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Kodera

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[54] **METHOD OF MAKING ELECTRET**

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[73] Assignee: **Sony Corporation,** Tokyo, Japan

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[30] **Foreign Application Priority Data**

July 5, 1973 Japan 48-76027

[52] **U.S. Cl.** ..... **29/592;** 179/111 E; 307/88 ET; 317/262 A

[51] **Int. Cl.²** **H01S 4/00**

[58] **Field of Search** ..... 29/592, 592 E; 317/262 A; 307/88 ET; 179/111 E, 100.41 B; 310/8.2, 8.8, 9.1, 9.2, 9.7; 340/173 PP; 427/39

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Assistant Examiner—Joseph A. Walkowski
Attorney, Agent, or Firm—Lewis H. Eslinger; Alvin Sinderbrand

[57] **ABSTRACT**

A method of making an electret by annealing a corona charged dielectric film on a metal plate is disclosed.

8 Claims, 11 Drawing Figures

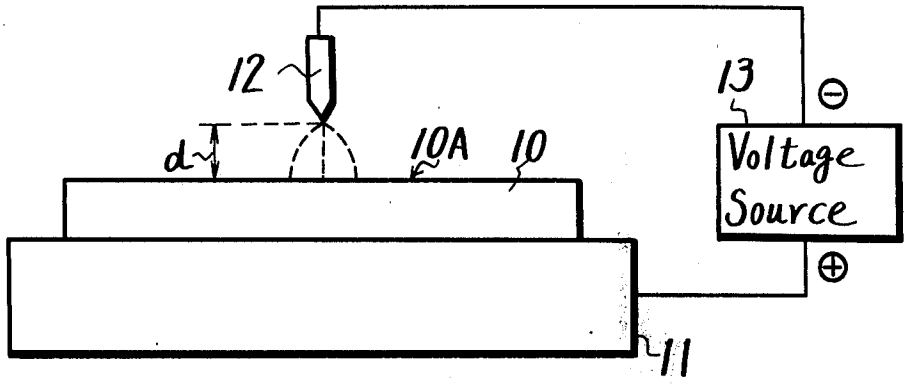


Fig. 1A

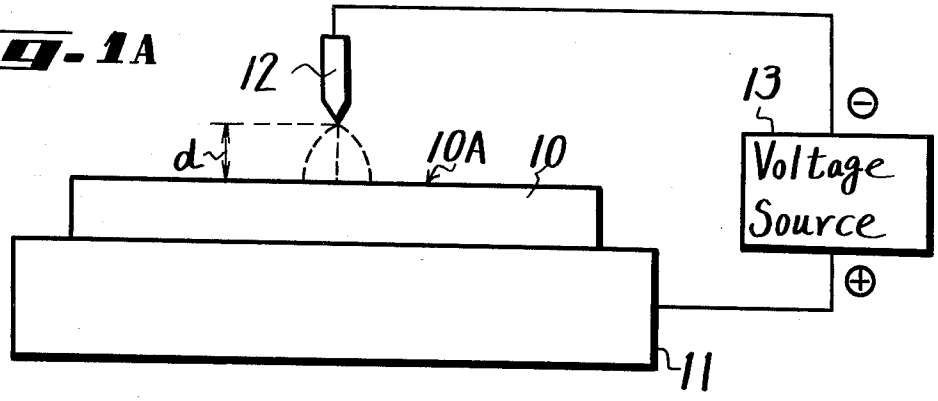


