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Whetstone et al.

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[54] **MICROPHONE CONSTRUCTION**

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[52] **U.S. Cl.** ..... **179/111 E,** 307/88 ET, 29/594

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

[58] **Field of Search** ..... 179/111 R, 111 E, 106, 179/1 R; 307/88 ET; 29/594

[56] **References Cited**

UNITED STATES PATENTS

1,644,387	10/1927	Kyle	179/111 R
1,983,377	12/1934	Kellogg	179/111 R
2,615,994	10/1952	Lindenberg et al.	179/111 R
3,008,013	11/1961	Williamson et al.	179/1 R
3,300,585	1/1967	Reedyk et al.	179/111 R
3,328,653	6/1967	Wolf, Jr.	179/111 R
3,373,251	3/1968	Seeler	179/111 R
3,474,197	10/1969	Koukal et al.	179/111 E
3,663,768	5/1972	Madsen et al.	179/111 E

FOREIGN PATENTS OR APPLICATIONS

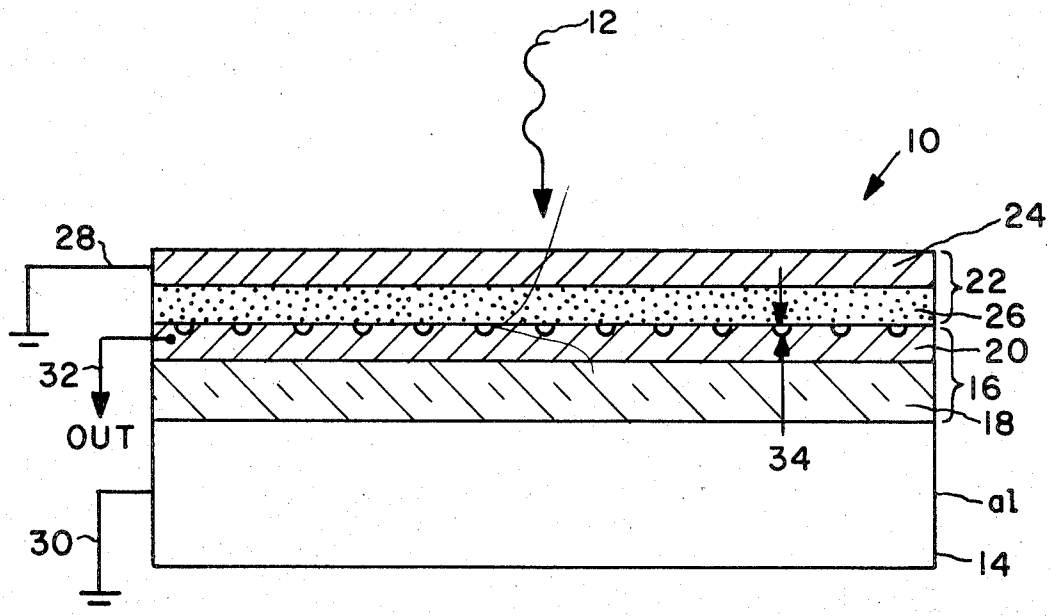
832,276	4/1960	Great Britain	179/111 E
537,931	7/1941	Great Britain	179/111 R

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Assistant Examiner—Thomas L. Kundert

[57] **ABSTRACT**

A novel construction method is provided for a linear extended capacitor electret foil construction microphone with a construction technique providing an infinite number of small capacitors in an equidistribution arrangement, for providing maximum sensitivity for given field strengths, and to provide an in situ method of microphone fabrication wherein the microphone is completely assembled and run through each heat cycling polarization to produce a finished thermo electret element.

