

"AN ELECTRODE PLATE ELECTRET FOR AN ELECTRO-ACOUSTIC
TRANSDUCER AND TO A METHOD OF MANUFACTURING AN ELECTRODE
PLATE ELECTRET"

5 This invention relates to an electret, namely an
electrode plate having a polarized polymer film, for
use in an electro-acoustic transducer which converts an
electrical signal into an acoustic signal or vice versa
through utilization of a change in electrostatic
capacitance.

10 An electrostatic speaker is known in which an electrode
plate electret having an electret deposited on one side
of an electrode plate and a diaphragm are disposed in
opposing relation and an electrical signal is applied
15 across them to vibrate the diaphragm in accordance with
the electrical signal, thus converting the electrical
signal into an acoustic signal. Also, an electrostatic
microphone is known in which an electrode plate
electret and a diaphragm are disposed opposite each
other, the diaphragm is vibrated by an acoustic signal
20 and the acoustic signal is converted into an electrical
signal by utilizing the change in the electrostatic
capacitance between the electrode plate electret and
the diaphragm.

25 The following methods have heretofore been employed in
the manufacture of electrode plate electrets used in
such electrostatic type electro-acoustic transducers.
In one method, a polarized polymer film, commonly
referred to as an electret film, is stuck to an
electrode plate with an adhesive binder. With this
30 method, however, the adhesive binder tends to impair
the characteristics of the electret and reduce the
conversion gain of the transducer. Also, it is
difficult to stick the electret film uniformly over the

entire area of the electrode plate so that the electret film is liable to become mechanically distorted, which hinders its electrification and reduces its service life. Furthermore, this method is disadvantageous in that sticking the electret film to the electrode plate is cumbersome and hence is difficult to mass produce and is susceptible to variation in quality.

Another method which has been employed to manufacture electrode plate electrets is to weld the polymer film to the electrode plate by fusion at a temperature close to the melting point of the film and then render the film into an electret. With this method, however, the thickness of the polymer film is made uneven by the heating involved in the fusion-welding operation, which results in the electret film becoming physically unstable and hence short-lived. Moreover, this method involves heating the assembly up to the vicinity of the melting point of the polymer film, and consequently this method is also poor in productivity.

An object of the present invention is therefore to overcome or alleviate the above-mentioned disadvantages experienced in the prior art.

Accordingly, the invention resides in one aspect in a method of manufacturing an electrode plate electret for an electrostatic type electro-acoustic transducer, wherein a polymer film for polarization is attached to an electrode plate and is then polarized, and wherein the method includes the steps of:

forming a laminated member by inserting between the polymer film for polarization and the electrode plate an intermediate polymer film having a lower melting point than the polymer film for polarization; and

heating the laminated member at a temperature near the melting point of the intermediate polymer film to fusion-weld the polymer film for polarization to the electrode plate through the intermediate polymer film.

5 In a further aspect, the invention resides in a method of manufacturing an electrode plate electret for an electrostatic type electro-acoustic transducer, wherein a polarized polymer film is attached to an electrode plate, and wherein the method includes the steps of:

10 forming a laminated member by inserting between the polarized polymer film and the electrode plate an intermediate polymer film having a lower melting point than the polarized polymer film; and

15 heating the laminated member at a temperature near the melting point of the intermediate polymer film to fusion-weld the polarized polymer film to the electrode plate through the intermediate polymer film.

In yet a further aspect, the invention resides in an electrode plate electret for an electrostatic type
20 electro-acoustic transducer wherein a polarized polymer film is attached to an electrode plate, and wherein an intermediate polymer film having a lower melting point than the polarized polymer film is sandwiched between, and is fusion-welded to, the polarized polymer film and
25 the electrode plate.

More specifically, in the electrode plate electret, an intermediate polymer film is interposed between a polarized polymer film and an electrode plate. The intermediate polymer film has a lower melting point and
30 a smaller thickness than the polarized polymer film. The electrode plate electret has formed therethrough a

suitable number of holes 80 corresponding to holes 34 and 56 in Figures 1 and 2.