Fig. 1B

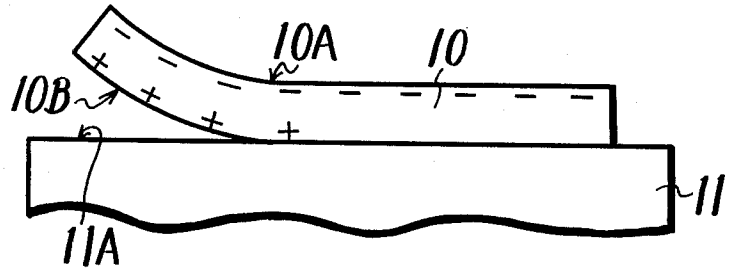


Fig. 1C

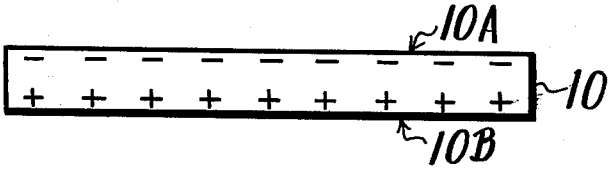


Fig. 1D

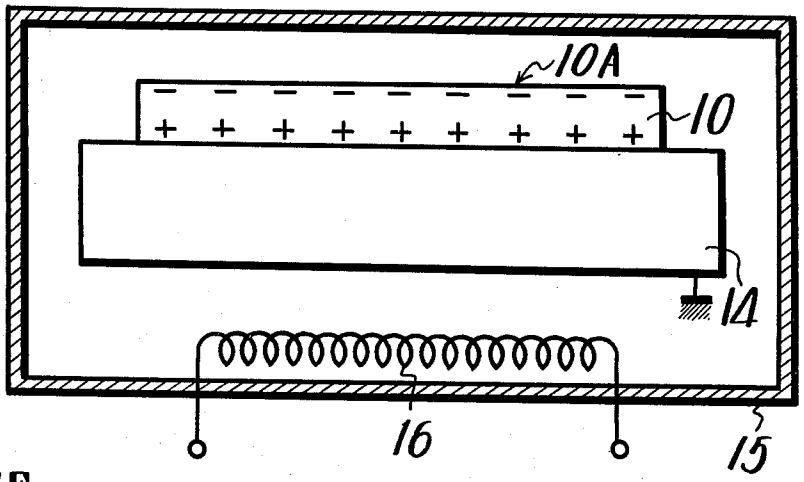


Fig. 1E

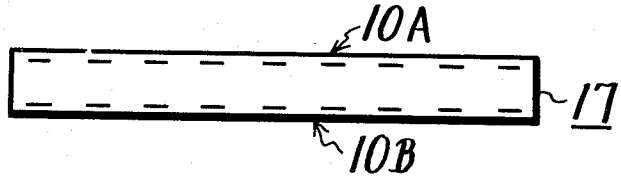


Fig. 2A

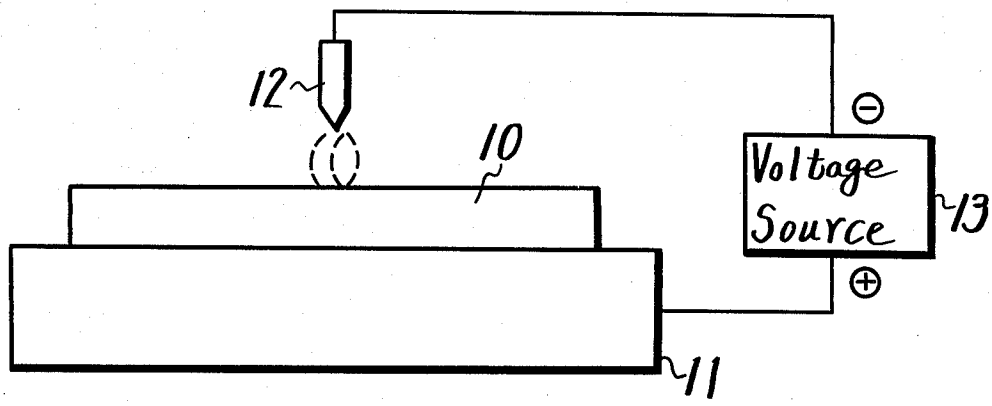


Fig. 2B

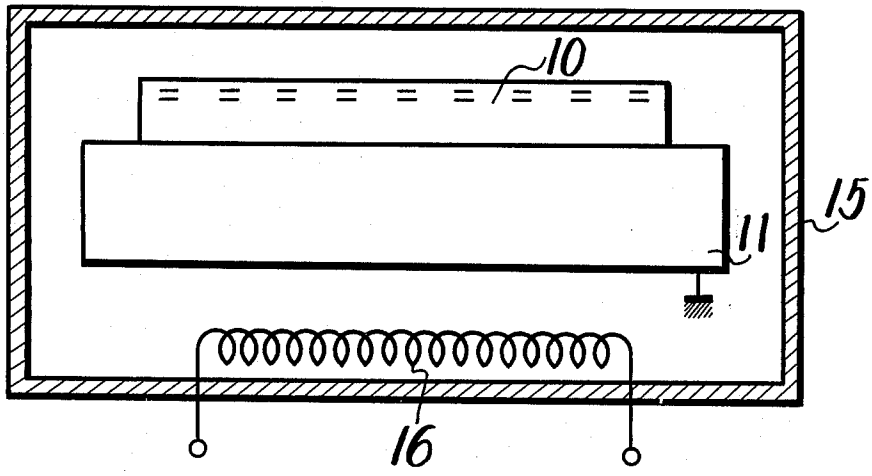


Fig. 2C

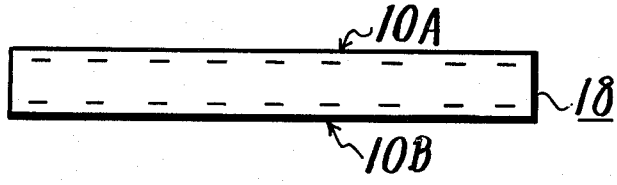


Fig. 3

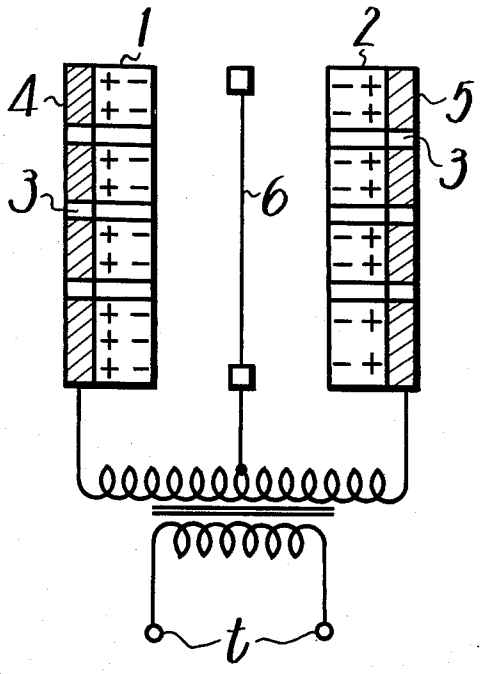


Fig. 4

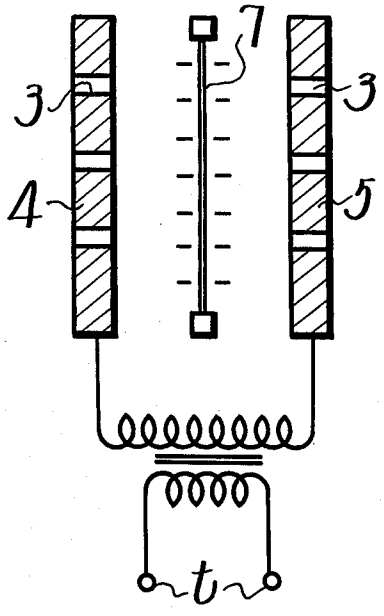
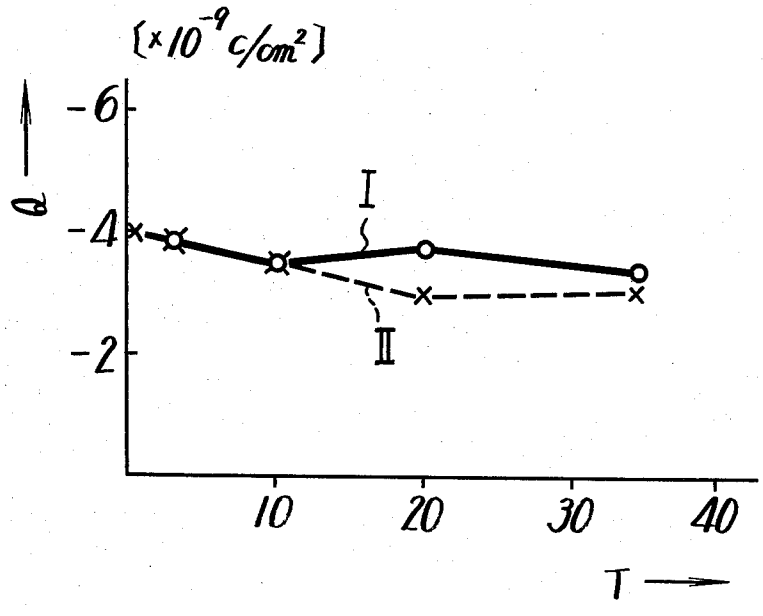


