United States Patent [19]

Boszor

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[54] **CARBON FIBER STRENGTHENED SPEAKER CONE**

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[73] Assignee: **Union Carbide Corporation**, New York, N.Y.

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[52] **U.S. Cl.** .... **179/181 R;** 181/169

[51] **Int. Cl.**^{2} **H04R 7/26**

[58] **Field of Search** .... 179/181 R, 111 R, 115 R; 423/447; 181/169

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Attorney, Agent, or Firm—Israel Blum

[57] **ABSTRACT**

A novel speaker diaphragm having a high specific modulus for use in conventional loudspeakers including the magnetic and electrostatic type loudspeakers, the diaphragm comprising a carbonaceous fibrous web impregnated by a resin. The speaker diaphragm has a sonic velocity that is comparable to or exceeds that of a speaker diaphragm made of aluminum.

11 Claims, No Drawings

CARBON FIBER STRENGHTHENED SPEAKER CONE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to loudspeakers and more specifically to speaker diaphragms having a high specific modulus for use in magnetic or electrostatic loudspeakers, the diaphragms comprising a carbonaceous fibrous web impregnated by a resin.

2. Description of the Prior Art

Loudspeakers are an integral part of sound reproduction systems. Conventional loudspeakers include electrostatic and magnetic loudspeakers. An electrostatic or condenser loudspeaker is fundamentally a huge capacitor and generally comprises a conducting diaphragm situated in a polarized field. Sound is produced when an audio signal is induced onto the diaphragm, the capacitor's inner plate, which modulates the polarized voltage, causing the diaphragm (inner plate) to be both "pushed" and "pulled" between two outer, fixed immovable electrodes in accordance with the signal. Heretofore, the flexible, conductive diaphragm has generally consisted of a nonconducting material coated with thin conducting material having a high degree of resistance, e.g., a very thin plastic film with a conducting metallic coating.

A magnetic or driving coil loudspeaker comprises a voice coil, diaphragm and suspension system. An electromagnetic motor transforms an audio signal into a vibrating diaphragm, the diaphragm being conically shaped to maximize mechanical stability. The vibrating surface of the diaphragm compresses air into motion (sound waves) which we recognize as sound.

Rigidity and lightness are two competing requirements in the design parameters of a conical diaphragm. A high modulus of elasticity optimizes the diaphrams's ability to function with piston-like movements and not break up into separate vibrating sections. Low mass is desired in order than the inertia of the diaphragm be low. Conical diaphragms have been composed of various materials, including metal, cellulose paper, plastic, cloth, wool and expanded polystyrene. However, it was apparent that no material previously attempted was ideal nor did it provide the proper balance between mechanical stability and acoustic performance.

Cellulose paper has long been a standard compromise between quality and economics in moving coil loudspeakers, providing a reasonable balance between mechanical stability and acoustical performance. However, it is known that even a quality Kraft paper impregnated with a stiffening resin has a maximum sonic velocity of only about 2.5×10^5 cm/sec. By sonic velocity of paper is meant the square root of the ratio of its Young's modulus to its density. Sonic velocity aids in analyzing the extent to which a conical diaphragm simulates ideal piston-like motion. Increasing the sonic velocity not only decreases frictional energy losses in the diaphragm produced from out of phase vibrational patterns and corresponding cancellation effects that result therefrom, but also increases high frequency response. Consequently, the sonic velocity of a diaphragm is a measure of the limits in the crispness of transient responses and range of linear frequencies the diaphragm may provide.

Because a higher specific modulus than possessed by the finest resin impregnated cellulose paper was desired, metals such as aluminum were attempted even though they had other defects. Aluminum, for example, provided a speaker diaphragm having a sonic velocity about twice that obtainable with cellulose paper, but the diaphragm required reinforcing joints to dampen circumferential vibrations associated with its inherent thinness. Anodising the aluminum diaphragm increased its maximum sonic velocity to about four times that obtainable with cellulose paper.

SUMMARY OF THE INVENTION

It is an object of this invention to provide a loudspeaker diaphragm comprising a carbonaceous fibrous web impregnated by a resin, the diaphragm having a high specific modulus of elasticity and a sonic velocity comparable or better than aluminum diaphragms. Another object of this invention is to provide a loudspeaker diaphragm comprising a carbonaceous fibrous web impregnated by a resin, the diaphragm having a sharper transient response and wider frequency range than cellulose paper. An object of this invention is to provide a woofer diaphragm comprising a carbonaceous fibrous web impregnated by a resin, which diaphragm is capable of reproducing a wider frequency range than comparable paper woofer diaphragms. A further object is to provide an electrostatically driven speaker diaphragm comprising a conductive carbonaceous fibrous web impregnated by a resin.