The electrode plate electret is produced in the following manner: The polymer film for polarization is fusion-welded to a thin film member, i.e. the electrode plate, with the intermediate polymer film sandwiched therebetween. The polymer film for polarization, thus fusion-welded to the electrode plate, is then polarized. The intermediate polymer film has a lower melting point than the polymer film for polarization, and the fusion-welding temperature is selected so as to be close to the melting point of the intermediate film. Accordingly, the fusion-welding takes place at a relatively low temperature and hence is easy to conduct. Moreover, the thickness of the polymer film for polarization is not changed by the fusion-welding. As a result, the final electrode plate electret is physically stable, excellent electrically and long-lived. It is preferred that the intermediate polymer film is smaller in thickness than the polymer film for polarization. In the fusion-welding, heating and pressurizing are carried out at the same time. The polymer film for polarization may also be fusion-welded to the electrode plate through the intermediate polymer film after being polarized. In this case, since the fusion-welding temperature is lower than the melting point of the polarized polymer film, there is no danger of the thickness of the polarized film being changed, and deterioration in the polarization characteristics are also negligible. Since the temperature and time required to effect fusion-welding of the polarized polymer film to the electrode plate through the intermediate polymer film are substantially equal to the temperature and time for ageing the polarized film, the overall manufacturing time can be reduced by

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performing the ageing concurrently with the fusion-welding.

The invention will now be more specifically described with reference to the accompanying drawings, wherein:

- 5 Figure 1 is a cross-sectional view of an electro-acoustic transducer for use in an electrostatic type headphone and employing an electrode plate electret according to one example of the invention;
- 10 Figure 2 is a cross-sectional view of an electrostatic type microphone employing the electrode plate electret according to said one example;
- Figure 3 is a cross-sectional view of the electrode plate electret of said one example;
- 15 Figure 4 is a cross-sectional view of heating apparatus for simultaneously subjecting a plurality of laminated electret assemblies placed one on another to a fusion-welding process;
- 20 Figure 5 is a cross-sectional view of apparatus for continuously forming a laminated electret assembly and continuously subjecting it to a fusion-welding process; and
- Figure 6 is a diagrammatic illustration of a method of polarizing a laminated electret assembly.

- 25 Referring to Figure 1, there is shown an electro-acoustic transducer including a cylindrical case 11 having inwardly extending flanges 12 and 13 formed integrally therewith at its opposite open ends. Electrode plate electrets 14 and 15 are respectively
- 30 disposed on the inside of the flanges 12 and 13 to close the open ends of the case 11. In the space defined between the electrode plate electrets 14 and 15 is disposed a diaphragm 16 with ring-shaped spacers 17 and 18 formed of an insulating material respectively

sandwiched between the diaphragm and the electrode plate electrets. The diaphragm 16 is formed by depositing conductive layers 21 and 22 on both sides of a polyester resin or like polymer film 19, conveniently 3 to 6 μ thick, by evaporating aluminum or a similar metal on the film. Metal rings 23 and 24 are interposed respectively between the conductive layers 21 and 22 and the spacers 17 and 18. The electrode plate electrets 14 and 15 are respectively composed of conductors, i.e. electrode plates 25 and 26 and electret films 27 and 28 respectively attached thereto. These electrode plate electrets are disposed with the electrode plates 25 and 26 held in contact with the flanges 12 and 13 of the case 11 respectively.

The electrode plate electrets 14 and 15 have polymer films 31 and 32 respectively interposed between the electret films 27 and 28 and the electrode plates 25 and 26. The electrode plate electrets 14 and 15 have formed therethrough sound emission holes 33 and 34 respectively. An electrical signal from a signal source 35 is applied to the primary side of a transformer 36, the secondary side of which has its both ends electrically connected to the electrode plates 25 and 26 respectively, and has its mid point electrically connected to the metal rings 21 and 22.

With such an arrangement, the diaphragm 16 is driven in a push-pull manner in response to the electrical signal supplied by the signal source 35. Either one of the conductive layers 21 and 22 of the diaphragm 16 may also be omitted.

Referring to Figure 2, there is shown therein an electrostatic microphone, in which a microphone unit 42 and an impedance conversion unit 43 are arranged in a

cylindrical case 41 in its axial direction. In the microphone unit 42, a cylindrical capsule 44 is housed in contact with the internal surface of the case, and a front plate 45 of the capsule 44 has formed therethrough a sound guide hole 46, which is covered by a dust-proof cloth 47. Mounted adjacent to, but spaced from, the internal surface of the front plate 45 is a diaphragm 48 which is formed by vapour-deposition of a metal on one side of a polymer film 49 to form thereon a conductive layer 51. A metal ring 52 is bonded to the conductive layer 51 and is disposed in contact with the inner surface of the front plate 45 of the capsule 44. Mounted adjacent the diaphragm 48 is an electrode plate electret 54 with a ring-shaped spacer 53 being interposed therebetween. The electrode plate electret 54 is supported by an electrode holder 55 defined by a cylindrical synthetic resin member which is closed at one end and which carries the electrode plate electret 54 at its opposite open end. The electrode plate electret 54 has formed therethrough an air hole 56. The electrode plate electret 54 comprises an electrode plate 57 and an electret film 58 attached thereto, with an intermediate polymer film 59 being sandwiched between the electrode plate 57 and the electret film 58.