4 Claims, 5 Drawing Figures



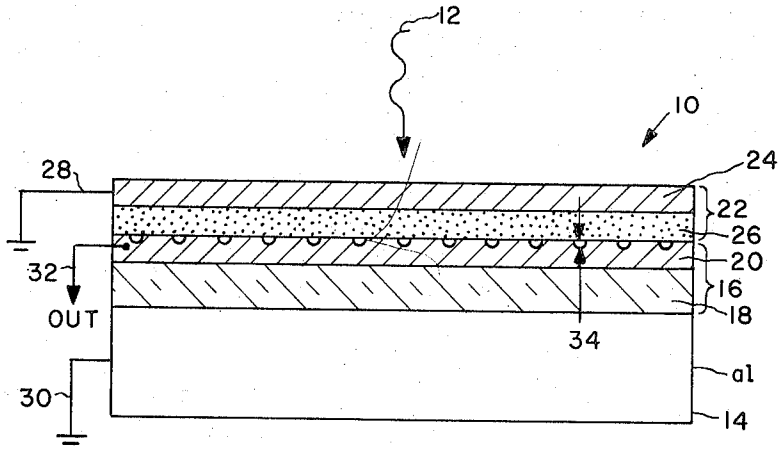

12
10
28
24
22
26
20
16
18
32
OUT
34
30
al
14

Fig. 1

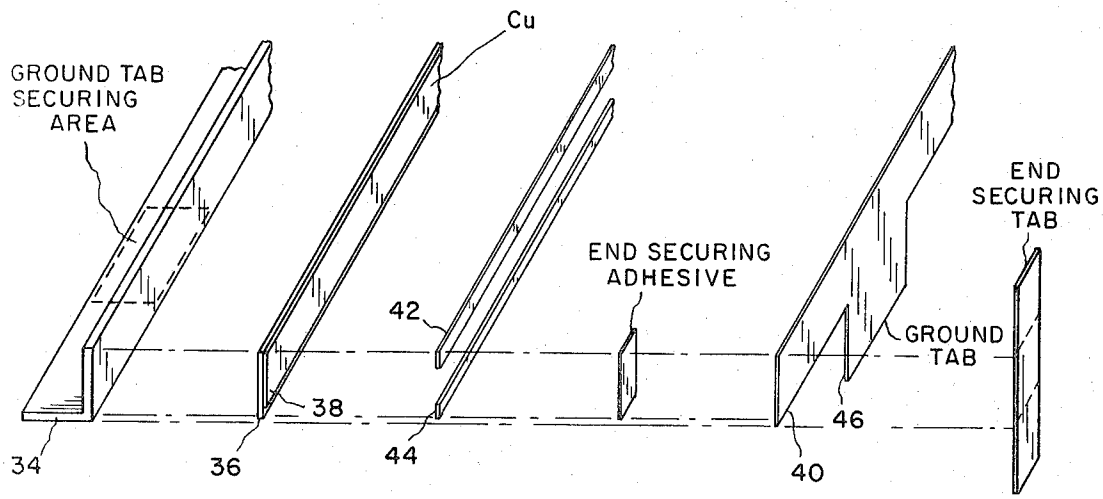

GROUND TAB SECURING AREA
Cu
END SECURING ADHESIVE
END SECURING TAB
42
GROUND TAB
38
46
34
36
44
40

Fig. 2

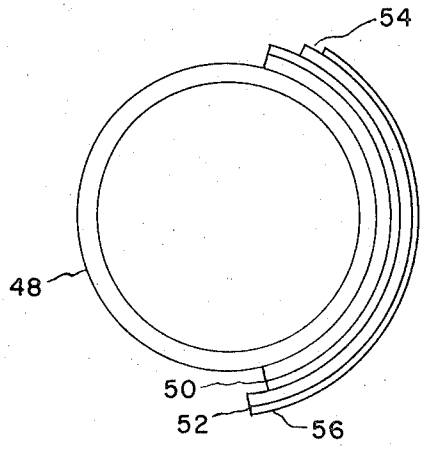


Fig. 3

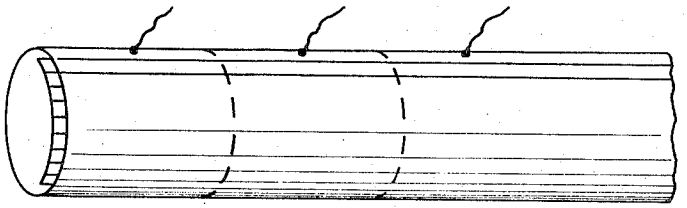


Fig. 4

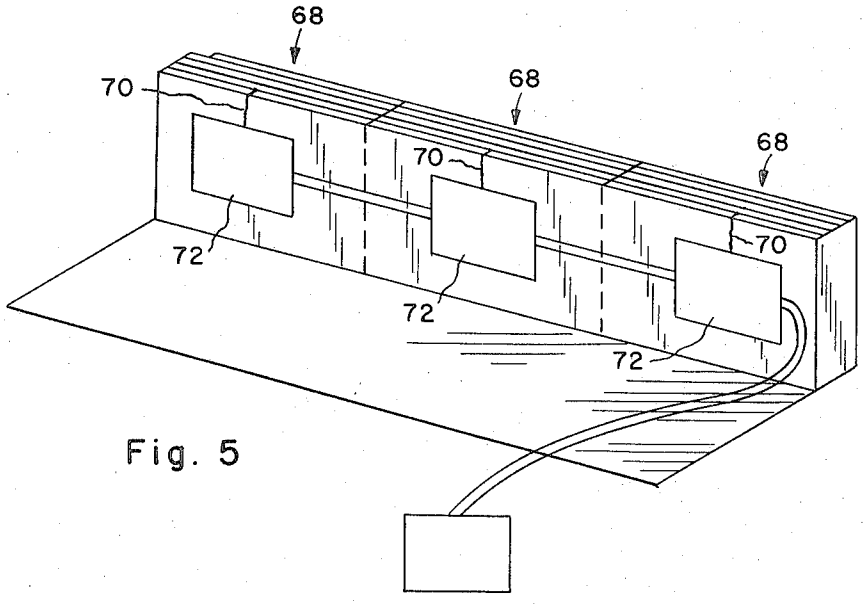


Fig. 5

MICROPHONE CONSTRUCTION

This invention relates to electro static transducers and more particularly to an improved method of constructing an electro static transducer employing the thermo electret foil construction.

Condenser or electro static microphones of the class described operate by means of a relative vibration of a pair of spaced electrodes. Efficient condenser type microphones having high capacitance are made possible by the use of a thin metalized dielectric film placed next to a solid back plate with a minimum air gap. The metal side of the dielectric forms one plate of the capacitor while the solid back forms the other. In this situation a DC bias is required to operate the solid dielectric microphone. In some dielectric materials, however, there exists a small electro static polarization which is created during the manufacturing process and can have a long lifetime. This polarization, which makes the foil electret, can aid or oppose applied DC voltage. Prepolarization of foils has certain distinct advantages and can be accomplished by the formation of a thermoelectret process wherein a dielectric foil can be heated to approximately 150°C and exposed to a high DC field. The foil is then allowed to cool in the DC field and a strong polarization of the foil results. This polarization eliminates the need of an external DC bias which is necessary in other types of condenser microphones. Construction of such devices in the past has proved relatively difficult in view of the high precision and manufacture