Briefly, this invention relates to a diaphragm for use in an electroacoustical device, the diaphragm comprising a carbonaceous fibrous web impregnated by a resin. The diaphragm of this invention is characterized by having a high specific modulus and sonic velocity.

The term "specific modulus" as used throughout the specification unless otherwise indicated, should be understood to equal the modulus of elasticity (Young's modulus) divided by the basis weight of the material, i.e. its weight per unit area.

The term "impregnated" as used throughout the specification and unless otherwise indicated, should be understood to signify the result of impregnating and/or surface coating the carbonaceous fibrous web with a resin. It does not necessarily imply that all, or even a major proportion of the interstices or other voids of the carbonaceous fibrous web must be filled or covered with resin. However, it is preferred to have the resin adhering or clinging to a major portion of the fibers of the carbonaceous fibrous web.

Individual filaments of carbon fiber which are useful in forming a diaphragm material are known to have a range of moduli extending from about 10 million psi to about 100 million psi and a maximum density of about 2 gm/cm^3. A carbonaceous fibrous web of this invention may be formed using these fibers and impregnated by a resin. It is possible for the diaphragm of this invention to reach a fiber loading of between about 30% to about 70% carbon fibers by volume, the balance being a resin. Preferably, diaphragms having a fiber loading between about 60% to about 70% carbon fibers by volume, the balance being a resin will be used in this invention. Moreover, the carbonaceous fibrous web impregnated by a resin which is used as the diaphragm material of this invention may have a maximum density of about 1.7 gm/cm^3 and a maximum modulus of elasticity of about 30 million psi. Preferably, a carbonaceous fibrous web impregnated by a resin useful in this invention should have a modulus of elasticity varying from about 3 million psi to about 30 million psi and a density varying between about 0.8 gm/cm^3 and about 1.7 gm/cm^3, respectively.

The diaphragms of this invention should have sonic velocities that exceed the maximum sonic velocity of a high quality, resin impregnated, cellulose paper diaphragm and equal or exceeding even aluminum diaphragms. Loudspeaker diaphragms comprising a carbonaceous fibrous web impregnated by a resin are characterized by having sonic velocities between about 2.5×10^5 cm/sec and about 11×10^5 cm/sec, based on available test data, the examples reported hereinafter and theoretical expectations. Preferably, a diaphragm comprising a carbonaceous fibrous web impregnated by a resin and having a sonic velocity greater than about 2.6×10^5 cm/sec and more preferably greater than about 4.6×10^5 cm/sec should be used in connection with this invention. Even more preferably, the diaphragm of this invention should have a sonic velocity defined by the formula

$$\frac{SV_1}{SV_2} \geqslant 1$$

wherein SV_1 is the sonic velocity of the diaphragm of this invention and SV_2 is the sonic velocity of an aluminum diaphragm.

Moreover, based on available test data and theoretical expectations, a carbonaceous fibrous web impregnated by a resin and useful in this invention may have a modulus of elasticity between about 4.4×10^{10} dynes/cm^2 and about 220×10^{10} dynes/cm^2, preferably between about 20×10^{10} dynes/cm^2 and about 220×10^{10} dynes/cm^2. More significant a characterizing property of the diaphragm of this invention is its specific modulus of elasticity. Indeed, the diaphragm of this invention preferably has a specific modulus of elasticity which may be defined by the formula

$$\frac{SM_1}{SM_2} \geqslant 1$$

wherein SM_1 is the specific modulus of elasticity of the diaphragm of this invention and SM_2 is the specific modulus of elasticity of an aluminum diaphragm.

The diaphragm of this invention, moreover, possesses both a higher specific modulus and sonic velocity when compared to the finest cellulose paper. As a result of having a higher specific modulus and sonic velocity, the diaphragm comprising a carbonaceous fibrous web impregnated by a resin may follow higher frequencies than a cellulose paper diaphragm of the same shape, size and weight. Preferably, the specific modulus and sonic velocity of the diaphragm comprising a carbonaceous fibrous web impregnated by a resin is also comparable or superior to the finest aluminum diaphragms. Furthermore, it is possible for the transient response of the diaphragm of this invention to be sharper than a comparable cellulose paper diaphragm's due to its superior specific modulus.