In the impedance conversion unit 43, a tubular member 61 is located adjacent the capsule 44 substantially in contact with the inner peripheral surface of the case 41 and a printed circuit board 62 is mounted at the open end of the tubular member 61 remote from the capsule 44. The printed circuit board 62 has formed thereon an impedance converter 63 which is located in the tubular member 61 and is connected to the electrode plate 57 of the electrode plate electret 54 through the closed end of the electrode holder 55. When an acoustic signal enters the microphone via the sound guide hole

46, the diaphragm 48 is vibrated to change the electrostatic capacitance between the diaphragm 48 and the electrode plate electret 54 and thereby produce an output in the form of a low impedance signal from the impedance converter 63.

The opposite end portions of the case 41 are respectively bent over the external surfaces of the front plate 45 and the printed circuit board 62, by which the microphone unit 42 and the impedance conversion unit 43 are mechanically coupled.

As indicated generally by 74 in Figure 3, the electrode plate electret of said one example of the present invention has a polymer film 73 for polarization which is deposited on a conductor i.e. the electrode plate 71, with an intermediate polymer film 72 being sandwiched therebetween. Suitable materials for the polymer film 73 include a tetrafluoroethylene-hexafluoropropylene copolymer film (FEP), a polycarbonate film (PC), a polyethylene film (PE), a polyvinylidene fluoride film (PVF₂) and a polypropylene film (PP). These polymer films have fusion-welding temperatures ranging from 282 to 371°C, 204 to 221°C, 121 to 204°C, 204 to 218°C and 140 to 240°C respectively.

Where the electrode plate electret is used in a headphone, the polymer film 73 for polarization is arranged to have a diameter of 50 to 60mm and a thickness of 75 to 125 μ and, in this case, it is possible to employ a known method for increasing the adhesiveness of the film, as required, by treating one side of the film with a naphthalene solution of sodium to make it relatively rough, or depositing aluminum, nickel or like metal on one side of the film by evaporation.

The intermediate polymer film 72 is conveniently arranged also to be 50 to 60mm in diameter and 10 to 30 μ thick and is interposed between the electrode plate 71 and the polymer film 73 for polarization. In this case, the electrode plate 71, the intermediate polymer film 72 and the polymer film 73 for polarization are placed one upon another in this order to form a laminated member 74, with the pretreated side of the film 73 contacting the film 72.

Then, the laminated member 74 is heated in air at a temperature lying within the fusion-welded temperature range of the intermediate polymer film 72, by which the polymer film 73 for polarization is adhered to the electrode plate 71 through the intermediate polymer film 72.

As shown in Figure 4, the above heat-fusing treatment is effected in a thermostat 75 including a base 76 on which the laminated member 74 is disposed with a separator 77 conveniently defined by a polytetrafluoroethylene film (PTFE film) being interposed between the electrode plate 71 and the base 76. The separator 77 is chosen so as to have a heat resistance above 300°C and hence is not fusion-welded to the laminated member 74.

In Figure 4, a plurality of laminated members 74 are heat-treated simultaneously; namely, a desired number of laminated members 74 are placed one on top of another with a separator 77 being inserted between adjacent members 74. Further, a weight, conveniently of about 2Kg, is placed on a further separator 77 mounted on the uppermost laminated member 74.

The temperature in the thermostat 75 is set to a value lying within the fusion-welded temperature range of the intermediate polymer film 72 used. In the case where, for example, a polycarbonate film is used as the intermediate polymer film 72, the heating temperature in the thermostat 75 would be in the range of 210 to 250°C; in the case of a polyethylene film, the heating temperature would be about 150°C; in the case of a polyvinylidene fluoride film, the heating temperature would be about 200°C; and in the case of a polypropylene film, the heating temperature would be approximately 200°C. The thermostat 75 is maintained at the set temperature for about an hour and then allowed to cool.

