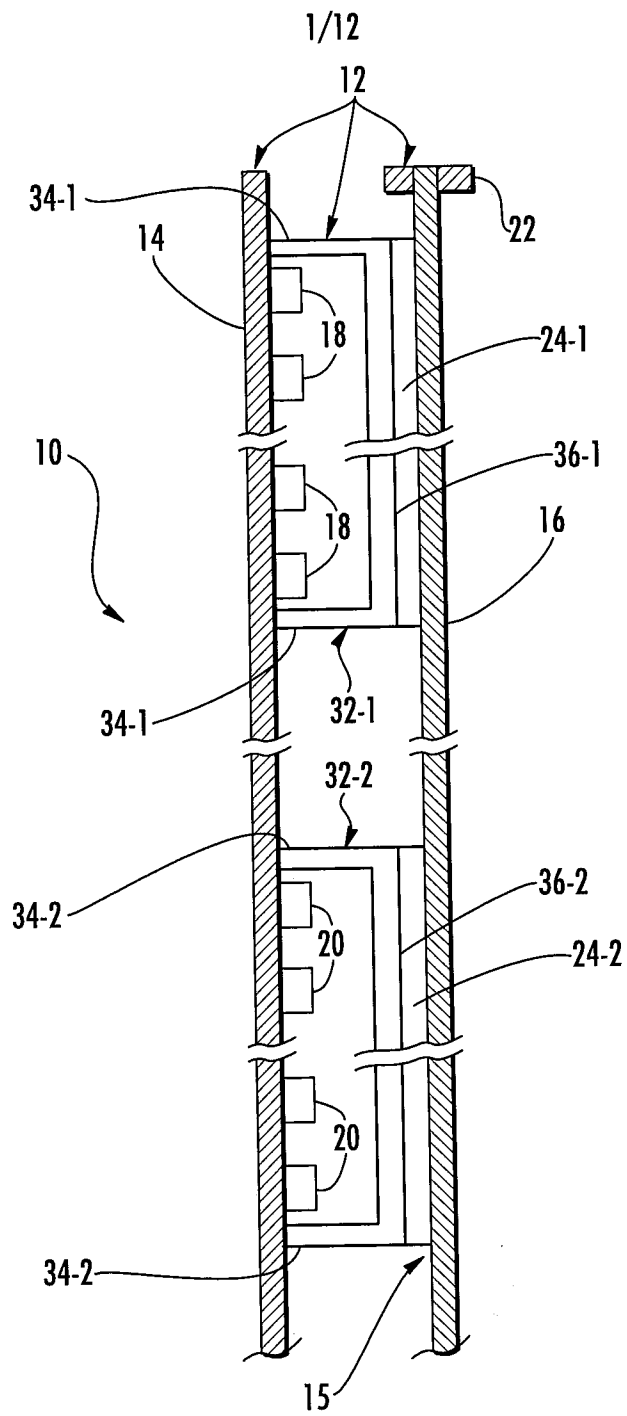


FIG. 1