High modulus, high strength carbon fibers suitable for use in this invention may be prepared as described in U.S. Pat. Nos. 3,412,062; 3,503,708 and 3,529,934. The carbon fibers when cut to a size suitable for process may be employed in the instant invention. Carbonized or graphitized pitch fibers may also be employed in this invention.

The carbonaceous fibrous web preferably employed in this invention may be prepared by processing carbon fibers by any method, either wet or dry, which effects the disposition of such fibers in intimately contacting relation in a fibrous body. Air laying operations such as carding and garnetting which effects a relatively oriented disposition of fibers into a paper sheet are suitable for this purpose.

A carbonaceous fibrous web impregnated by a resin is the preferred fabric for use in this invention. Preferably, a carbon fiber sheet or paper may be prepared by water laying short carbon fibers using well known paper making techniques. A carbonaceous fibrous web is also preferably prepared by collecting pitch fibers and forming them into a carbonaceous fibrous web. More preferably, a non-woven carbonaceous fiber web may be resin impregnated, shaped by well known techniques and the resin cured, forming a shaped diaphragm.

When preparing a paper by the water laying of carbon fibers, the fibers are first cut or chopped to a size suitable for processing, e.g., about ¼ inch in length; homogeneously intermixed with water and a suitable binder, such as starch or other well known binder, to form an aqueous slurry; then deposited from the slurry upon a substrate such as a flat sieve of fine mesh which retains the fibers to form a sheet. This sheet is then processed by conventional paper making techniques to produce the final carbonaceous product.

Converting the carbon fiber slurry into sheets of carbon fiber paper involves three general steps, or modifications of these, by which commercial base papers are made:

1. The arrangement of the fibers in the slurry into a wet sheet;
2. The removal of a portion of the free water from the wet sheet by wet pressing — this is reflected by improved physical characteristics of the paper;
3. The progressive removal of additional water by heat.

A wet sheet is generally formed either by running a dilute suspension of carbon fibers evenly onto the surface of a moving endless belt of wire cloth, through which excess water may be drained, or by running an endless belt of wire cloth through a suspension of carbon fibers. In the first case — the Fourdrinier process — part of the water drains off by gravity, a part is taken from the sheet by suction, and a part is removed by pressure; in the second case, a vacumm is maintained below the stock level in the cylinder in which the wire cloth is rotating and the sheet forms on the wire by suction much as does a cake on a vacuum filter. Generally, most paper grades are formed by the first process. In either case, the thickness of the sheet is controlled by the speed of travel of the machine, by the consistency (ratio of fiber to water) of the suspension, or by the amount of stock allowed to flow onto the machine.

After the carbon fiber sheets have been prepared as described hereinabove, they are physically processed, e.g., cut into a predetermined shape for assembly into a conically shaped diaphragm. A loudspeaker diaphragm typical of this invention may be constructed with paper prepared from artificial or natural carbon fibers having a diameter between about 3 μm and about 15 μm, and preferably between about 4 μm and about 8 μm. Moreover, the diaphragm may have a modulus exceeding about 3 million psi and preferably exceeding about 20 million psi and more preferably exceeding about 30 million psi.

Furthermore, a non-woven carbonized fiber web made from chopped or blow spun staple fibers may be used as the precursor to the speaker diaphragm of this invention. The non-woven carbonaceous web may be impregnated with a suitable resin such as an epoxy, furane, phenolic, melamine or the like. Thereafter, the web may be physically processed in a conventional manner to form a shaped web which shape the diaphragm will have. The resin impregnated web may then be heated a predetermined time at a temperature sufficient to cure the resin and maximize the diaphragm stiffness. This heat treatment may be combined with the shaping step, if desired.

Alternatively, a diaphragm typical of this invention may be formed by blowing carbonized staple fibers onto a preshaped screen. A vacuum is created behind the screen to assist collecting and binding the staple fibers together into a carbonaceous fibrous web. A binder dissolved in a solvent is preferably added to the staple fibers during this process. Preferably, the binder used is a resin such as an epoxy, furane, phenolic, melamine or the like dissolved in such solvents as acetone, toluene, benzene, methyl ethylketone or the like. Those skilled in the art will readily appreciate that the diaphragm may be directly formed in the above manner without need for further processing, the diaphragm having the shape of the preshaped screen.

