United States Patent

[11] 3,588,382

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[45] Patented **June 28, 1971**

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[54] **DIRECTIONAL ELECTRET TRANSDUCER**
9 Claims, 19 Drawing Figs.

[52] **U.S. Cl.** **179/111E,** 179/121D
[51] **Int. Cl.** **H04r 19/04,** H04r 1/32
[50] **Field of Search** ..... 179/100.41 (B), 111 (E); 307/88 (E); 317/24 (b)

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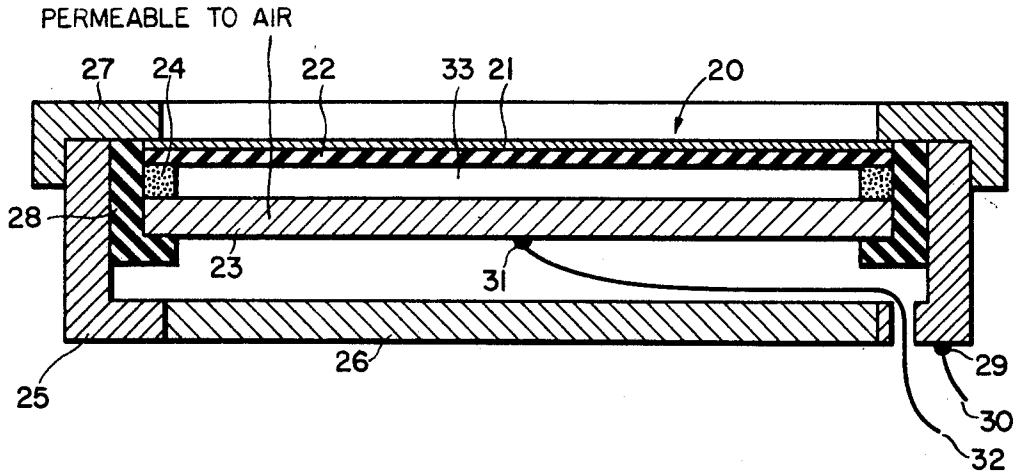
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ABSTRACT: An electroacoustic electret transducer which exhibits directional response characteristics resulting from an electrical interaction between at least two discrete prepolarized volumes within an electret, the volumes having oppositely poled dipole moment vectors.