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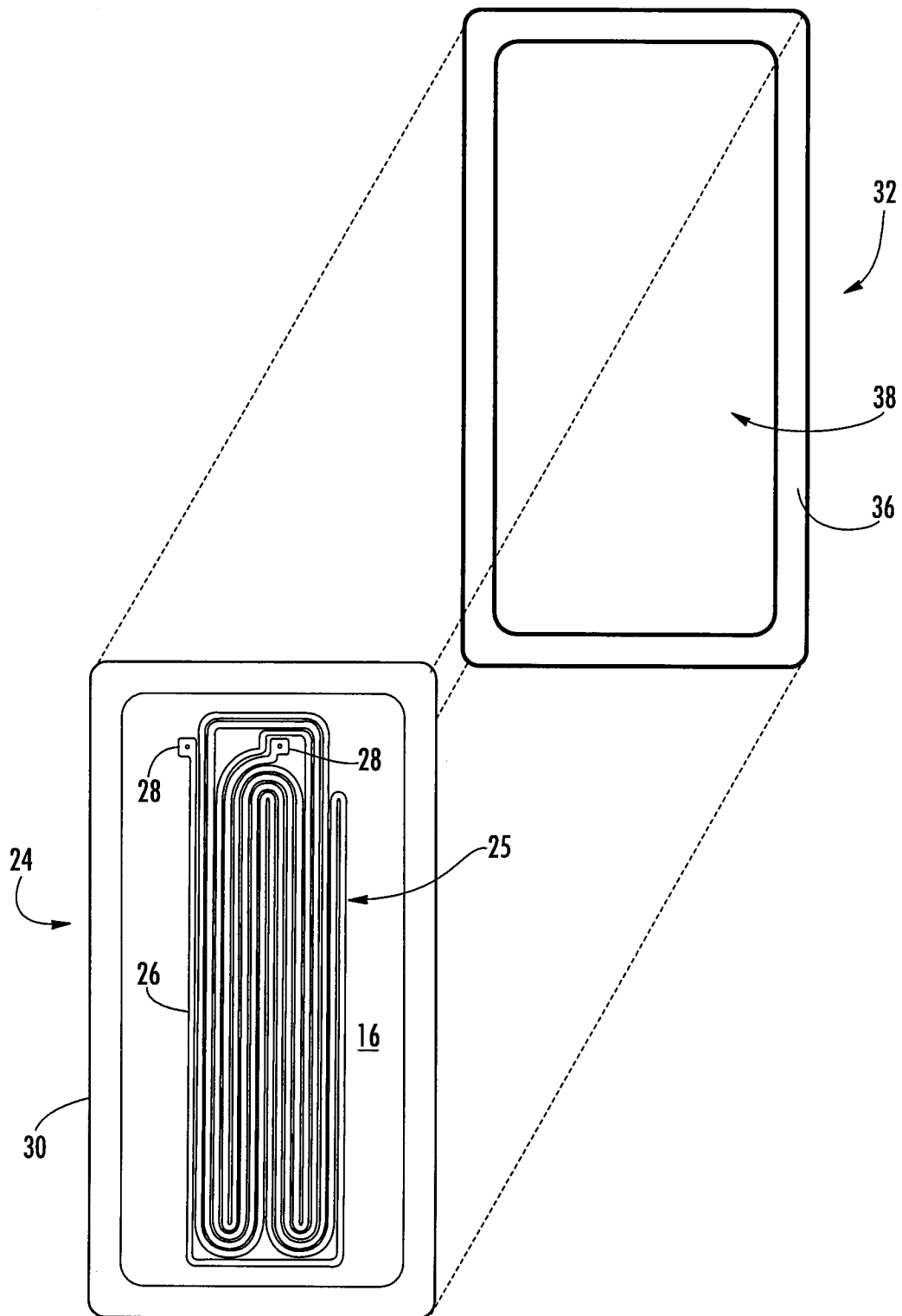
