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(54) SPEAKER DIAPHRAGM

(71) We, MATSUSHITA ELECTRIC INDUSTRIAL CO. LTD., a corporation organized under the laws of Japan, of 1006, Oaza Kadoma, Kadoma-shi, Osaka, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to speaker diaphragms suitable for use in dome or cone type speakers.

Several types of speaker diaphragm are known for example paper diaphragms, metal diaphragms, and plastic film diaphragms.

Each of these known types of speaker diaphragm, has some serious disadvantages. Paper diaphragms, for example need many production steps for their manufacture including making the paper and pressing the paper to shape and therefore great difficulties attend their mass production. Also paper diaphragms vary widely in thickness and weight making it difficult to obtain diaphragms having desired acoustic characteristics. Again paper diaphragms which may absorb water are liable to change their acoustic characteristics when exposed to a humid atmosphere, and may pose problems of safety as they are flammable.

Metal diaphragm although substantially free of the problems of flammability and variation in acoustic characteristic following humidity changes require drawing in a mold (by hydraulic press or other means) when molding to a desired form, so that the end products have a non-uniform thickness distribution; also draw marks remain in peripheral parts of the products. Furthermore as metal diaphragms have small inner losses strain may develop during use.

Plastics film diaphragms which have been developed recently as speaker diaphragms of polyvinyl chloride film or polyethylene terephthalate film (for example, "Mylar" (a trade name) film), meet many of the various problems found in production of the conventional paper and metal diaphragms but still have problems with providing proper acoustic characteristics. For example, a speaker diaphragm of polyvinyl chloride film hardens when exposed to low temperature (below −20° to 30°C) resulting in badly affected acoustic characteristics, whilst a diaphragm of polyethylene terephthalate film reproduces low-pitched sound badly.

Generally, the lowest resonant frequency f_o of speaker is given by the following equation:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{s_0}{m_0}}$$

(wherein s_o is stiffness in the diaphragm supporting portion, and m_o is effective mass of the vibration system).

Since conventional polyethylene terephthalate film has a high modulus of elasticity diaphragms made of such film have a high s_o factor and hence, as is apparent from the above equation, also have a high f_o factor, usually about 600 Hz, with resultant poor reproduction of low-pitched sound. If s_o is reduced (by reducing the film thickness) to improve low-pitched sound reproduction with a polyethylene terephthalate film diaphragm, divisional resonance is produced in the diaphragm causing development of strain during reproduction. It is therefore difficult to improve the acoustic characteristics of plastics film diaphragms.

An object of this invention is to provide a speaker diaphragm alleviating or overcoming the problems found with known speaker diaphragms.

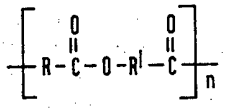
According to the present invention, there is provided a speaker diaphragm that is molded from a polybisphenol phthalate type resin film having ester linkages prepared from an aromatic dicarboxylic acid selected from the group consisting of isophthalic

acid, terephthalic acid and a mixture thereof, and a bifunctional phenol. When using a mixture of isophathalic acid and terephthalic acid, their molar ratio may be within the range of 1:9 to 9:1.

Characteristics of speaker diaphragms embodying the present invention will be described with reference to the accompanying drawings, in which:

Fig. 1 and Fig. 2 illustrate the acoustic pressure-frequency characteristic diagrams of a speaker diaphragm (a) embodying this invention and a conventional speaker diaphragm (Mylar film) (b).

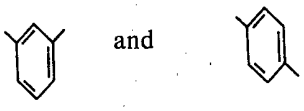
The said poly-bisphenol phthalate type resin film has the basic structure represented by the following formula:



(wherein R is

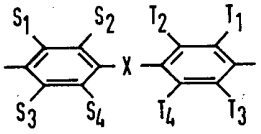
(from isophthalic acid) or

(from terephthalic acid) or a mixture of



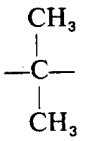
and

R′ is



(from bisphenols)

(wherein —X— is —O—, —S—, —SO_2— or an alkylene group such as



and S_1 to S_4 and T_1 to T_4 are hydrogen atoms, halogen atoms, hydrocarbon radicals or the like).