Fig. 5



METHOD OF MAKING ELECTRET

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to a method of making an electret, and more particularly is directed to a method of making an electret with a single electric charge or a monocharge electret.

2. Description of the Prior Art

Recently, a thin film electret is used as an oscillating plate or vibrating diaphragm of a microphone, speaker or the like. As the material for the thin film electret, by way of example, a high polymer film such as "Teflon FEP" (Trade name) consisting of a copolymer of tetrafluoro ethylene-hexafluoro propyrene or "Teflon TEF" (Trade name) is used.

Various methods have been known in the art to produce an electric charge on a dielectric material. In general, a dielectric material is gripped between two electrodes and subjected to heating process to make it as an electret by a heterocharge, which is known as a so-called thermo-electret method. In this case, when an electret, which is charged with positive and negative charges on its both surfaces, is used as an electrode layer is attached to one surface of the electret and the electric charge produced on the other surface thereof is utilized.

If an electret produced by the above prior art method is employed in an ear-speaker, two of such electrets are used in such a manner that they are mounted on fixed electrodes or back electrodes with apertures to face the charges of the electrets of the same polarity or sign, and an electric conductive vibrating diaphragm is located between the two electrets at their central portions from a spacial point of view to vibrate the vibrating diaphragm with an input signal applied to an input terminal.

However, such a method can not be free from the following defect. That is to say, when an dielectric film adhered to the back electrode is subjected to an electret making process, it is difficult to make an electret with a homogeneous electric charge due to the distortion of the back electrode caused by heating carried out in the electret-treatment, a time lapse change of the adhesive between the dielectric film and the back electrode, and a plurality of apertures bored through the dielectric film formed by a corona discharge. Further, when a film which is already made as an electret is attached to the back electrode, it is trouble to aligne the apertures of the film with those of the back electrode and there are a charge decay and so on due to a stain of the film.

Another method is also known in the art in which an electron beam with high energy is radiated to an dielectric film from a Van de Graaff generator. With such a method, upon an initial irradiation of the electron beam, a positive electric charge is produced on the surface of the dielectric film facing the electron beam irradiation, while a negative electric charge is produced on the other surface thereof. After a predetermined time period has lapsed, whole the film is charged with a negative electric charge entirely. This method, however, requires a much great size of an apparatus which is not preferred from a practical point of view, and the dielectric film is apt to be broken due to the irradiation of the electron beam, which causes the deterioration of a produced electret in characteristics.

SUMMARY OF THE INVENTION

According to this invention, there is proposed a method of making an electret, in which a high polymer film with no electrode is placed on a metal table and is charged with a negative corona, and then the high polymer film is subjected to an annealing treatment to be an electret with an electric charge of a single sign or a monocharge electret.

Further, after a corona discharge the film is peeled off from the metal table once, and the film is mounted on the table with its surface, which is charged with a positive charge, being faced to the surface of the table, and then the film is subjected to the annealing treatment to carry out a charging process with high efficiency for a short time period.

With this invention, it is possible that a high polymer film is charged at its both surfaces with a negative charge by a simple construction of a device with the utilization of a corona discharge.

In a practically used charging device, a negative corona discharge is applied to a non-polar high polymer film disposed on a metal table, and thereafter the film is annealed to obtain a mono-charge electret film.

In this invention, a stylus electrode is disposed apart from the surface of the film by 15mm and supplied with a voltage of −4 to −8KV (kilovolts). By the exposure of about 30 sec (seconds), an electret with an initial surface charge density of 10^{-7} to 10^{-8} C/cm² (coulombs per square centimeter) is obtained.

