United States Patent [19]

Young, Jr.

[11] **3,787,642**

[45] **Jan. 22, 1974**

[54] **ELECTROSTATIC TRANSDUCER HAVING RESILIENT ELECTRODE**

[75] Inventor: **Robert F. Young, Jr.**, Northfield, Ill.

[73] Assignee: **GTE Automatic Electric Laboratories, Incorporated,** Northlake, Ill.

[22] Filed: **Sept. 27, 1971**

[21] Appl. No.: **183,899**

[52] **U.S. Cl.** ..... **179/111 E,** 179/111 R

[51] **Int. Cl.** **H04r 19/00**

[58] **Field of Search** ..... 179/111 R, 111 E, 180, 106

[56] **References Cited**

UNITED STATES PATENTS

3,373,251	3/1968	Seeler	179/111 R
3,646,280	2/1972	Tamura et al.	179/111 E
2,645,301	7/1953	Vries	179/180
2,868,894	1/1959	Schultz	179/111 R

FOREIGN PATENTS OR APPLICATIONS

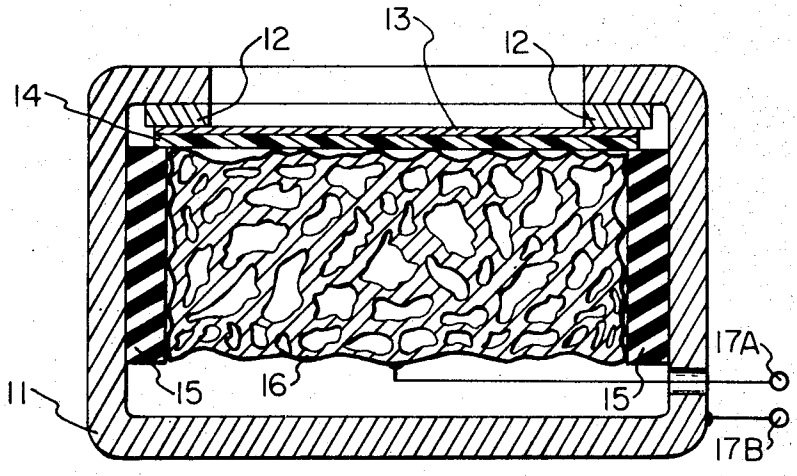
881,584	11/1961	Great Britain	179/111

Primary Examiner—Kathleen H. Claffy
Assistant Examiner—Thomas L. Kundert
Attorney, Agent, or Firm—Robert J. Black

[57] **ABSTRACT**

An electro-acoustic transducer having a flexible diaphragm and a backplate of resilient construction and a front element of metalized foil. In a preferred embodiment of the invention the transducer is a condenser microphone wherein the insulating film that comprises the diaphragm is an electret. In alternate embodiments the foil element may be replaced by an element constructed of resilient foam-like material.