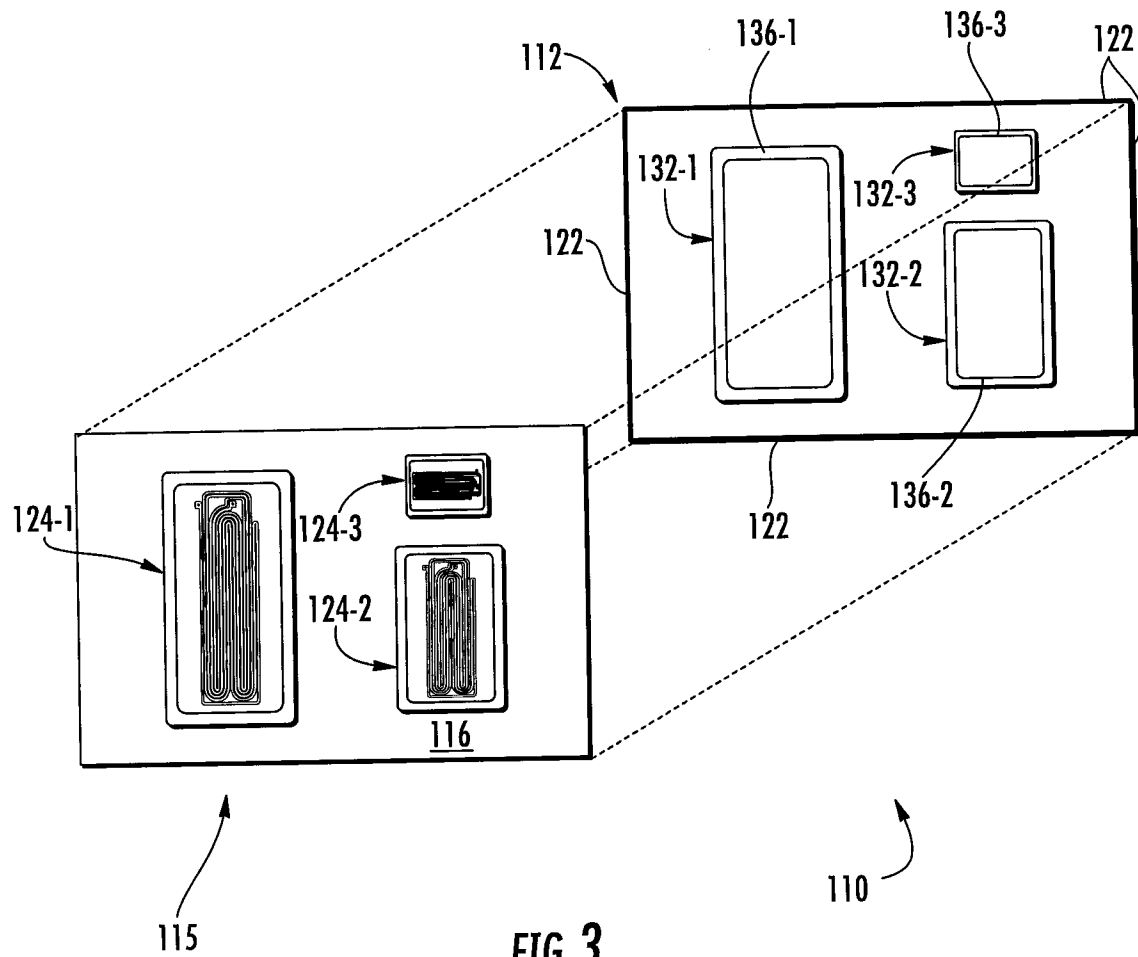