Thereafter, the electret is, at it is, annealed at a temperature of about 150°C to have a negative surface charge density of -10^{-9} C/cm², and then peeled off from the metal table to be a monocharge electret film with a net charge as maintained.

Further, if the film peeled off from the metal table is again mounted on the metal table with its positive charged surface in contact therewith and is then subjected to an annealing treatment, a monocharge electret film can be obtained for a short time period.

If after the corona discharge an annealing treatment is applied in the above method, the fact that a charged surface by the corona discharge is transferred from the discharging side to that of the metal table is shown by measuring a thermoelectric current spectrum. As a result, an electrified or charged film is obtained which is homogeneous and stable as compared with a film naturally charged by a static electricity.

Other objects, features and advantages of this invention will become obvious from the following description taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIGS. **1A** to **1E**, inclusive, are diagrams showing a process of one of the methods according to this invention;

FIGS. **2A** to **2C**, inclusive, are diagrams showing a process of another of the methods of this invention;

FIGS. **3** and **4** are respectively schematic theoretical diagrams showing head-phones used for the explanation of the invention; and

FIG. **5** is a graph showing the surface charge density-time lapse characteristics used for the explanation of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the prior art, when an electret is used in a head-phone, as shown in FIG. **3**, a pair of opposed electrets **1** and **2** are attached to a pair of fixed electrodes or back electrodes **4** and **5** which have bored there through apertures **3**, respectively, and an electrically conductive vibrating diaphragm **6** is disposed between the electrets **1** and **2** to vibrate in response to an input signal applied to an input terminal *t*. With such a prior art construction, the two electrets **1** and **2** are used in a single transducer, and upon the manufacture thereof two dielectric films to be made as the electrets **1** and **2** are attached to the back electrodes **4** and **5**, respectively, which is thereafter subjected to an electret treatment. However, there may be a difficulty in such an electret treatment due to the type of material used in the back electrodes. That is, there are problems of the distortion of the back electrodes and the deterioration of the adhesive used to attach the dielectric films to the back electrodes which may be caused by the heating during the electret treatment. Further, in the case of an electret treatment wherein the dielectric film is charged on its surface by a corona discharge, if there are many apertures in the dielectric film, there is the unfortunate possibility that a homogeneous charge production is not obtained on the surface of the dielectric film.

In order to avoid such a defect, there has been proposed a method with which a dielectric film is charged firstly to be an electret and the electret is attached to the back electrode. However, this method requires complicated procedures in that a plurality of apertures are bored through the electret film and the electret film is adhesively attached to the back electrode with the apertures of the electret film and those of the back electrodes being aligned with each other. In this process, there is a fear that the electret film is blured and the surface charge thereof is decreased.

In order to eliminate such a defect, it may be considered that a vibrating diaphragm is made as an electret. However, in such a case the vibrating diaphragm must have a monocharge that is, an electric charge of a single polarity so as to be operative as a vibrating diaphragm. By way of example, if such a vibrating diaphragm is used in a head-phone, as shown in FIG. **4**, the vibrating diaphragm **7**, which is made to be an electret to have, for example, only a negative charge, is centrally disposed and the back electrodes **4** and **5**, each of which has formed therethrough a plurality of apertures **3**, are disposed at the both sides of the diaphragm **7** in opposed relation with each other. Thus, the head-phone becomes simple in construction.

Hereinbelow, the method of making an electret according to this invention, which has a negative charge on its both surfaces and is stable, will be described in conjunction with the drawing.

As shown in FIG. **1A**, a dielectric film or a high polymer film **10** to be made as an electret is mounted on a metal table or plate **11** and a stylus electrode **12** is positioned above the high polymer film **10** apart from its upper surface **10A** by a predetermined distance *d*. A predetermined high voltage is applied across the stylus electrode **12** and the metal plate **11** from a high voltage source **13** with the metal plate **11** being connected to a positive electrode while the stylus electrode **12** being connected to a negative electrode to carry out a corona discharge between the stylus electrode **12** and the high polymer film **10** and to charge the high polymer film **10** with negative charge on its upper surface **10A**.