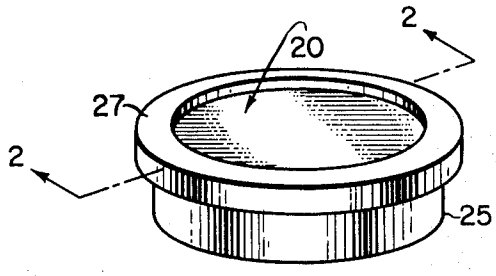


FIG. 1

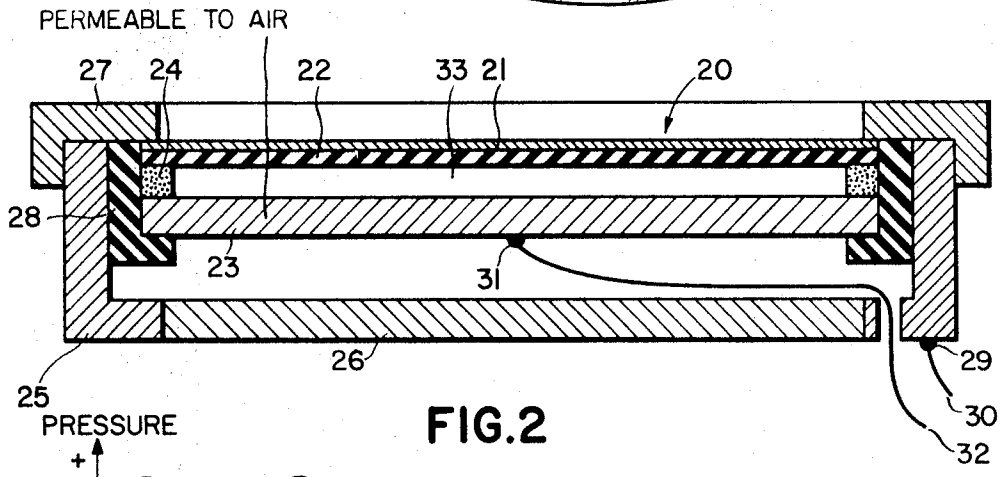


FIG. 2

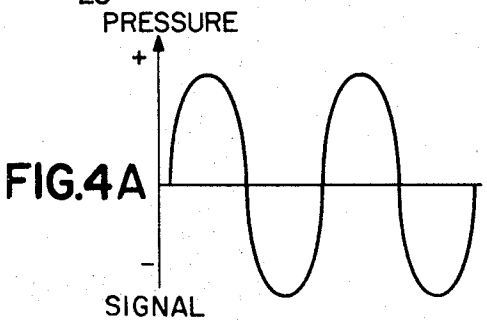


FIG. 4A

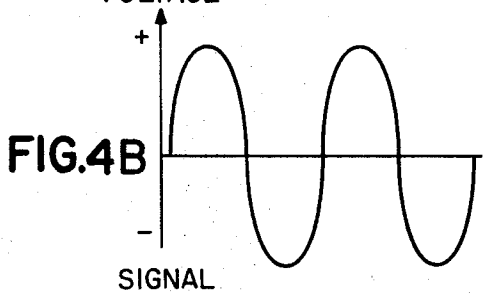


FIG. 4B

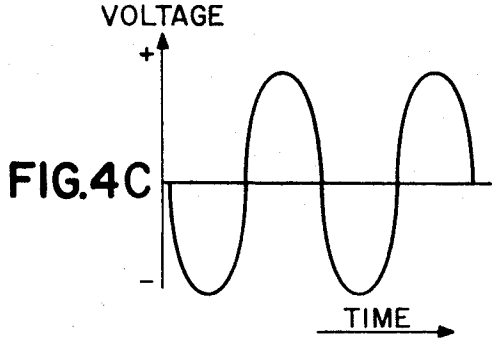


FIG. 4C

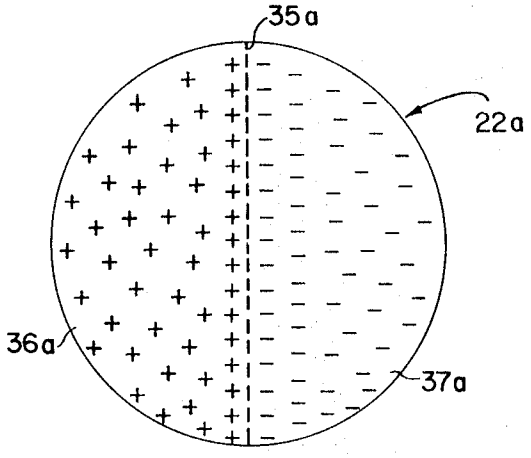


FIG. 3

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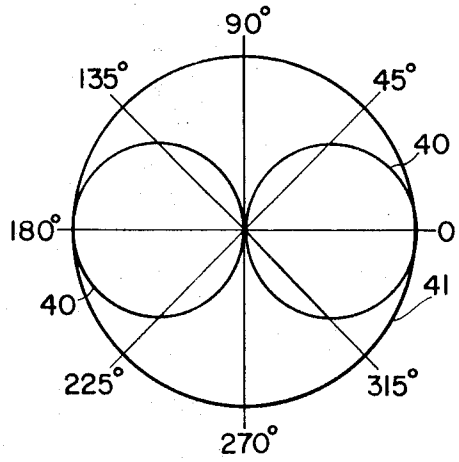


FIG.5

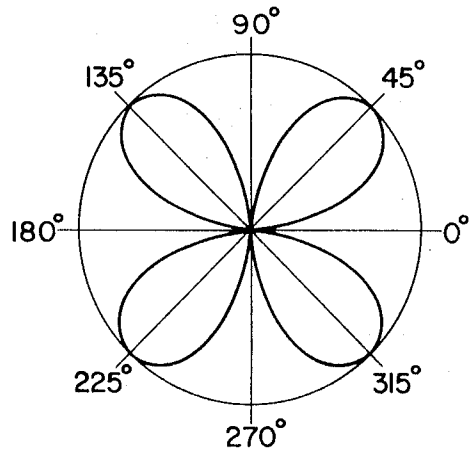


FIG.6

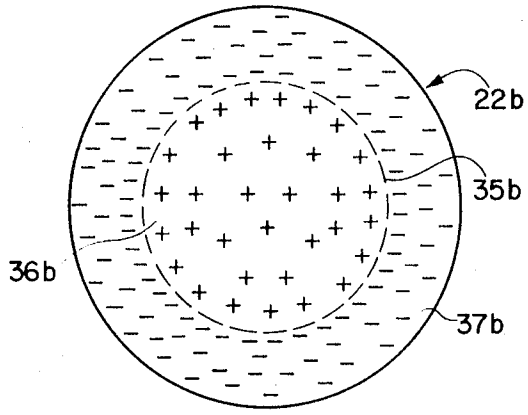
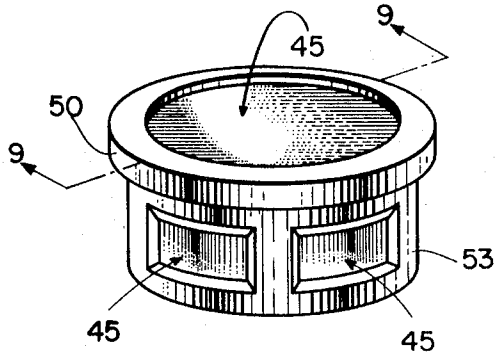