necessary in order to avoid foreign particles in the spacing between the movable plate and the back plate. One proposed solution has been to add additional dielectric layers between the movable and the back fixed plate, however, as a result the spacing between the movable plate and the fixed plate is relatively large and the transducer capacitance relatively low. Another proposed solution is to provide a porous back plate formed of a suitable texture and porosity so as to avoid an accumulation of air bubbles beneath the diaphragm and yet to provide a plurality of contact points between the movable plate and the fixed plate. The porous back plate in such case has been formed by the use of sintered porous materials, wire mesh screens, metallic foams, metalized plastic, and the like. Such manufacture has been relatively uneconomical as well as difficult in production. It is further desirable in the forming of an electret type microphone to provide a self shielding, self polarized construction of desired shape adaptable to be employed with an integrated amplifier. Each of the sensors described above have certain principles of operation and construction. Extended sensors are essential linear extended capacitors, flat or cylindrical in the sense that the ratio length to height of the sensitive surface is usually, although not always, a relatively large number. In this case, one capacitor plate is at a potential above or below ground and is not movable. The other capacitor plate, preferably in the form of a thin plastic film metalized on one surface, is capable of vibratory motion induced by the absorption of sonic energy. This plate is at ground potential. It is noted that the nonmovable plate from which a signal is taken, as through a series load resistor, is sandwiched between another nonmovable plate at ground potential from which it is insulated, the microphone frame itself, and the thin movable film which is also at ground.