Adding a binder not only joins the fibers together, but strengthens the carbonaceous fibrous web. Whether the binder such as a carbonizable resin is added during the carbonaceous fibrous web making process or applied as a coating to a finished carbonaceous fibrous web, it should be heated to a temperature sufficient to cure the resin and maximize stiffness of the web. Carbonizable resins which stiffen the carbonaceous fibrous web as described hereinabove include phenolic, epoxy, furane and the like.

In one embodiment, a diaphragm typical of this invention may be varied in shape. For example, it may be conical in shape or conically shaped near the apex of the cone. Furthermore, by any one of several conventional physical or machining methods such as a molding process and the like, a diaphragm typical of this invention may be provided with circumferencial, annular or sinusoidal shaped annular corrugations and the like.

In another embodiment, a diaphragm typical of this invention may be uniform in thickness or graduated, if desired at one end. A thickness of between about 0.005 inch and about 0.025 inch is employed for a diaphragm used in magnetic loudspeakers.

In still another embodiment, a diaphragm as described in this invention may be used in any one of several magnetic loudspeakers commonly employed. For example, the magnetic loudspeaker may employ multiple small conical diaphragms or conical diaphragms in sealed enclosures or conical diaphragms at the end of tubes. As is readily appreciated by those skilled in the art, improved magnetic loudspeakers of various shapes, dimensions and designs having superior tone qualities and frequency ranges can be produced employing diaphragms typical of this invention.

Moreover, while a diaphragm typical of this invention may be used to reproduce the entire audible range, i.e., from about 20 to about 20,000 HZ (cycles per second), it is preferable, in certain instances, to employ a combination of several speakers in a sound reproduction system each accurately reproducing only limited bands within the audible frequency range. As is readily understood by those skilled in the art, a diaphragm in accordance with this invention may be used in a woofer loudspeaker which generally reproduces the bass range of audible frequencies.

Furthermore, an electrostatic speaker diaphragm typical of this invention comprises a carbonaceous fibrous web impregnated by a resin. The results of the examples described hereinbelow illustrate the electric conductivity of the carbonaceous fibrous web impregnated by a resin. Being electrically conductive, the carbonaceous fibrous web impregnated by a resin not only fulfills the conductivity requirement of an electrostatic speaker diaphragm but also eliminates the need for applying a surface coating to make the electrostatic speaker diaphragm conductive as is now done.

The material employed for the electrostatic speaker diaphragm may be formed of a resin impregnated fibrous web and range in thickness from about 0.005 inch to about 0.01 inch. Preferably, a thickness of about 0.007 inch is employed. An electrostatic speaker diaphragm manufactured according to the teachings set forth herein can compare favorably with the linearity of frequency response curves of electrostatic speaker diaphragms consisting of conventional materials having comparable types of construction and capabilities.

EXAMPLE

Four epoxy resin impregnated sheets having a fiber loading of approximately 55% and four phenolic resin impregnated sheets having a fiber loading of approximately 60% were prepared for testing purposes. At the outset, two pieces each of four different carbon fiber mats were obtained. Two of the mats were blow spun, staple fiber mats, Grades VM0032 and VM0033 (commercially available from Union Carbide Corporation, Carbon Products Division, New York, N.Y.). The third was a VFB paper which is basically a low twist, rayon base, carbon yarn which has been carbonized at 700°C., chopped into staple fibers and made into a paper using the Fourdrinier process. The fourth was a carbon fiber mat having 16 inch staples, produced from melt spinning of pitch and subsequent heat treatment at 1400°C. In addition a resin impregnated cellulose paper was obtained from a 6 × 9 inch Utah RC 69 D speaker diaphragm (commercially available from Utah Electronics, Huntington, Ind.).

In preparing the epoxy resin impregnated sheets, one of each of the four different mats described hereinabove was cut into eight inch square samples. Then, the samples were immersed in Bakelite epoxy resin ERLB-4617 (commercially available from Union Carbide Corporation, Plastics Division, New York, N.Y.) to which 50 p.p.h. "Tonox" hardener (commercially available from Naugatuc Chemical Co., Division of Uniroyal, Naugatuc, Conn.) had been added. The samples were each laid on release coated aluminum foil and allowed to age 3 to 5 days. A pair of each of the samples was placed between aluminum foil in a heatable press and heated to 100°C. under light contact pressure for ½ hour. The samples are close pressed until each sample was approximately 0.01 inch thick and held still ½ hour at 100°C. The temperature was raised to 120°C. and held there for 2 hours, and then was raised to 160°C. and held there for 2 additional hours. The samples were cooled under pressure and removed from the press at 120°C.