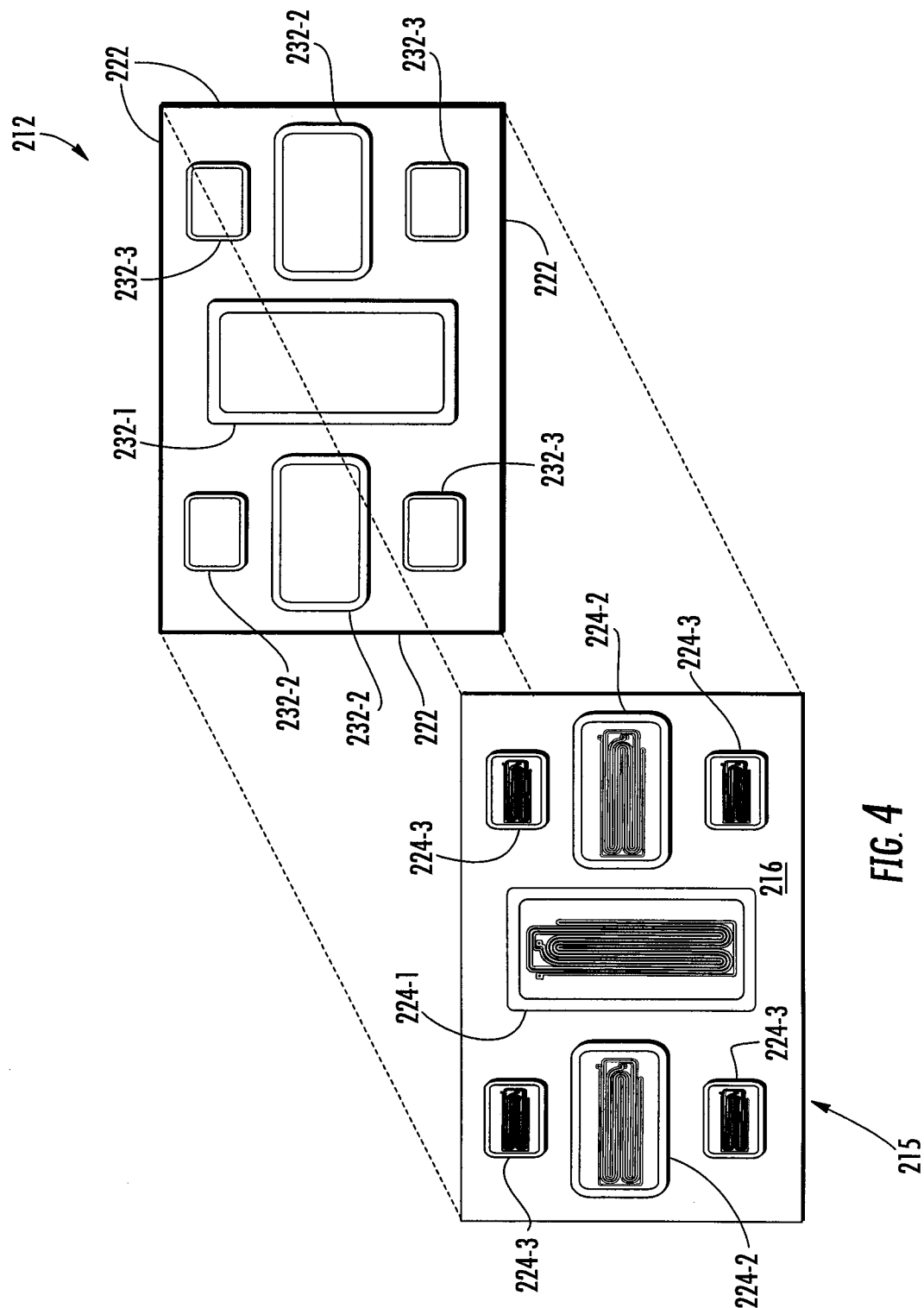
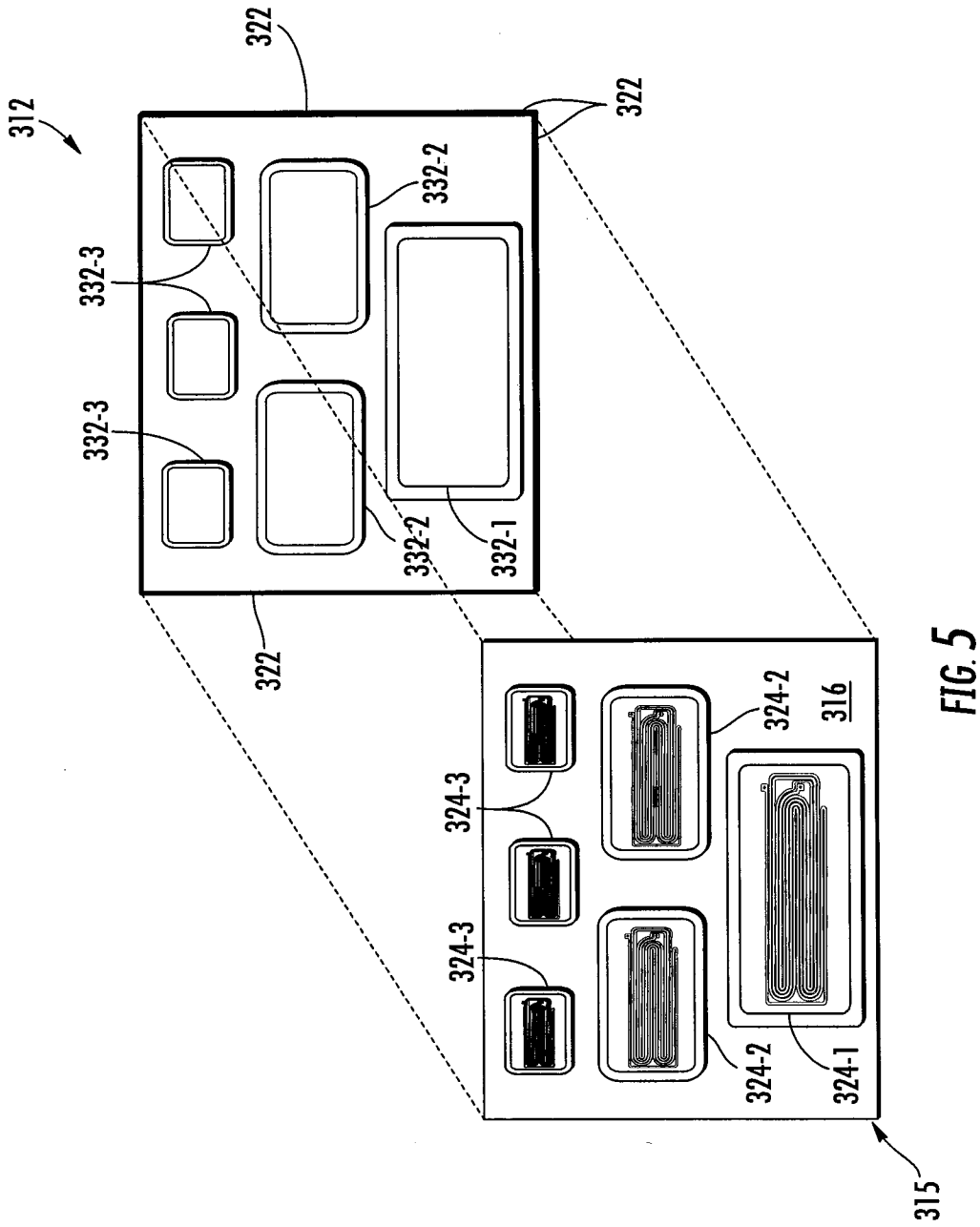