Thus, an excellently shielded microphone system is constructable.

Therefore, it is the prime object of the present invention to provide a novel electret microphone construction which provides for a superior microphone than has heretofor been available.

It is a further object of the present invention to provide a microphone construction employing a shielded sandwich structure.

It is a still further object of the present invention to provide a novel method of manufacturing the stationary plate forming the sub-surface of the microphone to provide an equidistribution of an infinite number of small d capacitors thereby improving the output level relative to noise.

It is another object of the present invention to provide a thermo electric microphone without the necessity of preheating the electret foil.

It is another object of the present invention to permit the construction of extremely long microphones by providing microphone sensors in segments with a preamplifier integrally connected to each segment.

The foregoing objects are accomplished by means of a microphone construction which employs the use of a mounted non-movable plate affixed to the microphone frame, which is used to supply the signal transduced by the microphone. This nonmovable plate is sandwiched between the microphone frame and the thin movable film. Since the thin movable film is at ground potential and the microphone frame is at ground potential, the movable film and thus the output of the microphone system is excellently shielded from any surrounding factors. The magnitude of the voltage output of a vibrating capacitor, such as is described above, can be calculated. Assuming a large load resistor so that the charge remains constant, then $v = q/c$ and $c = KA/d$, giving $v = qd/KA$ where v is voltage, c is capacitance, q is charge, K is the di-electric constant, A is area, d is spacing, and Δ is a partial derivative. Differentiating, $dv = q\,\Delta d/KA$ and $\Delta v/v = \Delta d/d$. Since Δd will be very small, $\Delta v/v$ is maximized if d is small but not zero. To take advantage of the forgoing, the present invention employs the technique of knurling or sanding the outer surface of the stationary plate affixed to the microphone frame which faces the thin film in order to form an equidistribution of an infinite number of small d capacitors, yielding an output estimated at three to five times greater than if the movable film were placed directly on a smooth fixed plate. The nature of the film used as the vibrating plate is also important in order to maximize Δd. To this end, the film must not be too thin or thick nor too stiff not pliant, so that it vibrates with the maximum amplitude in response to impinging sonic shock waves.

Prior art techniques also employ the practice of placing the film and applying an external polarizing voltage as a source of charge on the capacitor plates. This required an extremely controlled supply, and care to prevent ohmic leakage with attendant high noise level. This method was changed when it was discovered that many film materials could be permanently polarized by means of a suitable heating cycle in combination with a suitable polarizing voltage applied during the cooling period. Such a film, referred to as a thermo electret, retained a specific half life charge retention ranging from weeks to hundreds of years. The present invention further employs the novel and new technique of an in situ

method of microphone fabrication wherein the microphone is completely assembled and then placed through the heat cycling polarizing procedure to produce a finished thermo electret sensor.

The foregoing description and stated objects will become more apparent from the following more detailed description of the construction and operation of the microphone of the present invention wherein:

FIG. 1 shows a cross-section of a microphone in accordance with the present invention,

FIG. 2 shows an exploded isometric of a linear extended microphone,

FIG. 3 illustrates a cross-section of a cylindrical embodiment,

FIG. 4 a sectioned cylindrical unit, and

FIG. 5 shows the sectioned microphone and amplifier configuration.

Referring now to FIG. 1, a cross sectional embodiment of the microphone arrangement of the present invention is illustrated. As shown therein, an aluminum substrate 14 is provided with a first layer 16 attached thereto. The layer 16 includes a copper segment 20 formed as part of a film which includes an insulator backing 18. To the layer 16 is attached a second layer 22 which consists of an aluminized polycarbonate film having a layer of aluminum 24 forming the upper surface thereof and the polycarbonate thin film insulating material 26 forming the lower surface thereof. The insulting layer 18 may be any suitable insulating material with appropriate dielectric properties such as a glass loaded epoxy substance. To the upper metalized layer 24 is attached a ground lead 28 placing the upper layer 24 at a reference or ground potential. To the aluminum layer 14 is attached a ground lead 30 placing the aluminum layer at the same reference or ground potential. The operative layer, the copper layer 20, is provided with a lead 32 providing the output signal therefrom. The copper layer 20 itself is provided with a plurality of surface spacings indicated generally as 34 which provide the plurality of equidistant spaced d length capacitors as described above. The technique for creating these areas 34 will be described in further detail below.