With respect to the phenolic resin impregnated sheets, the remaining four different mats described hereinabove were prepared for testing purposes as follows: A Bakelite BLS-3536 phenolic resin (commercially available from Union Carbide Corporation, Plastics Division, New York, N.Y.) was mixed with 3 p.p.h. dimethyl sulfate catalyst and sufficient acetone to thin (approximately 5 parts acetone per 1 part resin). The resin was spread upon each mat sample using a paint brush to apply 130 p.b.w. resin to 100 p.b.w. carbon fibers. The samples were allowed to air dry overnight and then were cut into 7 inch square pieces. The samples were then molded in a steel mold using silicone release paper to separate plies at a pressure of 1000 psi and temperature of 125°C. for 15 minutes. The samples were then removed from the press.

The epoxy impregnated sheets, phenolic impregnated sheets and Utah paper were each tested using the

following procedure: Strips ½ inch wide and 5 inches in length were cut from the samples. The weight, area and thickness of each strip was determined to calculate the density of each sample. Resistivity of each sample was obtained by running 1 ampere current from a constant current supply through a 10 cm. length of each sample and measuring the voltage drop with a digital voltmeter. Lastly, to obtain tensile strength, modulus of elasticity and sonic velocity, the samples were each loaded in an Instron Table Model Test Machine with air-activated rubber faced grips and a 200 lb. load cell. The samples were broken with guage lengths of 1 and 4 inches at a cross head speed of 0.05 inches per minute and tensile strength, modulus of elasticity and sonic velocity were calculated from head speed values and chart rates. Results of the above-mentioned tests are summarized in Table 1 as follows:

TABLE I

	Utah Paper			Epoxy Impregnated VM0032		
Basic Weight gm/cm²	.00918			.034		
Density gm/cm³	.452			1.247		
Tensile Strength psi	min.	max.	avg.	min.	max.	avg.
	1900	4460	3000	3538	13537	9212
Tensile Strength dynes/cm²	2.07×10^8			6.4×10^8		
	min.	max.	avg.	min.	max.	avg.
Modulus of Elasticity psi	1.9×10^5	5.3×10^5	3.4×10^5	15×10^5	25×10^5	23×10^5
Modulus of Elasticity dynes/cm²	2.3×10^{10}			16×10^{10}		
	min.	max.	avg.	min.	max.	avg.
Specific Modulus of Elasticity psi/gm/cm²	1.8×10^7	5.8×10^7	3.7×10^7	4.4×10^7	7.4×10^7	6.8×10^7
Sonic Velocity cm/sec.	2.2×10^5			3.6×10^5		
Resistivity ohm/cm	—			180×10^{-4}		
	Phenolic Impregnated VM0032			Epoxy Impregnated VM0033		
Basic Weight gm/cm²	0.0254			.025		
Density gm/cm³	.834			1.346		
	min.	max.	avg.	min.	max.	avg.
Tensile Strength psi	423	1034	780	3367	11186	6620
Tensile Strength dynes/cm²	$.54\times10^8$			4.6×10^8		
	min.	max.	avg.	min.	max.	avg.
Modulus of Elasticity psi	12×10^5	39×10^5	28×10^5	27×10^5	45×10^5	34×10^5
Modulus of Elasticity dynes/cm²	19×10^{10}			23×10^{10}		
	min.	max.	avg.	min.	max.	avg.
Specific Modulus of Elasticity psi/gm/cm²	4.7×10^7	15×10^7	11×10^7	10.8×10^7	18×10^7	14×10^7
Sonic Velocity cm/sec.	4.8×10^5			4.2×10^5		
Resistivity ohm/cm	1230×10^{-4}			93×10^{-4}		
	Phenolic Impregnated VM0033			Epoxy Impregnated VFB Paper		
Basic Weight gm/cm²	0.0232			.029		
Density gm/cm³	1.302			1.067		
	min.	max.	avg.	min.	max.	avg.
Tensile Strength dynes/cm²	900	1515	1320	3345	12509	8186
	$.91\times10^8$			5.6×10^8		
	min.	max.	avg.	min.	max.	avg.
Modulus of Elasticity psi	42×10^5	58×10^5	50×10^5	7.5×10^5	10.5×10^5	9.310^5
Modulus of Elasticity dynes/cm²	34×10^{10}			6.4×10^{10}		
	min.	max.	avg.	min.	max.	avg.
Specific Modulus of Elasticity psi/gm/cm²	18×10^7	25×10^7	22×10^7	2.6×10^7	3.6×10^7	3.2×10^7
Sonic Velocity cm/sec.	5.1×10^5			2.4×10^5		
Resistivity ohm/cm	147×10^{-4}			254×10^{-4}		
	Phenolic Impregnated VFB Paper			Epoxy Impregnated 16 Inch Staple Mat		
Basic Weight gm/cm²	0.0230			.056		
Density gm/cm³	.346			1.108		
	min.	max.	avg.	min.	max.	avg.
Tensile Strength psi	163	619	340	1196	12690	8132
Tensile Strength dynes/cm²	$.23\times10^8$			5.6×10^8		
	min.	max.	avg.	min.	max.	avg.
Modulus of Elasticity psi	$.75\times10^5$	2.4×10^5	1.4×10^5	18×10^5	26×10^5	23×10^5
Modulus of Elasticity						