FIG.7

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FIG. 8



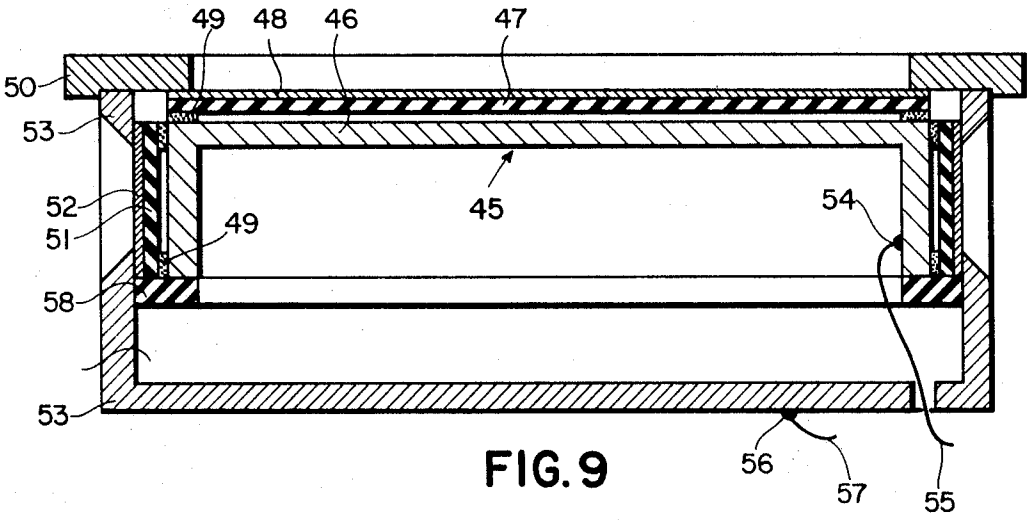


FIG. 9

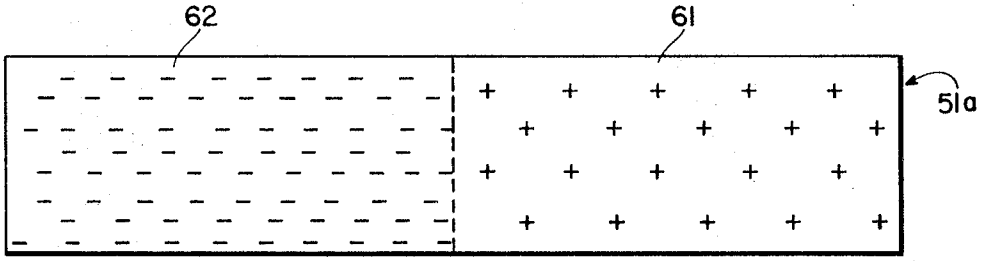


FIG. 10

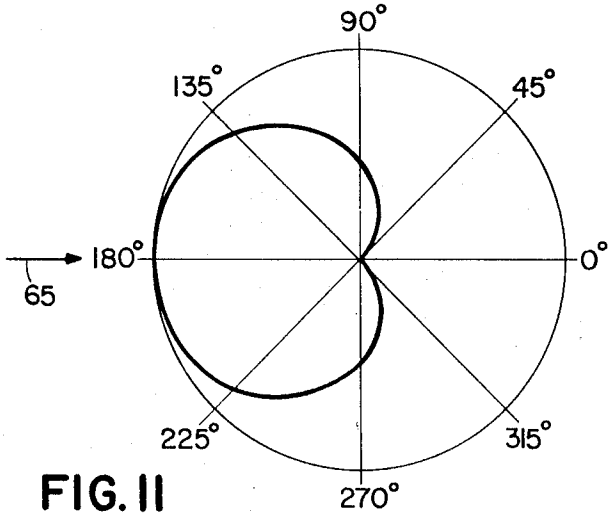


FIG. 11

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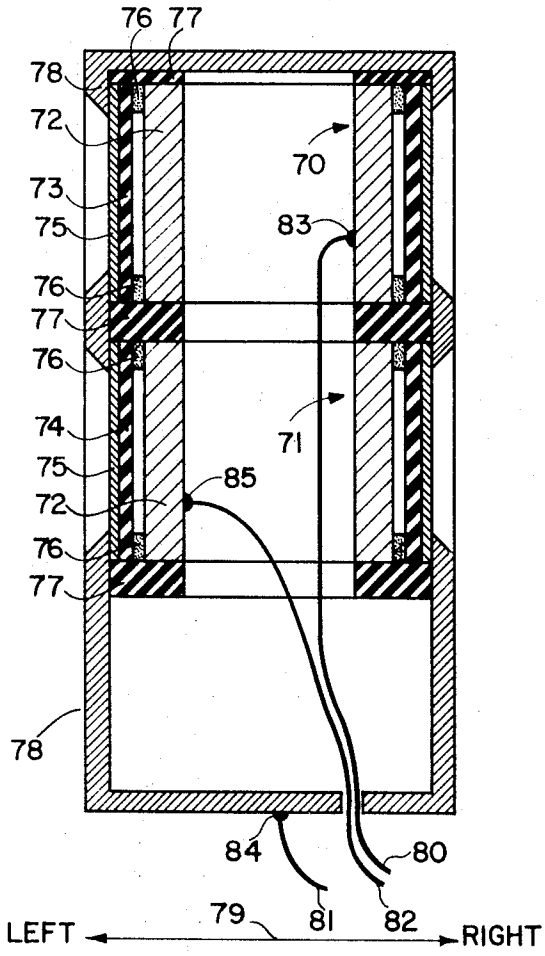


FIG. 13

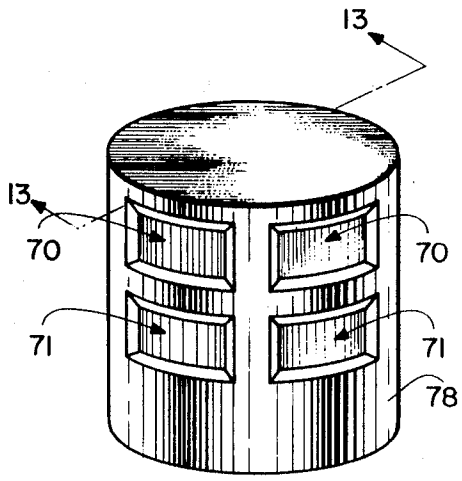


FIG. 12

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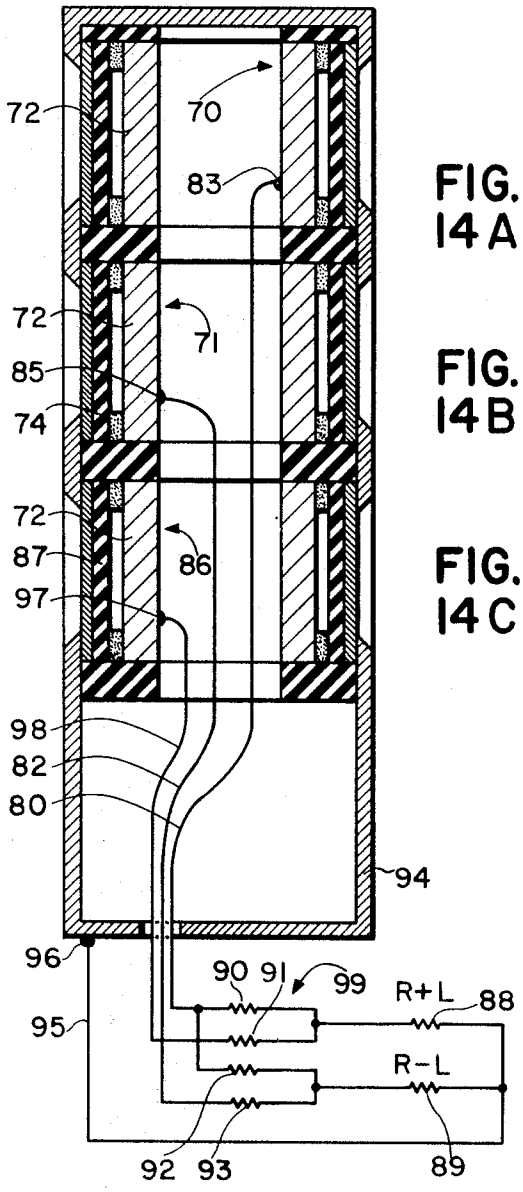


FIG. 15

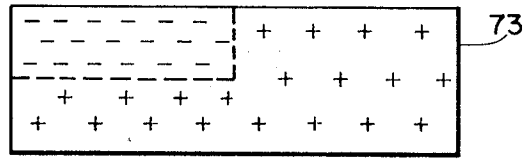


FIG. 14A

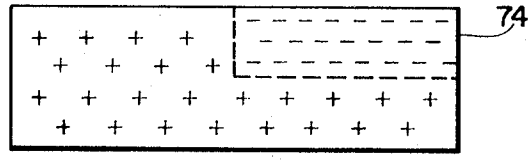


FIG. 14B

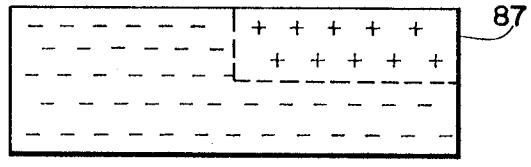


FIG. 14C

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DIRECTIONAL ELECTRET TRANSDUCER

This invention relates to electret microphones and more particularly to electret microphones which demonstrate predetermined directional properties.