Referring now to FIG. 2, an exploded isometric view of the microphone construction is illustrated. As shown therein, an aluminum extrusion in the shape of the ell bar 34 is provided. The ell bar is shown for the purpose of making a flat linear extended microphone. It should be noted that a cylindrical or other shape microphone can be formed as desired, as will be explained in further detail below. The construction technique remains the same as with the flat linear extended microphone. Thus, the aluminum extrusion 34 is designed to receive a copper clad epoxy film 36. The copper surface 38 of the epoxy film is previously treated by an appropriate scoring process such as sand blasting, or knurling. The effect of sand blasting or knurling is to produce a series of randomly spaced depressions within the copper surface which form an infinite plurality of substantially equidistant spaced d capacitors as described above. The film 36 may be attached to the surface of the aluminum extrusion 34 by means of a suitable adhesive, such as epoxy.

Since the electret, the outer element, which is preferably an aluminized mylar polycarbonate film 40, is hydroscopic in nature, it may be previously treated in an oven to eliminate any excess moisture which may have been formed prior to polarizing. Alternatively, moisture may be eliminated by use of a suitable desicant.

To the upper part of the assembled film and aluminum extrusion is placed a strip of tape 42 and a lower strip 44. To this tape, which is sticky on both sides, the aluminum polycarbonate material 40, is applied. The outer surfaces are now trimmed to assure the aluminized mylar element conforms to the surface of the aluminum extrusion 34 and the ground bar flap 46 is wrapped around and underneath the surface of the aluminum extrusion 34 and makes contact directly thereto to provide a common ground reference potential for both the aluminum extrusion frame element and the outer aluminum surface of the aluminized polycarbonate film 40. By making both the elements 40 and 34 at a common ground potential, adequate isolation of the internal copper element 38 is assured.

Next, electret polarization is effected by a thermal treatment. To this end, the entire assembly is placed in a furnace. A high voltage of approximately 500 volts negative is applied to the bar 34 with reference to the copper film 38. With the voltage on, the temperature of the oven is raised to 150° at which point the oven is turned off. The oven is then allowed to cool to 75° with the voltage on. When the work reaches the room temperature, and the aluminized surface is polarized as evidenced by adherence of the foil to the copper film, significant to show the grating detail of the scoring of the film, the voltage may be turned off.

As an alternative, a cylindrical embodiment may be employed. Thus, referring to FIGS. 3 and 4, an aluminum tube frame 48 is provided with a first layer 50 of copper laminate plate and a second layer 52 of an aluminized polycarbonate film. As shown, the copper layer 62 is electrically separated from the aluminum tube 48 by insulating layer 64, and the aluminized layer 58 separated from the copper layer by an insulator 60. Common ground is formed by electrically connecting the aluminized layer 58 to the frame 48. The techniques of applying the plate as well as thermally treating the film are precisely as described above in connection with the ell bar. With regard to this embodiment, a small region of the film 52 is devoid of foil 54 to prevent arcing from the aluminized layer to the copper. A further overhang of the layer 52 with respect to layer 50 to prevent arcing is shown in FIG. 3. Also, to facilitate connection of the lead, the film 52 may overlap the film 50 at one arcuate end, and underlap the film 50 at the other end.

As described above, in microphones of undue length, of either cylindrical or flat configuration, the signal to noise ratios may be improved by providing sectioning. Sectioning is accomplished by splitting the copper coating of the layer 50 in a radial fashion at set distance from the end of the frame to form a desired section length.