23 Claims, 3 Drawing Figures



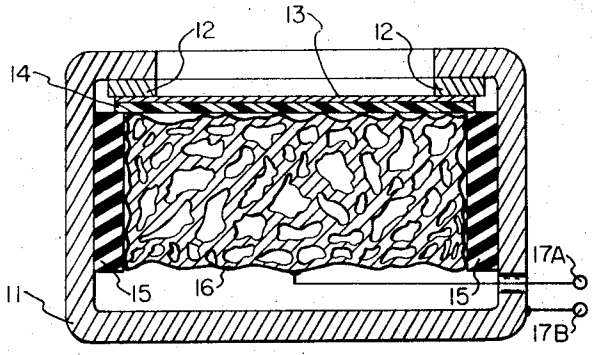


FIG. 1

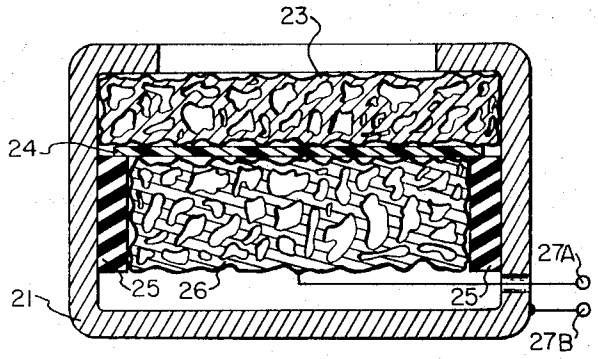


FIG. 2

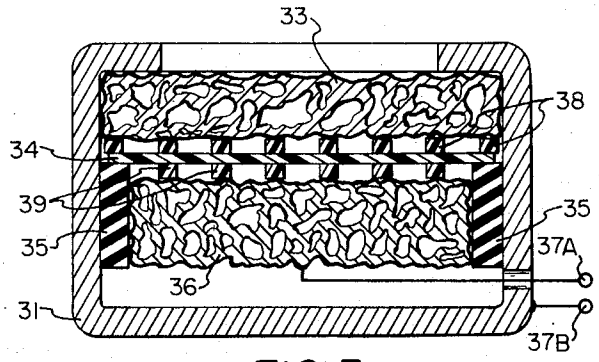


FIG. 3

INVENTOR
ROBERT F. YOUNG Jr.
BY
AGENT

ELECTROSTATIC TRANSDUCER HAVING RESILIENT ELECTRODE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention pertains to an electro-acoustic transducer having desirable electrical and acoustical properties. More specifically the present invention is drawn to a condenser microphone preferably of the electret type.

Electrostatic transducers and more particularly condenser microphones are well known finding usage in almost any environment where microphones are required. Condenser microphones are of particular interest because of their simplicity of design and potential ease of manufacture. Until recently, however, condenser microphones required an associated direct current high voltage source to provide a necessary polarizing voltage for the microphone.

This particular problem has been eliminated by usage of a precharged dielectric material as an element of the condenser microphone. These elements are referred to as electrets.

Electrets are most easily defined in terms of measurements performed on them. Given a material in block or slab form, one face is placed on a ground plane and the potential is measured at the other face. The two faces are interchanged and the process is repeated. If, with qualifications given below, the potentials differ, the material is an electret.

There are two qualifications to the above. The first is that the potential difference must not be due to static electricity. This may be taken care of in the same manner as is the same problem with phonograph records. The second qualification is that the potential difference must not be due to domain phenomenon. Materials which exhibit domain phenomenon are called piezoelectrics, and are the true electrical analogues of magnets. The determination of whether or not a material is piezoelectric is rather involved.

There are three microscopic phenomena which account for electret formation: dipole orientation, internal charge separation, and charge injection or removal. Certain materials, called "polar," have as constituents electric dipoles. These dipoles are usually oriented randomly, creating no net effect. If these dipoles are, at least partially, aligned in the same direction, they no longer cancel each other's effects, and a net result may be observed. Certain materials, called "conductors," have as constituents charges which are more or less free to move within the material. These charges are usually arranged so as to cancel each other's effects. If these charges are separated so that those of one polarity tend to be located near one face, and those of the opposite polarity tend to be located near the opposite face, then a net result may be observed. Finally, if charges are injected into a material, or removed from it, in such a manner as to create an unbalanced charge distribution between two opposite faces, a net effect may be observed.

Any material, with the aforementioned exceptions, able to sustain these phenomena for a usable period of time will, obviously, be an electret. Any process which produces any one or any combination of these effects is called polarization, although only dipole orientation is properly called polarization. The merit of an electret

is determined by two factors: the strength of the polarization, and the rate of decay of this strength.

The known polarizing techniques all involve the placement of a material between two electrodes of opposite polarity. These electrodes generate a strong electric field the direction of which is, of course, from the positive electrode to the negative. In most polar materials the dipoles will tend to be aligned in the direction of the field creating an effective positive (negative) surface charge on the face nearest to the negative (positive) electrode. In most conductive materials the positive (negative) charges will move towards the negative (positive) electrode creating an effective positive (negative) surface charge on the face nearest to the negative (positive) electrode. Since, for these two processes, the polarity of a face and a polarity of the electrode closest to that face are opposite, the surface charge generated by these two processes is called heterocharge. Materials undergoing heterocharging are often heated because this increases dipole and charge mobility.

If the applied electric field is strong enough, charges may actually be injected into or removed from the material. The face by the positive (negative) electrode will receive positive (negative) charges or give up negative (positive) charges. Since the lack of negative (positive) charge is equivalent to a surplus of positive (negative), injection and removal lead to similar results. Since, for this process, the polarity of the face and the polarity of the electrode closest to that face are the same, the surface charge generated by this phenomenon is called homocharge. The implementation of controlled charge injection is somewhat tricky since it involves the actual transport of material from one body to another.

Both heterocharging and homocharging may occur simultaneously, and the result is the difference of the magnitudes. Since the decay rate for each kind of charge may be different, an electret may actually undergo charge reversal. This would happen if the homocharge were initially predominent, but had a greater decay rate than the hetercharge. A desirable situation would be one in which the decay rates were the same since the difference, i.e. the net surface charge, would remain constant even though both types of charge were decaying. Unfortunately, the mechanism responsible for each type of charge is different, so it would be only luck to find such material. Most people in the field now seem to be looking for materials which have small decay rates for homocharge, and then use predominently charge injection.