Thereafter, as shown in FIG. **1B**, the high polymer film **10** is peeled off from the metal plate **11**. At this time, a discharge occurs between a peeled off surface **10B** of the polymer film **10** and an upper surface **11A** of the metal plate **11**, and hence the surface **10B** of the high polymer film **10** is charged with a positive charge. Thus, as shown in FIG. **1C**, the high polymer film **10** is charged with negative and positive charges on its surfaces **10A** and **10B**, respectively.

Thereafter, the high polymer film **10** is again placed on another metal plate **14**, with the surface **10B** having the positive charge being in contact with the plate, and is heated in a furnace **15** for a constant time period and then cooled. In this case, it may be preferred that the metal plate **14** is grounded, as shown in FIG. **1D**. In the figure, reference numeral **16** indicates a heater. In this process, the heating temperature is selected higher than the glass transition temperature of the high polymer film **10**, for example, more than 80°C for the case that the high polymer film **10** is made of Teflon FEP. If the heating temperature is too high, there may be a fear that the film is distorted or molten. Accordingly, it is necessary that the heating temperature is selected lower than the melting point of the film.

Thus, an electret film **17** which is charged with the negative charge on its both surfaces **10A** and **10B** is produced as shown in FIG. **1E**.

That is, it is ascertained by measuring the electric charge on the surfaces **10A** and **10B** of the high polymer film **10** that the surface **10B**, which is charged with the positive charge before heating, is charged with the negative charge by suitably selecting the time interval of the heating, while the amount of the negative electric charge stored in the surface **10A** before the heating is decreased somewhat, but the surface **10A** has still the negative charge, that is, both the surfaces **10A** and **10B** carry the negative charge. The amount of initial charge by the corona discharge is much greater than can be attained by the thermo electret method, and the charge level is sufficient for practical use after being heat-treated.

In general, if the heating temperature is low, the heating time interval required is long, so that it is most convenient and practicable that the heating temperature is selected about 120° to 160°C for the Teflon FEP, with no thermal distortion of the high polymer film as a result.

An electric field E established by a single sign of an electric charge layer is expressed by

$$E = \frac{\sigma}{2\epsilon_0}$$

where σ represents the charge density and ϵ_0 the dielectric constant in vacuum. Since the critical discharge of a uniform electric field in atmosphere is 30KV/cm at normal temperature and pressure, the maximum charge density of such a charged body becomes to 5.3×10^{-9} C/cm^2, which is smaller than that where the high polymer film is charged with positive and negative charges on its both surfaces or where the film is provided with a back electrode. In other words, a small charge density can provide the necessary electric field.

FIGS. 2A to 2C show another method of the invention. With the second method, the high polymer film 10 to be made as an electret is mounted on the metal plate 11 and the stylus electrode 12 is located above the film 10 apart from its upper surface 10A by a predetermined distance in opposed relation. A predetermined high voltage is applied across the stylus electrode 12 and the metal plate 11 from the high voltage source 13 with the metal plate 11 being positive and the stylus electrode 12 being negative to produce a negative electric charge on the upper surface 10A of the film 10 by the corona discharge (refer to FIG. 2A).

The film 10 and the metal plate 11 are located in the heating furnace 15 without the film 10 first being peeled off from the metal plate 11 as before; and the film 10 is heated (annealed) therein for a constant time interval. Thereafter the film 10 is cooled. In this case, the heating treatment is carried out longer than that in the case of the first method (FIGS. 1A–1D).

As a result of measuring the charge on both the surfaces 10A and 10B of the high polymer film 10 after cooling, it is ascertained that, by suitably selecting the heating time interval, an electret 18 (FIG. 2C), which is charged with the negative charge on its both surfaces 10A and 10B or carries a single sign of an electric charge (as desired), can be obtained.

Examples of the present invention will be provided.