The use of the electret principle in the construction of electrostatic acoustic devices, and in particular electret microphones, is well known in the microphone art as evidenced by G.M. Sessler's U.S. Pat. No. 3,118,022 bearing issue date Jan. 14, 1964. A dissertation on the known advantages to be obtained from the use of electrets and the reasons why the electret principle has seen little previous use in the construction of microphones is well described therein. As explained by Sessler, the development of improved plastic film materials which will retain an electric charge for considerable periods of time is largely responsible for renewed interest in electret transducers.

The methods by which directional response characteristics may be obtained in microphones generally is well documented in the microphone prior art. For example, it is known that some directional effects may be obtained, using any conventional microphone transducer element, by critically selecting the transducer's acoustic load. This is often done by mechanically varying the microphone cavity size. The disadvantages imposed by this method occur by virtue of the more complicated and expensive-to-manufacture mechanical structure used to contain the microphone transducer element.

In another method by which microphone directional characteristics may be obtained, it is known that two or more physically separated and electrically distinct transducer elements may have their respective electrical outputs combined through phase shifting networks to produce a desired directional effect. One disadvantage in this method is the spatial requirement of the separate transducer elements. Another is the required phase shifting networks, which also use up space in the microphone and which appreciably add to the cost of producing such a microphone. Collectively, the disadvantages result in a microphone that is physically large and relatively expensive. And, since directional microphones find considerable use in television studios, and on theatre stages, it is desirable that the microphones used by performers be small and as unobtrusive as possible. However, a small size is difficult to achieve when several bulky electrical circuit components comprise the microphone.

In still another form of microphone having a directional response characteristic, it is known that directional characteristics may be obtained when at least two capacitive microphone transducer elements are arranged in a circuit wherein a charging unidirectional potential applied to each capacitive transducer element is of a different value. Thus, by varying the biasing potentials on each transducer, the sensitivity of each transducer will change so that when all electrical output signals are combined, a desired directional response will result. The main disadvantage of this method is found in the extra components required, and the additional manufacturing costs involved in assembling such a relatively complex device.

The teachings of Sessler may be coupled with common knowledge in the directional microphone art in order to produce a microphone with directional characteristics, that is self-contained and which requires no external unipotential polarizing power supply. However, a directional electret microphone so produced still does not overcome the inherent disadvantages of bulk and mechanical complexity in view of the required separate electret transducers and the attendant electrical phase shifting circuitry.

I have invented an electret transducer comprising first and second electrically conductive layers separated by an electret sandwiched therebetween. The first layer is moveable, relative to the second layer, along an axis that is substantially normal to the broad surfaces of both conductive layers. In this way, the capacitance between the plates can be made to vary. Additionally, the electret has at least two prepolarized discrete volumes with their electric dipole moment vectors oriented in opposite directions, relative to one electret surface and coplanar with the normal axis. By means of my invention, electret microphones having predetermined polar response characteristics may be manufactured with greater ease, more economy, and in smaller size.

The dielectric material used in my invention, being prepolarized, comes within the known definition of an electret. Accordingly, an external unidirectional polarizing potential is not required for directional microphones using my invention, thereby eliminating all attendant polarizing power supply disadvantages. Furthermore, since only a single electret transducer unit is used in my invention, there is no need for complex electrical interconnections, nor is there required an elaborate mechanical housing structure to provide a critical acoustic load for the transducer. And, since only one transducer is used, having only one pair of output terminals, a complex phase delay network is not required. Manufacturing expenses are thus substantially reduced since fewer parts are used and because less manufacturing time is needed to fabricate a complete microphone assembly.

An electrical interaction takes place in the electret transducer and occurs between charged prepolarized volumes in the electret separating two parallel electrically conductive layers, one of which is vapor deposited on one side of the electret. The observable result of this interaction is a single electrical output signal which has a predictable directional characteristic. Shaping the charged volumes in the electret in a predetermined way will accordingly determine the directional characteristics of the transducer. For instance, microphones may be made, using my invention, which exhibit polar directional patterns that are dipole in form, quadrupole in form, and cardioid in form. Additionally, microphones may be made which exhibit other desirable directional characteristics as are found in "close-talking" microphones. By using a combination of electrostatic transducers, each with its own directivity pattern, and placing them together in one microphone case, a stereo microphone may be obtained.

Prior to describing the various microphone embodiments in the FIGS. it should be pointed out that since surface dimensions, e.g., radius, width, length, and area, constitute the major dimensions in my electret transducers, and since the dimension of thickness is small, the drawings have not been made to scale to more clearly show the structure of each microphone embodiment.

For purposes of description, it is convenient to consider the dipole electric charge in a prepolarized discrete volume of an electret as a surface charge. Accordingly, the following definitions are used in the descriptions of the FIGS.

a. When a part or the whole surface of the electret side opposite the metallized side exhibits a net positive surface charge, then this part or the whole electret will be referred to as a "+electret." Accordingly, the electric dipole moment vector of the discrete prepolarized volume bounded on one side by the +electret surface area is considered to be normal to the surface and unidirectional.

b. When a part or the whole surface of the electret side opposite the metallized side exhibits a net negative surface charge, then this part or the whole electret will be referred to as a "−electret." The electric dipole moment vector of the discrete prepolarized volume bounded on one side by the −electret surface area is considered to be normal to the surface by pointing in a direction opposite to that of the +electret vector.

c. An electret having both +electret and −electret areas as defined above shall be considered an electret of unitary construction.