Electrets typically are composed of either organic or inorganic material. In the past organic substances such as beeswax or carnuba wax were commonly used. However, because of their natural bulk only relatively thick transducer elements could be reproduced, with the result that close tolerances were difficult to maintain in these substances. Fabrication of sufficiently thin diaphragms of such material that were sufficiently vibratile and yet possessed the necessary mass and compliance to yield high conversion efficiency were extremely difficult to form.

Certain plastic film materials however have shown excellent potential for the formation of thin film electrets. Such materials as Mylar and Teflon have been particularly outstanding in this aspect.

2. Description of the Prior Art

Successful electret transducers are shown in the prior U.S. Pats. to G.M. Sessler et al. Nos. 3,118,022 and 3,118,979. Original attempts at the creation of electrostatic transducer employing electret elements, suggested the use of the electret film as a vibratile diaphragm adapted to vibrate relative to a fixed rigid backplate. Sessler interposes one or more additional thin dielectric layers between the diaphragm and the backplate. As a result spacing between the diaphragm and the backplate is relatively large and the transducer capacitance relatively low. Thus the transdcuer sensitivity is low because the electric field strength between diaphragm and backplate is relatively low for the same bias voltage. In the Sessler patents the use of blind holes as well as dielectric layers between the diaphragm and backplate is taught. This arrangement is such that air bubbles entrapped therein do not communicate with the outside air, thereby preventing atmospheric pressure equalization. As a result air bubbles expand and contract with changes of temperature and atmospheric pressure thus changing the capacitance and sensitivity of the transducer. In this manner the air filled holes of the prior transducer are entirely enclosed resulting in an acoustical impedance that is quite high and reduced only by the use of the multiple layers which mechanically align the bubbles in series. In another U.S. Pat. No. 3,373,251 to C.E. Seeler the use of a rigid porous backplate which is partially or totally permeable to air is taught. In Seeler's arrangement, a thin plastic film diaphragm is positioned directly upon a rigid porous backplate touching at only certain distributed points dependent upon the surface texture of the backplate. The metallic foil layer is placed on the other side of the electret element to form a microphone. In the Seeler patent it is suggested that a suitably porous material for the rigid backplate might be a sintered material consisting of a plurality of ball-shaped bronze powder elements compressed and heat-treated to provide the desired porosity. None of the designs taught by either Sessler or Seeler are capable of providing the high compliance and high damping characteristics that are found in the present invention.

SUMMARY OF THE INVENTION

The electrostatic transducer disclosed in the present invention differs from previous electrostatic transducers and particularly from prior art electrostatic transducers that include electret elements, by utilizing resiliently constructed elements for at least one of the conductive elements. That is to say that inasmuch as an electrostatic transducer is the equivalent of a capacitor, and includes two electrically conductive elements separated by a dielectric material, at least one of the two electrically conductive elements according to the present invention is of resilient construction.

For example, the backplate may be of resilient electrically conductive foam or similar material or alternately the front element placed in front of a dielectric diaphragm may be constructed of conductive foam. Or as would be obvious both backplate and front elements may be of resilient construction.

While the resiliently constructed elements may take several forms it has been found highly desirable to utilize a plastic foam that includes a high percentage of carbon to render it conductive. In such a foam material the porosity can be controlled by the use of a "blowing agent" in the fabrication of the foam itself. The degree of the resiliency of the foam can be regulated through a choice of materials. As is obvious from examining plastic foam, foam rubber or similar materials the bulk of the volume is comprised of air contained in pockets or cells. As a consequence the surface texture is usually copious with deep interstices. While the same texture may be had with solid materials, it is obvious they do not contain large amounts of air.

A similar successful usage has also been made of cloth, the porosity of which may be controlled by the weave and thread size. The resiliency may be controlled by choice of materials. Obviously some form of metallic impregnation or coating for conductivity is required. Whatever the choice of material the output becomes a direct function of the surface texture and the damping or acoustical resistance is the direct function of the porosity. Utilization of resilient elements provides a greater range of surface textures to choose from than might be available with the use of solid elements.

The utilization of foam elements in front of the diaphragm provides excellent damping particularly when the foam is in slight contact with the diaphragm. The inclusion of both front and rear elements of foam provides the obvious advantages of simplicity of electrical connection and extreme shock resistance as well as maximum protection for the diaphragm material itself.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-section view of a preferred embodiment of an electrostatic transducer in accordance with the present invention.

FIG. 2 is a cross-section view of an alternate arrangement of the present invention.