EXAMPLE I

A "Teflon FEP 100" (a copolymer of tetrafluoroethylenehexafluoropropyren) film with an area of 1.5 × 1.5 cm^2 and a thickness of 50μm (micro-meter) is mounted on the metal plate 11 and the stylus electrode 12 is located above the film apart therefrom by 15mm, as shown in FIG. 1A. A voltage of −6KV is applied to the tip end of the stylus electrode 12 to carry out the corona discharge for a time interval of 30 seconds. After the corona discharge is finished, the film is peeled off from the metal plate 11 and placed on the electrode of an electric charge measuring apparatus. After measuring the charge amount of the film, it is -8×10^{-8} C/cm^2 at its portion opposing the stylus electrode 12. After turning over the film and measuring the charge amount on the surface opposite to the discharged surface, it is $+7.8 \times 10^{-8}$ C/cm^2. After the measurement, the film is mounted on the metal plate with its positive charged surface facing the plate, and heated at 155°C for a time interval of ten minutes. When the charge amount of the film after heating is measured, it is -1.9×10^{-9} C/cm^2 on the surface of the film which was charged with the negative charge initially and -2.3×10^{-9} C/cm^2 on the surface of the film which was charged with the positive charge initially, that is, both the surfaces of the film are charged negatively.

EXAMPLE II

A Teflon FEP film with a thickness of 12.7 μm is attached to a metal ring with an outer diameter of 32mm and an inner diameter of 28mm and the film is mounted on the metal plate 11 with the film being directly contacted with the metal plate 11. The stylus electrode 12 is disposed above the film apart therefrom by 15mm and a voltage of −7KV is applied to the stylus electrode 12 to carry out the corona discharge for a time interval of 30 seconds. After the corona discharge is finished, the film is peeled off from the metal plate 11. Then, the film is placed on the second metal plate 14 with its corona-discharged surface facing upward and heated at 160°C for a time interval of 20 minutes. It is ascertained by the aforedescribed measurement that the charged amount after heating is -4.7×10^{-9} C/cm^2 on the corona-discharged surface and -4.0×10^{-9} C/cm^2 on the surface that was in contact with the metal plate, that is, both the surfaces are charged negatively. The change in the amount of the charge of the film with respect to the time lapse is shown in FIG. 5 in which the ordinate represents the surface charge density Q in multiple of 10^{-9} C/cm and the abscissa the elapsed time T in day, when the film is left at a room temperature.

In the graph of FIG. 5, a curve I shows the charge on the corona-discharged surface and a curve II shows the charge on the opposite surface. As may be obvious from the characteristic of the graph, it is noted that the charges on both the surfaces of the film are negative and settled after 10 days and the settled negative charge is stable without being changed with further time elapse.

EXAMPLE III

A Teflon FEP film with an area of 1.5 × 1.5 cm^2 and a thickness of 50 μm is mounted on the metal plate 11 and the stylus electrode 12 is located above the film apart therefrom by 15mm. A voltage of −6KV is applied to the tip end of the stylus electrode 12 to carry out the corona discharge for a time period of 30 seconds. After the corona discharge is finished, the film is heated at 150°C for a time interval of 1.5 hours without the film being peelef off from the metal plate 11. It is ascertained that the charge amount of the film after heating is -1.3×10^{-9} C/cm^2 on its corona-discharged surface and -2.4×10^{-9} C/cm^2 on the surface which was in contact with the metal plate, both surfaces thus negatively charged.

ANOTHER EXAMPLE (a)

A Teflon FEP film with an area of 1.5 × 1.5 cm^2 and a thickness of 50μm is placed on the metal plate 11 and the stylus electrode 12 is located above the film apart therefrom by 15mm. A voltage of −6KV is applied to the tip end of the stylus electrode 12 for a time interval of 30 seconds to carry out the corona discharge. As a result of this, an electric charge of -5.5×10^{-8} C/cm^2 is produced on the corona-discharged surface of the film. Then, the film is peeled off from the metal plate 11 and again placed on the metal plate. At this time, the peeled off surface of the film is charged with the positive charge. Thereafter, a metal mesh is disposed between the tip end of the stylus electrode and the metal plate and a voltage of about −100V is applied to the metal mesh relative to the metal plate, while a voltage of −6KV is applied to the tip end of the stylus electrode to carry out the corona discharge. In this case, the amount of the charge is -5.5×10^{-9} to -7×10^{-9} C/cm^2 on the corona-discharged surface but $+1 \times 10^{-9}$ to 0 to -1.4×10^{-9} C/cm^2 on the surface in contact with the metal plate. Thus, there is the case that both the surfaces are charged with the negative charge but its reproducibility is deteriorated.