Example embodiments of my invention will now be described with reference to the accompanying drawings in which:

FIG. 1 is a perspective view of one embodiment of a microphone;

FIG. 2 is a cross-sectional view of the microphone embodiment illustrated in FIG. 1 and taken along the line 2–2 thereof;

FIG. 3 is a plan view of the surface charge boundaries in one variation of an electret used in the microphone embodiment of FIG. 1;

FIGS. 4A, 4B, and 4C are graphs depicting the relationship between sound pressure forces and corresponding electrical signals obtainable from an electret transducer with a +electret, and an electret transducer with a −electret;

FIG. 5 is a polar graph showing the dipole directional response pattern obtainable from the microphone embodiment of FIG. 1 when using the electret of FIG. 3 and the omnidirectional polar response pattern obtainable from the microphone embodiment of FIG. 1 when using a single polarity electret;

FIG. 6 is a polar graph showing a quadrupole directional response pattern obtainable from the microphone embodiment of FIG. 1;

FIG. 7 is a plan view of the surface charge boundaries in another variation of an electret used in the microphone embodiment of FIG. 1;

FIG. 8 is a perspective view of a second embodiment of a microphone;

FIG. 9 is a cross-sectional view of the microphone embodiment illustrated in FIG. 8 and taken along the line 9–9 thereof;

FIG. 10 is a plan view of the surface charge boundaries in one variation of an electret used in the microphone embodiment of FIG. 8, the electret being unrolled and laid out flat;

FIG. 11 is a polar graph showing a cardioid directional response pattern obtainable from the microphone embodiment of FIG. 8;

FIG. 12 is a perspective view of a third embodiment of a microphone;

FIG. 13 is a cross-sectional view of the microphone embodiment illustrated in FIG. 12 and taken along the line 13–13 thereof;

FIGS. 14A, 14B, and 14C comprise plan views of the surface charge boundaries in the electrets which may be used in the microphones shown in FIGS. 12 and 15, the electrets being unrolled and laid out flat; and,

FIG. 15 is a cross-sectional view of a fourth embodiment of a microphone and its associated circuitry.

Referring now to the drawings, FIG. 1 shows a perspective view and FIG. 2 shows a cross-sectional view of one microphone embodiment constructed in accordance with my invention. Shown therein is a novel electret transducer 20 which comprises the working component of this microphone embodiment. The construction of the electret transducer 20 includes a first electrically conductive layer which is shown as a metallic film 21, vapor deposited on one surface of an electret 22. The electret 22 thus serves as a supportive member for the metallic film 21 and also as a prepolarized dielectric member separating the metallic film 21 from a second electrically conductive layer shown as a backplate 23. An adhesive 24 is used to adhere the electret 22 along its periphery to the backplate 23 to form an integral unit capable of translating sound pressure variations into corresponding electrical output signals.

As illustrated in FIGS. 1 and 2, the microphone embodiment includes a metal microphone case 25 having one end substantially closed by a cover 26 and its other end connected to a metal cap 27 which is open to allow air pressure variations to act upon the electret transducer 20. The electret transducer 20 is mounted within the case 25 and is held against the cap 27 by an insulating spacer 28. This assembly method provides a friction fit which inhibits movement of the transducer 20 within the case 25 and also provides an electrical contact from the case 25, through the cap 27 to the metallic film 21. Electrical output signals appearing between the film 21 and the backplate 23 may be conducted to an external circuit from the film 21 via the cap 27, the case 25, the electrical contact 29 and an electrical wire 30; and, from the backplate 23 by way of an electrical contact 31 and an electrical wire 32.

The metallic film 21 is vapor deposited on one surface of the electret 22, but any method may be used which will provide a uniform metallic layer on a dielectric surface. For example, a thin metal film could be cemented to the electret or may even be held in place against the electret by means of clamps. Various methods are available and are well-known by those skilled in the art. But, the vapor deposition process herein mentioned is a preferred method.

FIG. 3 shows a plan view of a circular electret 22*a*, one variation of the electret 22 used in the microphone embodiment of FIG. 2. A dashed line 35*a* separating the electret 22*a* into equal half areas is an imaginary line used only to depict a separation of positive and negative charges as shown therein. That portion of the electret 22*a* containing positive charges is indicated as a +electret 36*a*, whereas that portion of the electret 22*a* dominated by a negative charge distribution is shown as a −electret 37*a*. Thus, the +electret 36*a* and the −electret 37*a* represent two electrical poles of equal but opposite polarity. The positive and negative charge distributions on the electret 22 *a* have been made equal by using equal areas of the +electret 36*a* and the −electret 37*a*, the halves being located on each side of a plane that is normal to the electret surface, the plane intersecting the circular electret 22*a* along a diameter.

For ease of manufacture, it has been found that the backplate 23 of FIG. 2 may be made from a sintered metallic material. The preferred embodiment of my invention uses sintered bronze; however, any metallic material which is permeable to air may be used. One example would be a simple perforated disc.

The electret 22 may be affixed to the backplate 23, as illustrated in FIG. 2, by means of the adhesive 24 which is applied circumferentially between the unmetallized electret 22 surface and the backplate 23. An effective air space 33 is thus formed between the electret 22 and the backplate 23 because of the thickness of the adhesive 24 as well as the air spaces arising from the specially prepared surface of the backplate 23 on which the electret rests.

The principle of operation of the microphone embodiment shown in FIGS. 1 and 2 when employing the electret 22*a* of FIG. 3 may be understood in the following manner:

Assume that the electret transducer 20 is subjected to a plane progressive sound wave. When the direction of the sound wave is perpendicular to the plane of the electret 22 and the wavelength is large compared to the dimensions of the electret, it may be assumed that the sound pressure is distributed evenly over the entire surface area of the metallic film 21. It is important to note that the electret 22*a* unmetallized surface is substantially isolated from the atmosphere. Although the backplate 23 is permeable to air, since it is substantially enclosed by the case 25, and the cover 26, it is thereby effectively isolated from atmospheric air pressure variations. Consequently, the electret 22*a* unmetallized surface is also substantially isolated from air pressure variations. As a result, forces applied to the electret transducer 20 via its acoustic environment act only upon the metallized film 21.

FIG. 4(A) shows a graph of sound wave air pressure variations versus time on the same sheet as FIGS. 4(B) and 4(C) that show varying electrical potentials $e+$ and $e-$ which can be measured between the backplate 23 and the metallic film 21. These voltage waveforms represent the electrical signals that would be generated by the +electret 36*a* and −electret 37*a* halves, respectively, of electret 22*a* in FIG. 3, when sound pressure of the form shown in FIG. 4 (A) is applied evenly against and perpendicular to the metallic film 21 in the FIG. 2 microphone embodiment. The resulting combined output signal from the electret transducer 20 would, of course, be zero since the two halves of the electret 22*a* are connected in parallel and $e+=-e-$. However, when the direction of propagation of the sound wave of FIG. 4(A) is not perpendicular to both the metallic film 21 and the line 35*a* between the +electret 36*a* and the −electret 37*a*, the average force exerted on the +electret 36*a* will differ slightly from that exerted on the −electret 37*a*. The electret transducer 20 will then generate an output voltage between the metallic film 21 and the backplate 23, proportional to this force difference. When

the direction of propagation of the said sound wave lies in the plane of the electret 22*a* and is perpendicular to the line 35*a*, the differential output signal of the microphone will reach a maximum. A minimum occurs when the direction of propagation of the said sound wave lies in the electret 22*a* plane and is coaxial with line 35*a*. The dipole or figure-eight-shaped polar response pattern 40 in FIG. 5 is derived in accordance with this explanation.