In the continuous heat-fusion process shown in Figure 5, a strip of aluminum or like metal to define the electrode plate 71 and having a thickness of about 0.6 to 1mm is fed in the direction of the arrow 79, and the intermediate polymer film 72 wound on a supply bobbin 81 is fed onto the strip 71 through guide rollers 82. Further, the polymer film 73 for polarization wound on a supply bobbin 83 is similarly fed onto the intermediate polymer film 72 through guide rollers 84. The polymer film 73 for polarization is 75 to 125 μ thick and the side of the film for contact with the intermediate polymer film 72 can be roughened by treatment with a naphthalene solution of sodium, or deposited with aluminum, nickel or like metal by evaporation, as described previously. The intermediate polymer film 72 is approximately 20 to 30 μ thick. The laminated member 74 composed of the electrode plate strip 71, the intermediate polymer film 72 and the polymer film 73 for polarization is fed into a heating furnace 86 via heat rollers 85 at a predetermined speed. The temperature in the heating furnace 86 is set

at a predetermined value within the fusion-welding temperature range of the intermediate polymer film 72. Heat rollers (not shown) are also provided in the heating furnace 86 for imparting a predetermined pressure to the laminated member 74; namely, the laminated member 74 passes through the heating furnace 86 while being heated and pressurized for a predetermined period of time. In this way, the polymer film 73 for polarization is bonded to the electrode plate 71 through the intermediate polymer film 72.

The laminated member 74 composed of the polymer film 73 for polarization, the intermediate polymer film 72 and the electrode plate 71, thus bonded together by the heat-fusing process then undergoes a polarization process for polarizing the polymer film 73. Prior to the polarization process, holes 80 (see Fig. 6) corresponding to the holes 34 and 56 in Figures 1 and 2 are made in the laminated member 74 by means of, for example, a press. In the case of the continuously formed laminated member 74 shown in Figure 5, the laminated member 74 can be simultaneously blanked into the shape of the electrode plate electret which is ultimately to be used in an electro-acoustic transducer.

In the polarization process illustrated in Figure 6, the laminated member 74 after being subjected to the heat-fusing process is placed on a base (not shown). The positive terminal of a power source 87 is then connected to the electrode plate 71 which is arranged to be the lowermost layer of the laminated member 74, and a needle electrode 88, which is connected to the negative terminal of the power source 87, is disposed substantially centrally above the uppermost polymer film 73 of the laminated member 74 so as to extend perpendicularly thereto to a distance of about 50mm.

from the film 73. A DC voltage of about 25 KV is then applied across the electrode plate 71 and the needle electrode 88 for about 20 to 30 minutes to produce a corona discharge on the surface of the polymer film 73. After the polarization process, the laminated member 73 is subjected to ageing at a temperature of approximately 150°C for about an hour to complete the manufacturing process.

EXAMPLE

The polymer film 73 for polarization was defined by a tetrafluoroethylene-hexafluoropropylene copolymer film having a melting point of 260 to 280°C and a thickness of 125 μ , one side of the film having been slightly roughened using a sodium solution. The polymer film 73 was fusion-welded to a 1 mm thick aluminum electrode plate 71 at a temperature of 240°C using, as the intermediate polymer film 72, a 20 μ thick polycarbonate film having a melting point of 220 to 230°C. Thereafter the fusion-welded polymer film 73 was polarized at -25 KV by the needle electrode corona discharge method described previously in connection with Figure 6 and then the film was aged at 150°C for an hour. As a result, the initial value of the surface potential was about -850 V. This sample was subjected to a temperature-acceleration test at 90°C, and the time taken for the magnitude of the surface potential to be attenuated by 1 dB, that is, down to 89.1% of its initial value was 1920 hours.

By way of comparison, the same polymer film for polarization use as mentioned above was fusion-welded to the aforesaid electrode plate at 280°C without using the intermediate polymer film and was polarized under the same conditions as referred to above, and then

aged. The initial surface potential of this sample was about -850 V as in the case where the intermediate polymer film as used. However, the time for the magnitude of the surface potential to be attenuated by 1 dB in the temperature-acceleration test was 150 hours, which was markedly shorter than the case where the intermediate polymer film was used.

As described above, since the electrode plate electret of the present invention employs the intermediate polymer film and is fusion-welded to the electrode plate at the fusion-welding temperature of the intermediate film, the fusion-welding temperature is relatively low, thereby making the fusion-welding easier. In addition, since the melting point of the polymer film for polarization is higher than the fusion-welding temperature, the polymer film for polarization fusion-welded to the electrode plate is uniformly thick, physically stable and long-lived. As compared with the case of using an adhesive binder, the fusion-welding provides for enhanced workability of the polymer film for polarization and ensures uniform joining of the film to the electrode plate over the entire area thereof. Moreover, the electrode electret of this invention is suitable for mass production.