The laminate 50 is sectioned by split down through the conductive surface 62 to, but not through, the insulation backing 64. The outside layer 52 need not be split since it forms a common ground reference for the laminate segments.

During the formation of the microphone, where two segments of laminate material are epoxied to the frame in a side by side relationship, it has been found that epoxy material inevitably leaks between the segments. When thermally treated, the epoxy becomes conductive, and forms a conductive path from aluminum to

the copper, and thus inhibits polarization during the thermal cycle. To prevent this occurrence, this invention employs the technique of providing a slit, made through the butt area all the way down to the frame and thus removing the excess epoxy path.

Referring to FIG. 5, showing the rear of a linear flat surface microphone, each microphone section **68** is coupled by virtue of an electrical lead **70** to an amplifier **72**. The output of each amplifier is coupled through each subsequent amplifier for providing a common output. It has been found that this arrangement results in an output characteristic equivalent to that caused by a single microphone section, and that this characteristic remains regardless of the length of the microphone or the number of sections. Obviously, the cylindrical embodiment may employ the same configuration.

Alternatively, a summing amplifier may be employed with each amplifier section **72** coupled thereto.

Amplifiers may be physically attached to the reverse side of the surface of the microphone which receives sound sensing and a lead attached to the copper area directly. The lower end of the microphone may include a slight overhang of metalized film **56** to prevent arcing therein as well. As shown in FIG. **4**, a sectional microphone is illustrated. By removing elements of the upper film, segments of the copper can be exposed to allow for a microphone amplifier connection to be made directly to the copper.

In a typical physical embodiment, a cylindrical microphone may embrace a cylinder of aluminum with a 2 inch outside diameter 36 inches long covered with a 2½ inch wide 5 mil copper laminate. As described above, the copper is scored as by sand blasting and may be split into three equal sections. The copper area is covered with a 2 inch wide film which is formed with a capacity of about 10,000 picofarads for 12 inch lengths in a manner similar to that described for a flat sensor. In a cylindrical embodiment, the arcuate angular sweep is as much as 104°, the pulse output in this case with a sound source 36 inches away is 2milli volts for each section.

With faster response times, noise is less of a problem. The response time of the microphone output is markedly affected by the thickness, density, stiffness of the vibrating film. The following list of film material, and processing temperatures, is not intended to be exclusive but merely illustrative of the different film materials and their properties. Also, variation within the temperature regions may be realized within the scope of the invention.

MATERIAL (FILM)	PROCESSING TEMPERATURE	
	Heat	Cool
½ mil aluminized mylar	125°C	60°C
½ mil aluminized polycarbonate	150°C	75°C
½ mil goldized polyimide	150°C	75°C
½ mil aluminized polypropylene	110°C	55°C
½ mil aluminized polystryene	70°C	35°C
1 mil aluminized teflon	150°C	75°C
½ mil aluminized polysulfonr	150°C	75°C

While the invention has been described and shown with reference to certain preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A microphone construction comprising:
an elongated conductive frame member;
a plurality of non-moveable plate sections affixed to and insulated from said frame, each said plate section including a conductive surface facing away from said frame and having a multiplicity of distributed minute depressions therein;
a plurality of thin moveable electret insulating film sections disposed on the conductive surfaces of said plate sections, each of said film sections having an outer conductive layer;
means for coupling each of said outer conductive layers to said frame; and
means for coupling the plate sections in series to a common output.

2. A method of manufacturing a microphone on an elongated frame member comprising the steps of:
applying a conductor-clad insulator to said frame, the insulating side facing said frame;
sectioning the first applied layer into multiple sections;
applying an insulating layer having a thin conductive film on the outer surface thereof to said conductor-clad insulator;
electrically coupling said sections in series;
applying a voltage between said conductive film and the conductive sections of said conductor-clad insulator; and
heating the entire assembly while said voltage is being applied.

3. The method as defined by claim **2** comprising the additional step of removing a multiplicity of particles from the conductive portion of said conductor-clad insulator before the application of said insulating layer thereto.

4. The method as defined by claim **2** comprising the additional step of electrically coupling said conductive film to said frame before application of said voltage.

* * * * *