If only a single pole electret is used for the electret 22 in FIG. 2, whether it be all +electret, or all −electret, then a monopole or omnidirectional polar response pattern 41 will be obtained as shown in FIG. 5.

Removing the cover 26 from the microphone embodiment of FIG. 2 in combination with the electret 22*a* permits acoustic pressure waves to act on both the metallic film 21, and through the backplate 23, which is permeable to air, onto the unmetallized surface of the electret 22*a*. As a result, a quadrupole polar response pattern as shown in FIG. 6 would be obtained thereby.

The known "noise-cancelling" or "close-talking" effect which is obtained from differential microphones is due partly to the difference in shape of the sound waves near a talker's lips and the sound waves from a distant source. The first-mentioned waves are nearly spherical in shape, whereas the latter waves may be regarded as plane waves. Sound waves from a distant source are plane waves which apply pressure evenly over the entire electret to produce equal *e*+ and *e*− output signals which cancel each other out. However, the spherical sound waves near a talker's lips when directed against the electret at an angle produce an output signal in accordance with the microphone's directional response pattern and the relative direction of approach.

FIG. 7 is a plan view of an electret 22*b* comprising substantially equal areas of +electret 36*b* and −electret 37*b*. Both are shown separated by an imaginary dashed line 35*b*. When electret 22*b* is used in the microphone structure of FIG. 2, a microphone with a noise-cancelling or close-talking characteristic will be obtained. The charged surface areas of the electret 22*b* in FIG. 7 are of such geometrical shape that an electrical signal is generated by the transducer 20 of FIGS. 1 and 2 when the metallic film 21 is subjected to a spherical pressure wave. However, no substantial electrical output signal is generated when the metallic film 21 is subjected to a plane pressure wave.

It will be seen that the electret 22*b* of FIG. 7 has a different charge distribution from the electret 22*a* shown in FIG. 3. The charge distribution in the electret 22*b* of FIG. 7 is one of a series of preferred forms that exhibits a necessary symmetry, i.e., in the form of an annular ring comprising −electret 37*b* which surrounds +electret 36*b*. The two poles so formed may be interchanged so that the annular ring comprises +electret 36*b* while the enclosed pole comprises −electret 37*b*. No difference in operation will occur as a result of this change except for the polarity (phase) reversal of the output signal voltage.

Another microphone embodiment of my invention which also provides characteristics of a close-talking microphone is shown in FIGS. 8 and 9. The structural form of the electret transducer 45 therein differs from the electret transducer 20 shown and described in FIGS. 1 and 2. The difference, however, is one of addition only. As electret transducer 45 is in the form of a cylindrical cup having a closed end, it may be seen that its closed end, or flat portion, is of the same structural form as the electret transducer 20 of FIGS. 1 and 2. The backplate 23 of FIG. 2, however, is now in the form of a cylinder with a closed end shown as a backplate 46 in FIG. 9. Thus, it may be seen that the backplate 46 of FIG. 9 could be assembled using a flat circular disc placed against one end of a cylindrical sleeve to form an assembly in the shape of a cylindrical cup.

In each preferred embodiment of my invention the backplate is made of sintered metals which are easily formed. Consequently, the backplate 46 of FIG. 9 is shown formed as a single piece.

The method of making the electret transducer 45 of FIGS. 8 and 9 is similar to that previously described in the electret transducer 20 of FIGS. 1 and 2. For example, on the flat surface of the backplate 46 a circularly shaped +electret 47, having a metallic film 48, is affixed by means of an adhesive 49 placed on the periphery of the electret 47 surface in contact with the backplate 46. One pole is thus formed. An electrical contact to metallic film 48 is made by the contacting edges on the microphone case cap 50.

The second pole in the electret transducer 45 of FIGS. 8 and 9 is formed by a −electret 51 which is wrapped around the outer surface of the cylindrical wall of the backplate 46. A thin layer of an adhesive 49 is placed on the peripheral edges of the −electret 51 to affix it to the backplate 46. Electrical contact to a metallic film 52 on the −electret 51 is made by the contacting edges of the microphone case 53.

The two poles so formed may be interchanged so that the −electret 51 lies on the flat surface of the backplate 46. The +electret 47 would then be wrapped around the outer surface of the cylindrical wall of the backplate 46. No difference in operation would occur as a result of this change except for the polarity (phase) reversal of the output signal voltage.

One electrical output signal connection is made at the electret transducer 45 from the backplate 46, through an electrical contact 54 and an electrical wire 55. A second electrical output connection occurs from the metallic film 48 through the cap 50, the case 53, the metallic film 52, the electrical contact 56, and an electrical wire 57.

An insulating spacer 58 is used as a means to support the electret transducer 45 within the microphone case 53, and to position the transducer so that a good friction and electrical contact is made to the metallic films 45 and 52 by the contacting cap 50 and case 53 edges.

In order to ensure close-talking microphone characteristics as earlier described in the close-talking microphone embodiment of FIGS. 1 and 2, the microphone case 53 of FIGS. 8 and 9 must substantially enclose the ummetallized surfaces of the electrets 47 and 51 to isolate them from acoustic forces in the surrounding environment.

Using the same structural elements as may be seen in FIG. 9, but with a change in electret charge distribution, a microphone with a cardioid directional response pattern as shown in FIG. 11, may be obtained. The new electret charge distribution may be seen in the plan view of an electret 51*a*, in FIG. 10, which is wrapped around the outer surface of the cylindrical wall of the backplate 46 in FIG. 9. One-half of the electret area comprises −electret 62, whereas the remaining half area comprises +electret 61. In addition to the electret 51*a*, a circularly shaped flat laminar + or −electret 47 is required to cover the flat end portion of the backplate 46. For description purposes, a +electret is assumed. A direction arrow 65 in FIG. 11 indicates the direction of an applied sound source and the corresponding cardioid response pattern obtained thereby. A maximum occurs in the direction of the electret 51*a* portion which is of the same polarity as the flat circularly shaped electret 47. A null occurs in the direction of the electret 51*a* portion which is of opposite polarity to the flat circularly shaped electret 47. When the microphone is rotated about its vertical axis and is positioned so that the +electret 61 directly faces the sound source, the −electret 62 is on the opposite side of the microphone and is consequently farther away. Because the spatial separation of the electrets 61 and 62 is assumed to be small compared with the sound source wavelength, the −electret 62 generates an output signal of identical amplitude but of opposite phase to that generated by the +electret 61. The result of the signal additive properties of the +electret 61 and the flat circularly shaped +electret and the signal subtractive properties of the flat circularly shaped +electret and the −electret 62, is the cardioid pattern of FIG. 11.