FIG. 3 is a cross-section view of another alternate arrangement of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1 a microphone embodying the principles of the present invention is shown. The microphone consists of a housing **11** constructed of metal or other electrically conductive material. Enclosed within the housing is an electrically conductive spacing or support ring **12** which is in direct contact with the housing. Directly beneath the support ring is the front element **13** of metallic foil or similar material. The front element **13** is in direct contact with the spacer ring **12** providing electrical circuit continuity. Directly below front element **13** and comprising a portion of the diaphragm is a layer of plastic film such as Mylar, acting as a dielectric element of the present condenser microphone. In a preferred embodiment the Mylar element **14** is pre-polarized to form an electret.

The manner in which the film layer **14** is prepolarized may include any of the known techniques of forming electrets, including the exposure of the material to corona discharge, heating in a high potential field, etc.

Supporting the diaphragm assembly at its periphery is an insulator ring that extends around the inner circumference of the microhone housing. Alternately the insulator may be formed of several strips of dielectric material spaced radially around the inner circumference of the housing.

The second element or backplate of the microphone **16** is positioned directly below and in contact with the

Mylar film portion of the diaphragm. In the present embodiment the ridges and points of the topmost surface of the backplate **16** are in contact with and support the Mylar film element **14.** The backplate **16** is insulated from the microphone housing by insulator **15** and is so spaced that it is not in contact with the bottom portion of the housing **11.** Alternately an additional layer of insulation between the backplate and the bottom of the housing may be provided.

An electrical connection is made between the backplate **16** and terminal **17A** passing through the microphone housing and insulated from the housing. A second electrical connection is made to the conductive housing **11** and extended to terminal **17B.** At terminals **17A** and **17B** connections are then made to an amplifier to be driven by the microphone of the present invention.

As noted previously the backplate **16** is of resilient construction and in the present embodiment is constructed of a plastic foam material impregnated with carbon so as to make it electrically conductive.

In operation sound waves entering the microphone cause the diaphragm assembly consisting of foil element **13** and the Mylar electret **14** to be forced toward the backplate **16,** changing the relative capacitance between element **13** and backplate **16.** The resultant capacitance changes are translated as electrical signals which are applied at terminals **17A** and **17B** to an amplifier.

As an alternative the use of a film element **14,** that has not been pre-polarized is also possible. In this particular instance a direct current polarizing potential is applied across terminals **17A** and **17B** to polarize the capacitor that is formed by elements **13,** backplate **16** and dielectric **14.** Then by means of an audio coupling capacitor connected to either terminal **17A** or **17B** the alternating current component resulting may be transferred to an amplifier with return being made through the other terminal.

The use of a resilient backplate in the present embodiment provides a highly compliant acoustic impedance to sound waves directed toward the microphone. The present backplate also provides a high damping quality to the present unit. Different than prior art condenser microphones, no additional impedance need be provided other than the backplate itself. The resilient quality of the backplate in addition to providing an acoustic impedance, provides a variable mechanical impedance helping to restore the diaphragm portion of the present transducer to its normal condition.

Alternate arrangements of the present invention are shown in FIGS. **2** and **3.** In FIG. **2** the basic structure is similar to that shown in FIG. **1** with housing **21,** Mylar element **24.** insulator **25,** backplate **26** and terminals **27A** and **27B** all corresponding to elements **11, 14, 15, 16,** and **17A** and **17B** respectively of FIG. **1.** The principal difference in the embodiment shown in FIG. **2** being the replacement of the foil front element **13** of FIG. **1** with a front element of resilient construction **23.** This element may be of construction similar to that of the backplate **26,** i.e., a resiliently constructed element of plastic foam impregnated with carbon or similar material to make it electrically conductive.

As may be observed by referring to FIG. **2** the front element **23** is in contact with the electrically conductive case **21** at its sides and a portion of its top surface, with the bottom of element **23** having points and ridges in contact with the upper surface of the Mylar film **24.** Operationally this embodiment is similar to that described previously while providing greater shock resistance and protection against diaphragm rupture. Increased efficiency of damping is also provided by utilization of the resilient foam element **23** which is in slight contact with the Mylar element **24.**

Yet another arrangement is shown in FIG. **3** wherein elements **31, 33, 34, 35, 36, 37A** and **37B** all correspond respectively to similar elements **21, 23, 24, 25, 26** and **27A** and **27B** of FIG. **2.** The principal difference between the arrangement shown in FIG. **3** and that of FIG. **2** is the inclusion of additional dielectric spacers or strips **38** and **39** with the strips **38** placed between the lower surface of front element **33** and the upper surface of Mylar diaphragm **34** and strips **39** providing a spacing between the lower surface of Mylar diaphragm **34** and the upper surface of backplate **36.** In this particular embodiment the additional air space above and below the diaphragm acts to improve the vibratile action of the diaphragm. The inclusion of the spacing strips **38** and **39** while slightly decreasing the capacitance of the present unit acts to increase the acoustic efficiency.