FIG. 2

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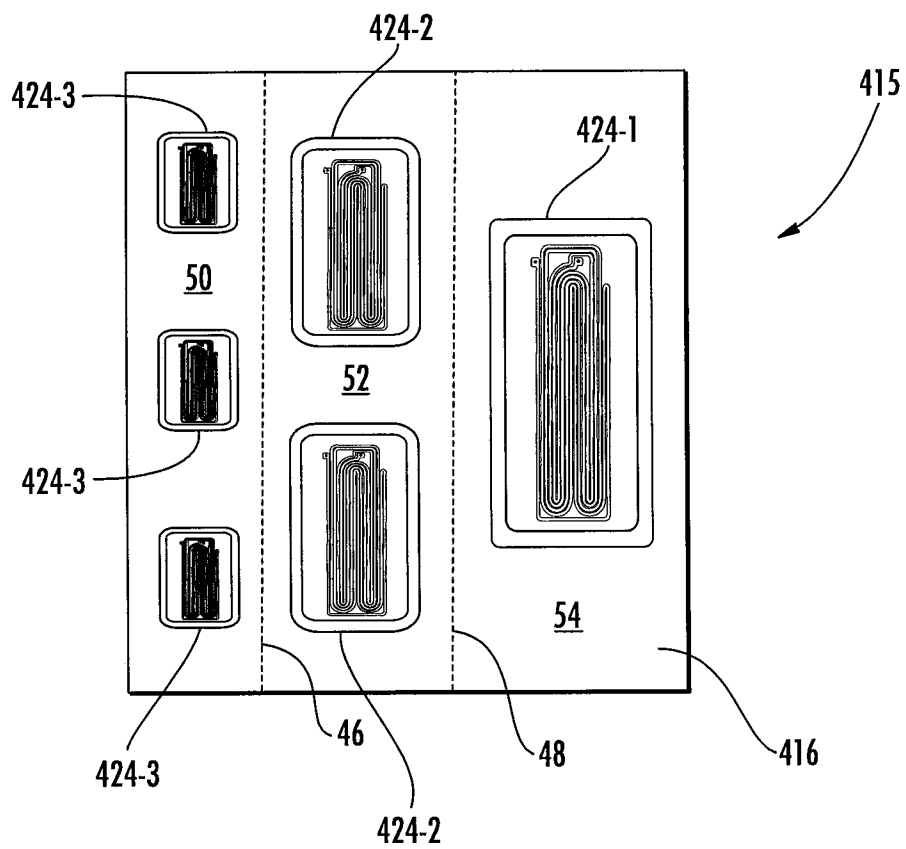