TABLE I-continued

	Utah Paper			Epoxy Impregnated VM0032		
dynes/cm^2	$.96\times10^{10}$			16×10^{10}		
	min.	max.	avg.	min.	max.	avg.
Specific Modulus of Elasticity psi/gm/cm^2	$.33\times10^7$	1.0×10^7	$.61\times10^7$	3.2×10^7	4.6×10^7	4.1×10^7
Sonic Velocity cm/sec.	1.7×10^5			3.8×10^5		
RResistivity ohm/cm	563000×10^{-4}			134×10^{-4}		

	Phenolic Impregnated 16 Inch Staple Mat		
Basic Weight gm/cm^2	0.0200		
Density gm/cm^3	1.1705		
	min.	max.	avg.
Tensile Strength psi	2309	3264	2770
Tensile Strength dynes/cm^2	1.9×10^8		
	min.	max.	avg.
Modulus of Elasticity psi	3.7×10^5	7.3×10^5	5.5×10^5
Modulus of Elasticity dynes/cm^2	3.8×10^{10}		
	min.	max.	avg.
Specific Modulus of Elasticity psi/gm/cm^2	1.8×10^7	3.7×10^7	2.8×10^7
Sonic Velocity cm/sec.	1.8×10^5		
Resistivity ohm/cm	160×10^{-4}		

Those skilled in the art will appreciate that the particular embodiments of the invention described hereinabove are intended to be illustrative only and are not intended to limit the scope of the invention.

What is claimed is:

1. A loudspeaker diaphragm, said diaphragm consisting essentially of a carbonaceous fibrous web of carbon fibers and a resin, said carbon fibers representing between about 30% and about 70% by volume of said diaphragm, the balance being said resin, said diaphragm having a Young's modulus between about 3 million psi and about 30 million psi and a density between about 0.8 gm/cm^3 and about 1.7 gm/cm^3 so as to provide a sonic velocity for said diaphragm between about 2.5×10^5 cm/sec and about 11×10^5 cm/sec.

2. A diaphragm as defined in claim **1** wherein said carbon fibers are staple carbon fibers.

3. A diaphragm as defined in claim **2** wherein said resin is a resin selected from the group consisting of epoxy, furane, phenolic and melamine.

4. A diaphragm as defined in claim **3** wherein staple pitch fibers represent between about 60% to about 70% by volume of said diaphragm.

5. A diaphragm as defined in claim **1** wherein the sonic velocity of said diaphragm is greater than about 4.6×10^5 cm/sec.

6. A diaphragm as defined in claim **1** having a thickness between about 0.005 inches and about 0.025 inches.

7. A diaphragm as defined in claim **1** wherein said loudspeaker is an electrostatic loudspeaker.

8. A diaphragm as defined in claim **11** having a thickness between about 0.005 inches and about 0.010 inches.

9. A diaphragm as defined in claim **8** wherein said thickness is about 0.007 inches.

10. A diaphragm as defined in claim **1** wherein said carbon fibers represent between about 60% and about 70% by volume of said diaphragm.

11. A diaphragm as defined in claim **5** wherein said sonic velocity is greater than about 10×10^5 cm/sec.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

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Inventor(s) Samuel M. Boszor

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

On the front page of the patent, after the list of U. S. Patents cited, add the following:

--Foreign Patents or Applications 48/25515 4/1973 Japan (Early Disclosure Application) --.

At column 10, claim 8, line 38, delete "11" and substitute therefor -- 7 --.

Signed and Sealed this

eighteenth Day of *May 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

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