Numerous other embodiments incorporating the resilient elements of the present invention can be constructed utilizing some or all of the techniques described above. For example, the use of resilient front elements and solid backplates or elements providing spacers associated with only front element or backplate would be well within the teachings of the present invention.

Likewise all of the techniques disclosed may be applied to transducer forms, other than microphones. The principles disclosed are equally well applied to earphones, loudspeakers, etc. Numerous other modifications would also be obvious to one skilled in the art and accordingly the present invention should only be limited by scope of the claims appended hereto.

What is claimed is:

1. An electrostatic transducer comprising: a movable diaphragm of dielectric material including first and second surface areas; a first electrically conductive element positioned adjacent to said diaphragm first surface area; a second electrically conductive element positioned adjacent said diaphragm second surface area; at least one of said electrically conductive elements being movable and of resilient construction, said resilient construction enabling said conductive element to function as a variable mechanical impedance; and electrical conductors connected to said elements, to permit electrical connections to be made to said transducer.

2. An electrostatic transducer as claimed in claim **1** wherein said diaphragm dielectric material is prepolarized.

3. An electrostatic transducer as claimed in claim **1** wherein said diaphragm dielectric material is polarized by application of a bias voltage to said electrical conductors.

4. An electrostatic transducer as claimed in claim **1** wherein said second element is movable and of resilient construction.

5. An electrostatic transducer as claimed in claim **4** wherein said first element is constructed of electrically conductive foil.

6. An electrostatic transducer as claimed in claim 5 wherein said foil first element is in direct contact with said diaphragm first surface area.

7. An electrostatic transducer as claimed in claim 4 wherein said resiliently constructed second element includes a plurality of raised areas in contact with said diaphragm second surface area.

8. An electrostatic transducer as claimed in claim 4 wherein said resiliently constructed second element is spatially separated from said diaphragm second surface area, by spacing means.

9. An electrostatic transducer as claimed in claim 8 wherein said spacing means comprise a plurality of strips of dielectric material positioned between said second element and said diaphragm second surface area.

10. An electrostatic transducer as claimed in claim 4 wherein said resiliently constructed second element is formed of electrically conductive foam material.

11. An electrostatic transducer as claimed in claim 10 wherein said foam material contains a substantially high percentage of carbon.

12. An electrostatic transducer as claimed in claim 1 wherein said first electrically conductive element is movable and of resilient construction.

13. An electrostatic transducer as claimed in claim 12 wherein said resiliently constructed first element includes a plurality of raised areas in contact with said diaphragm first surface area.

14. An electrostatic transducer as claimed in claim 12 wherein said resiliently constructed first element is spatially separated from said diaphragm first surface area, by spacing means.

15. An electrostatic transducer as claimed in claim 14 wherein said spring means comprise a plurality of strips of dielectric material positioned between said first element and said diaphragm first surface area.

16. An electrostatic transducer as claimed in claim 12 wherein said resiliently constructed first element is formed of electrically conductive foam material.

17. An electrostatic transducer as claimed in claim 16 wherein said foam material contains a substantially high percentage of carbon.

18. An electrostatic transducer as claimed in claim 1 wherein said first and second electrically conductive elements are both movable and of resilient construction.

19. An electrostatic transducer as claimed in claim 18 wherein said resiliently constructed first element includes a plurality of raised areas in contact with said diaphragm first surface area and said resiliently constructed second element includes a plurality of raised areas in contact with said diaphragm second surface area.

20. An electrostatic transducer as claimed in claim 18 wherein said resiliently constructed first element is spatially separated from said diaphragm first surface area by first spacing means and said resiliently constructed second element is spatially separated from said diaphragm second surface area by second spacing means.

21. An electrostatic transducer as claimed in claim 20 wherein said first spacing means comprise a plurality of strips of dielectric material positioned between said first element and said diaphragm first surface area and said second spacing means comprise a plurality of strips of dielectric material positioned between said second element and said diaphragm second surface area.

22. An electrostatic transducer as claimed in claim 18 wherein said resiliently constructed first and second elements are both formed of electrically conductive foam material.

23. An electrostatic transducer as claimed in claim 22 wherein said foam material contains a substantially high percentage of carbon.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,787,642 Dated January 22, 1974

Inventor(s) Robert F. Young Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, line 35, the word "spring" should read --spacing--

Signed and sealed this 21st day of May 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
☆ U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.