The illustrations in FIGS. 12 and 13 represent a perspective and a cross-sectional view of a stereo microphone embodiment with a structure similar to that hereinbefore described. Two electret transducers 70 and 71 are used in this

microphone with each acting independently to produce an electrical output signal. The combination of these transducers, each having a cardioid response, provides a right channel and left channel stereo microphone characteristic. Both transducers are identical in structure, but differ in their respective electret charge distributions.

Each electret transducer is in the form of a cylindrical sleeve which is of the same structural form as the cylindrical portion of the electret transducer **45** in FIG. **9**. The backplate **72** in FIG. **13** is the structural member which gives rise to the cylindrical sleeve form and has wrapped around its entire exterior surface area a rectangularly shaped electret, **73** or **74**, having one of its surfaces covered by a metal film **75**. The nonmetallized electret surface is affixed by means of an adhesive **76** on its periphery to the contacting surface of the backplate **72**. Spacers **77** are used to isolate the electret transducers **70** and **71** from one another, provide necessary mechanical support within the microphone case **78**, and also to electrically isolate the backplates **72** from the microphone case **78**.

The charge distribution layouts of the electrets used in the electret transducers **70** and **71** of FIGS. **12** and **13** are shown in FIGS. **14A** and **14B** in a flat and unrolled form. The length of each electret equals the circumference of the backplate **72** around which it is wrapped.

A maximum output signal, as shown in the cardioid directional response curve of FIG. **11**, is obtainable when the half area of each electret **73** or **74** which is of one polarity only is directed to the sound source. The electret half area which contains equal portions of the +electret and the −electret areas and which is opposite to the sound source will produce a minimum output signal corresponding to the null shown in the cardioid directional response pattern of FIG. **11**. Thus, the electret transducers **70** and **71** in FIGS. **12** and **13** each have a cardioid response characteristic and an output signal phase as determined by the polarity of the maximum single charge area in the electret. Referring now to the electrets **73** and **74** shown in FIG. **14A** and FIG. **14B**, it will be apparent that output signals from the electret transducers will be in phase since each electret shown is predominantly positive in polarity.

The structural microphone form shown in FIGS. **12** and **13** is a convenient embodiment because of the ease with which the angle between the major axes of the electret transducer polar response patterns can be adjusted. The electret transducer **70** is made rotatable thereby permitting relative movement with respect to the electret transducer **71**. The direction arrow **79** in FIG. **13** shows that the orientation of the electret transducer **70** and the electret transducer **71** is such that the major axes of their respective carioid response curves are 180° apart thereby providing a left and a right channel. If the electret transducer **70** reproduces sounds coming from the right, the generated output signal will appear mainly between the electrical wires **80** and **81**. Accordingly, if the electret transducer **71** reproduces sounds coming from the left, the generated output signal will appear between the electrical wires **82** and **81**. Reference to FIG. **13** will show where the electrical wires **80, 81** and **82** are connected via electrical contacts **83, 84**, and **85**, to the various signal takeoff points in the microphone.

FIG. **15** is another cross-sectional view of a stereo microphone embodiment. The structure shown is identical to that of FIG. **13** plus an additional electret transducer **86**. A layout showing the charge distribution of electret **87**, used therein, is shown in FIG. **14C**.

The method of electret transducer orientation described for FIG. **13** also applies to FIG. **15**. Accordingly, the electret transducer **70** reproduces sounds coming from the right. Its output signal may be designated R. The electret transducer **71** reproduces sounds coming from the left, and its output signal may be designated L. The orientation of the electret transducer **86** and the charge distribution in its electret **87** are the determining factors which direct it to also reproduce sounds approaching from the left. However, the polarity of the output signal from the electret transducer **86** is opposite to the signal produced by the electret transducer **71** because of a polarity reversal between their respective electret poles. It can be seen that the polarity of the major pole of the electret **74** in FIG. **14B** is positive, whereas the polarity of the major pole of the electret **87** in FIG. **14C** is negative. Since the phase of an output signal is determined by the maximum single charge area in a given electret and since the polarity of these two charges is opposite, the two output signals will be 180° out of phase. Consequently, the output signal from the electret transducer **86** is designated −L. Since the electret transducers **71** and **86** have colinear directivity responses, it is only necessary to make the electret transducer **70** rotatable to be able to adjust the angle between the major axes of the right and left cardioid directional patterns.

With the three signals R, L and −L, direct matrixing is possible. Through signal addition, by means of a simple matrixing network **99** shown in FIG. **15**, an R+L signal can be developed across a resistor **88**, and an R−L signal can be developed across a resistor **89**. An output signal of this form is desirable since it is often used in stereo recording techniques.

The matrixing circuit **99** comprises resistors **88, 89, 90, 91, 92**, and **93**. Three inputs to this circuit are provided, one from each electret transducer. The common electrical point for the matrixing circuit **99** is provided by the microphone case **94** via an electrical wire **95** connected to the case at contact **96**. Input connections to the matrixing circuit **99** are made from the backplate **72** in each electret transducer. The signal path taken from the electret transducer **70** is from electrical contact **83** through an electrical wire **80**. From the electret transducer **71**, the signal path taken is from an electrical contact **85** through the electrical wire **82**. And, in the case of the electret transducer **86**, the signal path goes from an electrical contact **97** through the electrical wire **98**.

In the preceding descriptions of the various microphone structures using my invention, each of the embodiments shown makes use of a prepolarized, thin and flexible dielectric membrane which comprises a novel electret. Any of the known methods to prepolarize a dielectric body to make an electret may be used to form electrets of the type described in the various embodiments of my invention. One method is described in U.S. Pat. No. 3,354,373 issued on 21 Nov. 1967 to P. Fatovic and teaches that sheet electret material of any shape may be polarized. Accordingly, an electret of the form shown in FIG. **3** herein may be polarized by these teachings. For example, the +electret **36***a* material may first be polarized, using the Fatovic fixture for polarizing sheet electret material. After which, the electret **22***a* may be rotated by 180° to bring the −electret **37***a* material under the polarizing electrodes within the fixture and the −electret **37***a* material may be polarized by reversing the polarity of the voltage used to polarize the +electret **36***a* material.