FURTHER EXAMPLE (b)

A separate specimen (Teflon FEP film), which is charged by the similar corona discharge to that of the Example I, has the charge of -8.6×10^{-8} C/cm^2 on its corona-discharged surface and that of $+8.3 \times 10^{-1}$ C/cm^2 on its surface in contact with the metal plate Next, the film is placed on the metal plate 14 with it

negatively charged surface in contact therewith and heated under the similar condition of the Example I or at 155°C for 10 minutes. When measuring the charge on both the surfaces of the film, the surface which is charged with the negative charge initially is charged at -5.7×10^{-9} C/cm² and the surface which is charged with the positive charge initially is charged at $+2.1 \times 10^{-9}$ C/cm², that is, the sign of the charges is not changed.

THE OTHER EXAMPLE (c)

A separate specimen (Teflon FEP film), which is charged by the similar corona discharge to that of the Example I, is peeled off from the metal plate. Then, the film which is charged with the negative and positive charges on its both surfaces, respectively, is heated without being in contact with the metal plate. After heating, the measurement of the charges shows that the positively charged surface remained positive and the other surface remained negative. That is, the film with a single sign of charge can not be obtained.

If a Teflon FEP film with a thickness of 50μm is placed on a metal plate and a negative charge is produced on the surface of the film of -5.5×10^{-8} C/cm², this charge is below its critical stability. However, since the stable charge is on the order of -5×10^{-9} C/cm² when the film is peeled off from the metal, a discharge occurs on the peeled off surface upon the peeling off to cause the production of the positive charge. Accordingly, if the film on the metal plate is charged at lower than about -5×10^{-9} C/cm² initially, theoretically there appears no discharge on the peeled off surface when the film is peeled off from the metal plate. Thus, there must be obtained an electret with a monocharge or a single sign of electric charge. However, from a practical point of view, its reproducibility is low, and the reproducibility and the amount of a charge in the case of heating treatment are less than desired as compared with the former case. Further, in order to shorten the time interval of heating treatment, it is better that after the corona discharge the film is peeled off from the metal plate once.

In the above example, a Teflon FEP film is used as a high polymer film, but even if a Teflon TFE film, a Tefzel film and the like are used as the high polymer film, an electret film with a single sign of an electric charge can be also obtained.

As described above, with this invention, by taking the step of charging the surface of a high polymer film with the corona discharge and the step of heating the high polymer film after the corona discharge, an electret having a monocharge, that is, a single sign of an electric charge such as a negative electric charge, can be easily obtained. Further, an apparatus for performing the method of this invention requires no complete redesign and thus can be the apparatus used for making the prior art electret.

It may be obvious that many variations and changes could be effected by those skilled in the art without departing from the spirit and scope of the novel concepts of this invention.

I claim as my invention:

1. A method of making a mono-charge electret, comprising the steps of charging a dielectric film which is mounted on a metal electrode by subjecting said film to a corona discharge; and then, after said corona discharge is completed and while said film is still mounted on said electrode, heating said charged dielectric film.

2. A method of making a mono-charge electret as claimed in claim 1 in which said step of heating is carried out at a temperature higher than the glass transition temperature of said dielectric film.

3. A method of making a mono-charge electret as claimed in claim 1 in which said dielectric film is made of fluoride.

4. A method of making a mono-charge electret as claimed in claim 1 in which dielectret is charged by a negative corona discharge.

5. A method of making a mono-charge electret, comprising the steps of charging a dielectric film which is mounted on a metal electrode by subjecting said film to a corona discharge to thereby charge one surface of said film with the polarity of said corona discharge; peeling off said charged dielectric film from said electrode; placing said dielectric film on a metal backing with the other surface of said film in contact with said metal backing; and, while said film is on said metal backing, heating said dielectric film.

6. A method of making a mono-charge electret as claimed in claim 5, in which said step of heating is carried out at a temperature higher than the glass transition temperature of said dielectric film.

7. A method of making a mono-charge electret as claimed in claim 5 in which said dielectric film is made of fluoride.

8. A method of making a mono-charge electret as claimed in claim 5 in which said dielectret is charged by a negative corona discharge.

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