The poly-bisphenol phthalate type resin film embodying this invention has a modulus of elasticity in the range of 9,000 to 13,000 kg/cm², or about half of that (19,000 kg/cm²) of Mylar film, so that a speaker diaphragm obtained from molding such poly-bisphenol phthalate type resin film has a low stiffness and hence low in the lowest resonant frequency f_o and is therefore capable of reproducing a wide range of sound including low-pitched sounds. Also, since the inner loss of said film is within the range of 0.009 to 0.02, (which is large compared to that—0.005—of Mylar film) speaker diaphragms molded from said poly-bisphenol phthalate type resin film are "flattened" in the acoustic pressure-frequency characteristic. The specific gravity of the film is approximately 1.2, which is less than that (1.4 approximately) of Mylar film. This proves to be of importance when the film is molded to form a speaker diaphragm as it enables a sizable reduction weight of the diaphragm to be made allowing of a speaker of high efficiency to be manufactured. Further, the film has excellent heat resistance characteristics, the deformation temperature of the film being approximately 150°C, and it is self-extinguishing as has been found from flame resistance tests, so that a speaker diaphragm molded from such a film is both resistant to high temperature and flame-retardant. Therefore, such a film may be used to provide a diaphragm suited for use in a speaker for which high heat resistance and flame retardancy are required. Another important feature of said poly-bisphenol phthalate type resin film is its non-crystalline structure. It is to be noted that this film is not crystallized and stays non-crystalline even if exposed in a high-temperature atmosphere for a long period of time, therefore, neither the external appearance nor the acoustic properties of the film vary. The non-crystalline structure of the film has advantages when molding diaphragms as it permits easier molding than the more highly crystalline Mylar film and enables mass production of speaker diaphragms. Moreover, the film embodying this invention is not cured even if exposed to a low temperature below approximately −60°C, so that diaphragms made of the film are more highly resistant to deterioration in their acoustic characteristics at low temperatures than are diaphragms of conventional polyvinyl chloride film.

As explained above, speaker diaphragms of poly-bisphenol phthalate type resin film embodying this invention have the following effects when compared with conventional plastics film diaphragms.

(1) Owing to the low modulus of elasticity of the film, it is possible to decrease the stiffness of the diaphragm supporting portion, making it possible to reduce the

lowest resonant frequency f_o to about 300 to 400 Hz and allowing reproduction of low-pitched sounds.

(2) Owing to a large inner loss in the speaker diaphragm, a flat acoustic pressure-frequency characteristic can be obtained.

(3) As the specific gravity of the film of this invention is relatively low (1.21) compared with those of Mylar film (1.4) and polyvinyl chloride film (1.35), a speaker made with a diaphragm embodying this invention has a higher efficiency than have speakers with conventional plastics film diaphragms.

(4) The film of diaphragms embodying this invention does not harden even if exposed to temperatures of approximately −60°C, so that the diaphragms are better able to resist low-temperatures than are conventional polyvinyl chloride film diaphragm (which harden at temperatures of −20° to −60°C).

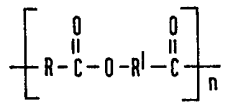
(5) As the film embodying this invention has a high deformation temperature (approximately 150°C) and also is self-extinguishing, speaker diaphragms made of the film are flame-retardant and safe in use.

(6) The water absorptivity of the film embodying this invention is as slow as 0.5% as compared with 0.8% of Mylar film diaphragm, deterioration of acoustic characteristics by humidity, if any, is negligible.

The invention is now described in further detail by way of some embodiments thereof.

Example 1

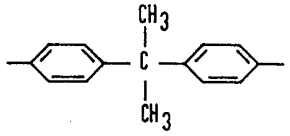
A methylene chloride solution (with concentration of 50 g/l) of a mixture of isophthalyl dichloride and terephthalyl dichloride mixed in the molar ratio of 3:7 and an alkaline solution of bisphenol A (with concentration of 40 g/l) were subjected to interfacial polymerization at room temperature to produce a copolymer having logarithmic viscosity of 0.62, and this copolymer was made into chips with diameter of about 2 to 4 mm and length of 3 mm logarithmic viscosity of the copolymer was determined by dissolving said copolymer in a phenol/tetrachloroethane mixture (6/4 v/v) to prepare a 1 g/dl solution and measuring the viscosity by Ubbelohde viscometer at 25°C. Said chips had the basic structure represented by the following formula:



(wherein R is a mixture of

(from isophthalyl dichloride) and

(from terephthalyl dichloride) in the ratio of 3:7, and R′ is



(from bisphenol A).)