FIG. 6

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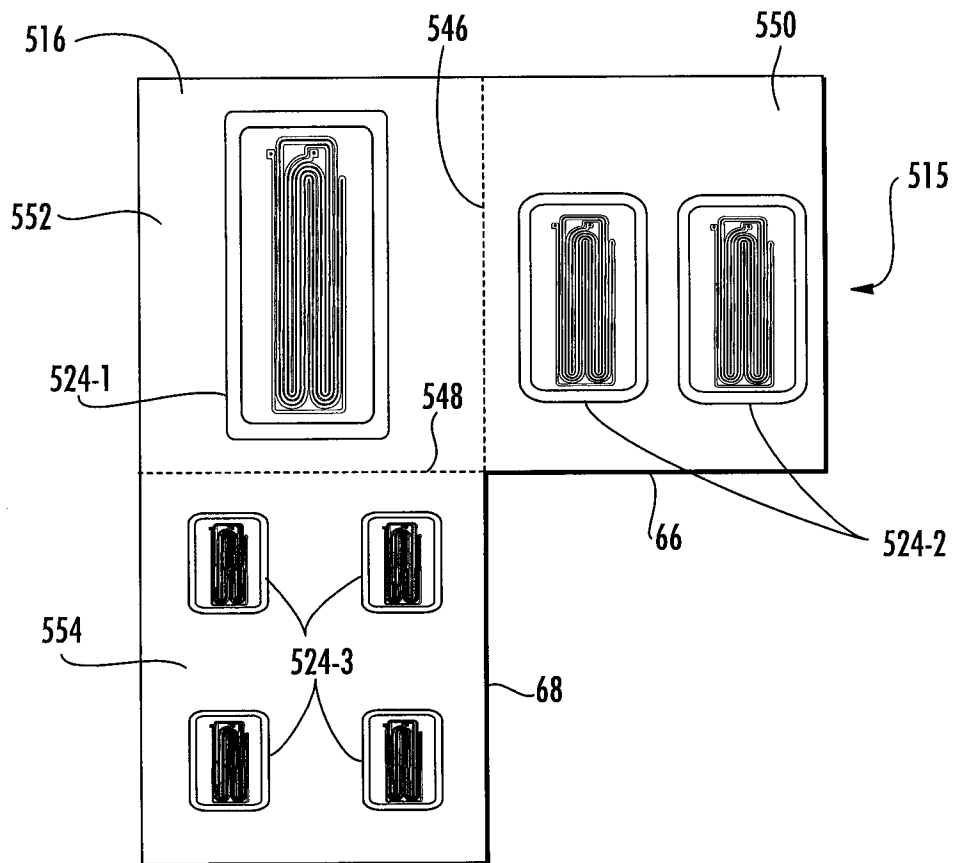


FIG. 7A

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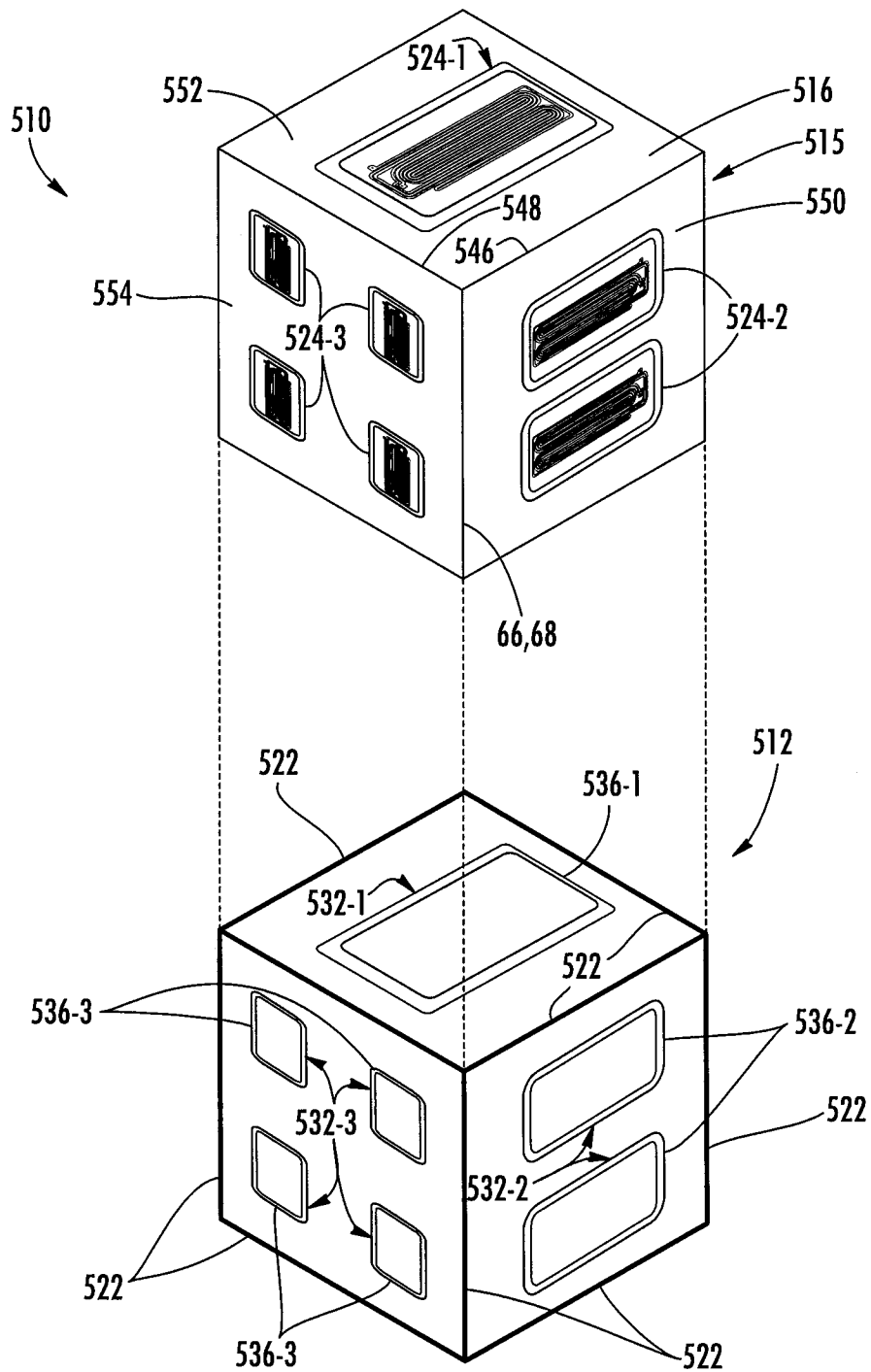