In the foregoing, the polymer film for polarization is fusion-welded to the electrode plate and then rendered into an electret, but it is also possible to polarize the polymer film in advance and then fusion-weld the polarized film to the electrode plate using the intermediate polymer film. In this case, since the fusion-welding takes place at a temperature lower than the melting point of the polymer film for polarization, the polarization of the polymer film is hardly deteriorated. Further, the conditions for fusion-welding, such as

temperature and time, are substantially the same as the ageing conditions for rendering the polarized film into an electret, so that ageing for polarization can be conductive concurrently with heating for fusion-welding, making it possible to reduce the overall manufacturing time.

The polarization of the polymer film can be achieved not only by the corona discharge polarization method described but also by a heat polarization method, an electron beam polarization method and so forth. However, the corona discharge method is preferred since it enables the polarization to be conducted in air at room temperature using simple equipment. Further, using the corona discharge polarization method, a number of laminated members can be subjected to the polarization treatment in succession by feeding the laminated member 74 having the holes 80 shown in Figure 6 to a corona discharge polarization room by means of a belt conveyor. In this case, a conductive belt conveyor is employed and is electrically earthed, with the electrode plate being in contact with the belt conveyor.

It is preferred that the side of the electrode plate to which the intermediate polymer film is fusion-welded is roughened by sand-blasting using, for example, a No. 80 to 600 sand-blast. In such a case, the rough surface produces a key for the intermediate polymer film, making it difficult for the film to be peeled off. In the case where the polymer film for polarization is fusion-welded to the electrode plate first and then polarized, providing a rough surface on the electrode plate increases its effective area for polarization. This causes scattering of potential lines and increases the number of potential lines of the polarized polymer film per unit area, so that the applied voltage per

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unit area is increased and polarization is performed sufficiently and uniformly and is stable.



(23)

CLAIMS:

1. A method of manufacturing an electrode plate
electret for an electrostatic type electro-acoustic
transducer, wherein a polymer film for polarization is
5 attached to an electrode plate and is then polarized,
and wherein the method includes the steps of:

forming a laminated member by inserting between the
polymer film for polarization and the electrode plate
an intermediate polymer film having a lower melting
10 point than the polymer film for polarization; and

heating the laminated member at a temperature near the
melting point of the intermediate polymer film to
fusion-weld the polymer film for polarization to the
electrode plate through the intermediate polymer film.

15 2. A method as claimed in claim 1, wherein the
fusion welding is effected by placing a plurality of
said laminated members one upon another with a
separator interposed between adjacent members, the
separator having a high melting point than the
20 intermediate polymer film and being readily removable
from the electrode plate and the polymer film for
polarization, disposing the laminated members in a
thermostat while applying pressure to the members, and
maintaining the thermostat at the temperature required
for the fusion welding.

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3. A method as claimed in claim 1, wherein the laminated member is formed by continuously feeding the electrode plate; continuously feeding the intermediate polymer film onto the electrode plate from a supply bobbin at the same speed as the electrode plate; and continuously feeding the polymer film for polarization onto the intermediate polymer film from a supply bobbin at the same speed as the electrode plate.

4. A method as claimed in claim 3, wherein the fusion-welding step is effected by passing the continuously formed laminated member through a heating furnace for a predetermined period of time.

5. A method as claimed in any one of the preceding claims, wherein the surface of the polymer film for polarization required to contact the intermediate polymer film is roughened.

6. A method as claimed in any one of claims 1 to 4, wherein the intermediate polymer film is 10 to 30 μ thick.

7. A method of manufacturing an electrode plate electret for an electrostatic type electro-acoustic transducer, wherein a polarized polymer film is attached to an electrode plate, and wherein the method includes the steps of:

forming a laminated member by inserting between the polarized polymer film and the electrode plate an intermediate polymer film having a lower melting point than the polarized polymer film; and

heating the laminated member at a temperature near the melting point of the intermediate polymer film to fusion-weld the polarized polymer film to the electrode plate through the intermediate polymer film.



8. A method as claimed in claim 7, wherein the fusion welding step also serves to age the polarized polymer film.
9. A method as claimed in claim 1 or claim 7, substantially as hereinbefore described with reference to Figures 4 and 6 or Figures 5 and 6 of the accompanying drawings.
10. An electrode plate electret manufactured by a method as claimed in any preceding claim.
- 10 11. An electrode plate electret for an electrostatic type electro-acoustic transducer wherein a polarized polymer film is attached to an electrode plate, and wherein an intermediate polymer film having a lower melting point than the polarized polymer film is sandwiched between, and is fusion welded to, the
- 15 polarized polymer film and the electrode.
12. An electrode plate electret as claimed in claim 11, wherein the surface of the electrode plate in contact with the intermediate polymer film is roughened.
- 20 13. An electrode plate electret substantially as hereinbefore described with reference to, and as shown in, Figure 3 of the accompanying drawings.

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