Many of the recently discovered plastic substances, as brought out by Sessler, could be used as electret material since they have the necessary mechanical attributes and electrical charge retaining qualities to perform well as the electret element in my electret transducer. One side of the electret is covered by a vapor deposited metal layer and this layer serves as one plate of a capacitor. The unmetallized side of the electret is attached to a second metallic layer in the form of a rigid metallic backplate, a second capacitor plate. The complete capacitor so formed being a self-polarized directional electret transducer.

I have found the most useful material for the backplate to be sintered-bronze or sintered-stainless steel. Another useful substance for backplates is sintered-plastic with an electrically conductive metallic layer vapor deposited onto the side making contact with the electret. The advantages to be derived from using these materials are, (1) they provide almost purely resistive acoustic impedance which is a basic requirement in obtaining a uniform frequency response characteristic in the microphone, and (2) they are easily formed into backplates of various shapes. A further advantage of the sintered-plastic backplate is that its surfaces can be readily prepared concur-

rently with forming operations, thereby reducing manufacturing costs.

In the backplate, the surface in contact with the electret is specially processed to produce small ridges and valleys of which the ridges act as supports for the electret. The special process involves lapping the outer surfaces of the backplate using number 240 grit emery cloth in a figure 8 motion pattern. The ridges and valleys are the means which permit relative motion between the parallel plates, i.e., force applied to the metallized surface of the electret pushes the electret into the valleys tending to fill them up, thereby bringing the electret's metallized surface closer to the backplate and increasing the electrical capacitance between the plates for as long as the force is applied. With the charge held constant in the electret, and with the capacitance between the plates varying under a correspondingly varying applied acoustic pressure, a varying electrical signal output is generated between the two plates.

The preferred embodiment of my invention shows a flexible laminar electret, with one metallized surface, as being the moveable member of an electret transducer. But, other variations giving the same end result are possible. One example would be a rigid electret, covered by a flexible metallic membrane, in which case the electret surface under the flexible metallic membrane would be specially processed as described for backplates in the preceding paragraph. The flexible metallic membrane when exposed to acoustic pressure forces would then tend to fill the valleys in the prepared electret surface to produce a change in capacitance.

Although example embodiments of the invention herein disclosed describe various electret transducers as directional microphones, by the principle of reciprocity any such electret transducer may be used as a loudspeaker to convert electrical input signals to sound pressure variations. The term transducer has, for this reason, been used to define the unit structurally without regard to its function of converting air pressure variations into electrical signals or vice versa.

I claim:

1. A self-polarized electret transducer comprising:
a. first and second electrically conductive layers separated by an electret sandwiched therebetween,
b. the first layer being moveable relative to the second layer along an axis substantially normal to the broad surfaces of the layers to vary the capacitance therebetween,
c. and the electret having at least two discrete prepolarized volumes with their electric dipole moment vectors oriented in opposite directions relative to one electret surface and coplanar with said axis, whereby a predictable directional response characteristic is obtained.

2. A transducer as defined in claim 1 wherein:
a. said first layer comprises a flexible metallic film deposited upon one surface of the electret and is intimately affixed thereto,
b. said second layer is a substantially rigid body which is permeable to a gas,
c. the combination of the said first layer and the electret being affixed to the said second layer along a common peripheral boundary,
d. said conductive layers each being connectable to a separate electrical terminal.

3. A transducer as defined in claim 2 wherein the electret comprises two substantially equal volumes.

4. A transducer as defined in claim 3 adapted for use as a microphone in an acoustic medium, wherein the electret is in a disc form and the said volumes are disposed one on each side of a diameter of the disc; whereby, the transducer in response to acoustic pressure waves applied thereto generates an electrical output signal between said conductive layers, the transducer exhibiting substantially a quadrupole polar response pattern orthogonal to the plane of the electret.

5. A transducer as defined in claim 3 adapted for use as a microphone in an acoustic medium, and further comprising means for substantially isolating said second layer from the acoustic medium; whereby, the transducer in response to acoustic pressure waves applied thereto generates an electrical output signal between said conductive layers, the transducer exhibiting substantially a dipole response pattern coplanar with the plane of the electret.

6. A transducer as defined in claim 3 adapted for use as a microphone in an acoustic medium, wherein the electret is in a disc form and the said volumes are disposed concentrically about the center, one encircled by the other; and further comprising means for substantially isolating said second layer from the acoustic medium; whereby, the transducer in response to acoustic pressure waves applied thereto generates an electrical output signal between said conductive layers, and exhibits substantially a close-talking microphone characteristic.

7. A transducer as defined in claim 3 adapted for use as a microphone in an acoustic medium, wherein the electret is in the form of a hollow cylinder with a closed end, one of the said volumes comprising the cylinder walls and the other volume comprising the closed end; and further comprising means for substantially isolating said second layer from the acoustic medium; whereby, the transducer in response to acoustic pressure waves applied thereto generates an electrical output signal between said conductive layers, and exhibits substantially a close-talking microphone characteristic.

8. A transducer as defined in claim 2 adapted for use as a microphone in an acoustic medium, wherein the electret comprises a hollow cylinder with a closed end, one of the volumes comprising the closed end and a semicylindrical section of the cylinder walls, and the other volume comprising the remaining semicylinder; and further comprising means for substantially isolating said second layer from the acoustic medium; whereby, the transducer in response to acoustic pressure waves applied thereto generates an electrical output signal between said conductive layers, the transducer exhibiting substantially a cardioid polar response pattern orthogonal to the plane of the closed end.

9. A self-polarized electret transducer as defined in claim 2 adapted for use as a microphone in an acoustic medium, wherein the electret is in the form of a hollow cylinder, one of the volumes comprising a semicylinder and a semicylindrical half portion of the remaining semicylinder, and the other volume comprising the remainder of the cylinder; and further comprising means for substantially isolating said second layer from the acoustic medium; whereby, the transducer in response to acoustic pressure waves applied thereto generates an electrical output signal between said conductive layers, the transducer exhibiting substantially a cardioid polar response pattern coaxial with the axis of the electret.