FIG. 7B

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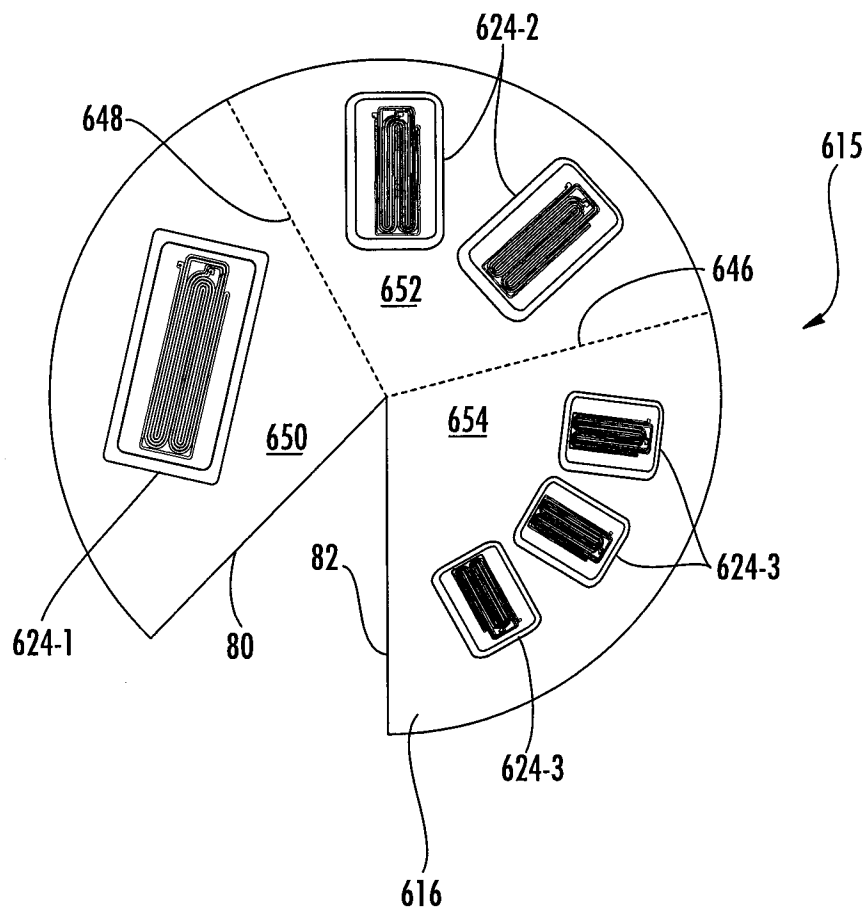