The said chips were heated and melt-extruded into a film. The extrusion conditions were as follows:

Extruder used: 25 mm extruder (L/D=20) manufactured by Union Plastic Co., Ltd.

Extruding conditions: Cylinder temperature: 270°C Die temperature: 280°C Haul-off roll temperature: 85°C Haul-off speed: 3.3 m/min.

The film produced had the following physical properties: specific gravity, 1.21; elastic modulus, 9,300 (kg/cm²); inner loss, 0.01; film thickness, 65 μ. This film was molded by a vacuum molding method to form a cone shaped diaphragm with diameter of 40 mm, a height of 2 mm and a thickness of 50 μ. Curve (a) in Fig. 1 indicates the acoustic characteristic of the speaker using the said diaphragm and curve (b) indicates the acoustic characteristic of the speaker using a cone shaped Mylar film diaphragm having the same diameter and thickness as the diaphragm of curve (a). As apparent from fig. 1, a speaker using the diaphragm embodying this invention is low in the lowest resonant frequency f_o owing to low stiffness of the film and also flat in acoustic pressure-frequency characteristic owing to large inner loss of the film.

Example 2

The same chips as used in Example 1 were heated and melt extruded by using the same extruder under the same conditions as Example 1 except for a change of haul-off speed to 4.2 m/min to obtain a film. The film thickness was 50 μ—due to the noted change in haul-off speed. This film was vacuum-molded by a method similar to the manner described in Example 1 to produce a cone shaped diaphragm with diameter of 25 mm, height of 3 mm and thickness of 40 μ. In Fig. 2, curve (a) shows the acoustic pressure-frequency characteristic of the speaker using the said diaphragm of this invention and curve (b) shows the acoustic pressure-frequency characteristic of the speaker using a Mylar film diaphragm having the same shape, same diameter and

same thickness as the same diaphragm of this invention.

As apparent from Fig. 2, a speaker using the diaphragm obtained according to this example of the present invention is low in the lowest resonant frequency f_o owing to low stiffness s_o of the film and also flat in acoustic pressure-frequency characteristic owing to large inner loss of the film.

WHAT WE CLAIM IS:—

1. A speaker diaphragm molded from a poly-bisphenol phthalate type resin film having ester linkages prepared from an aromatic dicarboxylic acid selected from isophthalic acid, terephthalic acid and a mixture thereof and a bifunctional phenol.

2. A speaker diaphragm according to Claim 1, wherein the aromatic dicarboxylic acid is a mixture of isophthalic acid and terephthalic acid mixed in the ratio of 1:9 to 9:1, and the bifunctional phenol is bisphenol A.

3. A speaker diaphragm according to Claim 2, wherein the aromatic dicarboxylic acid is a mixture of isophthalic acid and terephthalic acid mixed in the ratio of 3:7, and the bifunctional phenol is bisphenol A.

4. A molded speaker diaphragm substantially as hereinbefore described with reference to the accompanying drawings.

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1 SHEET This drawing is a reproduction of the Original on a reduced scale

FIG.1

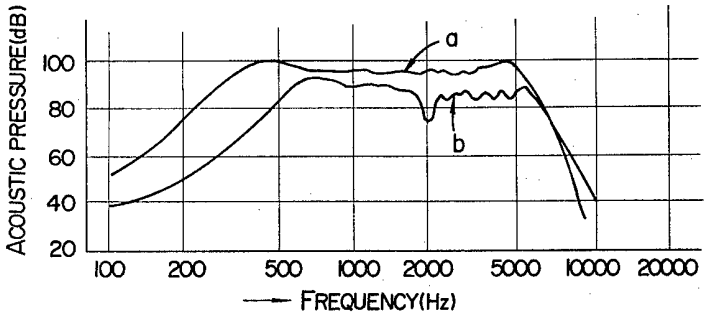

FIG.2