FIG. 8A

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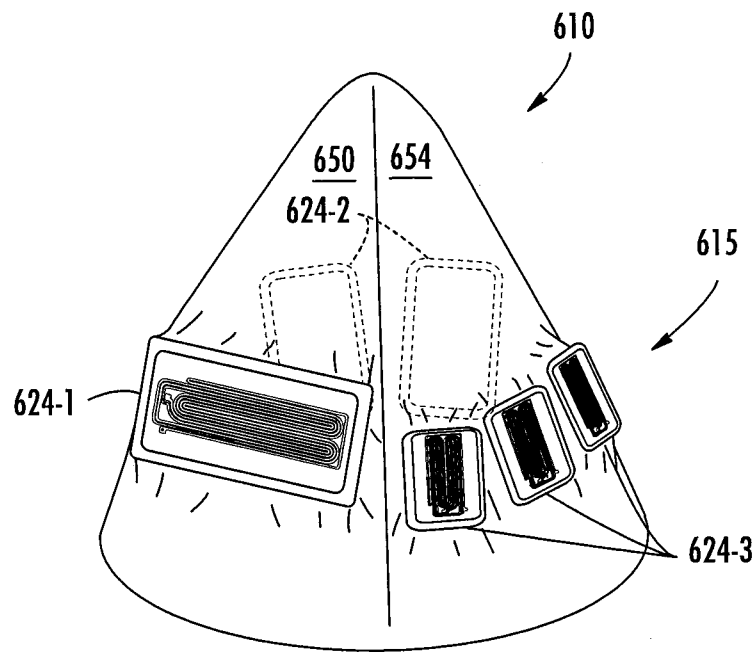
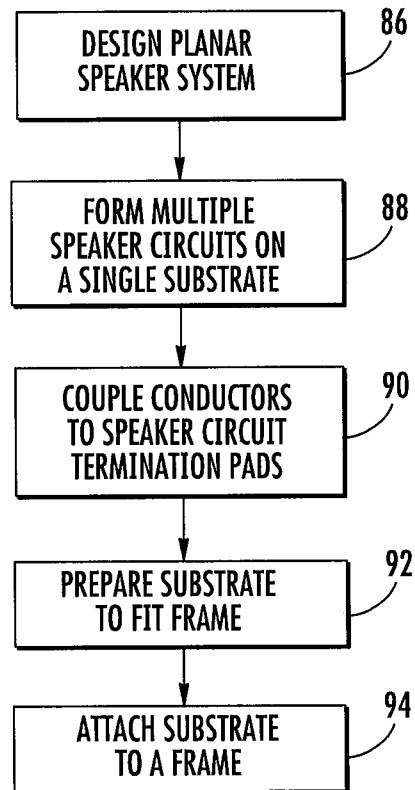
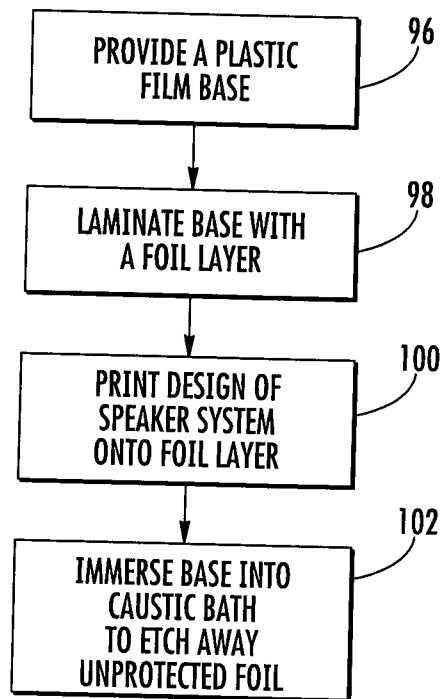


FIG. 8B

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**FIG. 9**

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**FIG. 10**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2008/055836**A. CLASSIFICATION OF SUBJECT MATTER****H04R 7/04(2006.01)i, H04R 9/02(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)

IPC 8 : H04R

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

Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PAJ, FPD, USPAT, eKIPASS, IEEE, YAHOO, GOOGLE, Keyword: "planar speaker, echting, echant, foil"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	US 7142688 B2 (JAMES J. CROFT et al) 28 November 2006 (See Abstract, Figs.24, 25, column 30 line 59-column 31 line 15, column 31 line 53- column 32 line 21)	3-20
X Y	US 2003-0035938 A1 (Laurence M.C. Lai) 20 February 2003 (See Abstract, Figs.2A-4, paragraphs [0009]-[0016], [0033]-[0036])	1-2 3-20
A	KR 10-2004-0091056 A (THE FURUKAWA ELECTRIC CO., LTD.) 27 October 2004 (See Abstract, Figs.2-5, pages 6-7)	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search

27 NOVEMBER 2008 (27.11.2008)

Date of mailing of the international search report

27 NOVEMBER 2008 (27.11.2008)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2008/055836

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