LOW FREQUENCY ELECTROCERAMIC SONAR TRANSUDER

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ABSTRACT

Four orthogonally disposed ceramic stacks are enclosed by a sheathing membrane cooperating with a pair of end members to form an elongate transducer a greatly increased projection surface is provided between the transducer and water via the outer surface of the membrane, to enable broadband, linear operation. Since immersing the transducer in the water medium forces the membrane to assume a cross-sectional, concave configuration, the large, bowed surface in contact with the water allows the more linear impedance match. Additionally, the bowed membrane transfers a compressive force to the orthogonally disposed ceramic stacks dynamically loading them to prevent their self-destruction when high driving potentials are applied.

5 Claims, 2 Drawing Figures
LOW FREQUENCY ELECTROCERAMIC SONAR TRANSDUCER

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

Transducers employing ferroelectric materials, usually arranged in stacks of conductors sandwiching ceramics, must be constructed to match the mechanical driving impedance to the natural impedance of the water medium to ensure efficient operation. Since the normally stiff ferroelectric materials, by themselves, provide an inefficient coupling to the water, large, stiff piston surfaces have been connected to the stacks to achieve a partially satisfactory coupling. The main disadvantage of this design was that, in order to achieve satisfac-

tory, low frequency coupling, the transducers were large, bulky affairs. An improvement over having large, stiff piston surfaces was advocated by the present inventor, Dr. Frank R. Abbott, in his patent titled "Broad Band Electroacoustic Transducer," issued July 14, 1959, U.S. Pat. No. 2,895,062, in which an annular, ferroelectric element imparted reciprocal vibrations to a pair of round, metallic shells. This design, while providing more efficient coupling, was fragile due to the relatively thin walls of the annular ferroelectric element. In addition, radial deformations of the element tended to tear the element apart when driven at high potential since it was not completely radially, compressively loaded. Radiating power was also limited due to its configuration since lower frequency operation depended on increased, overall diameter of the ceramic element which, in turn, created a greater susceptibility to damage from shock and a consequent greater cost.

SUMMARY OF THE INVENTION

The present invention is directed to providing a transducer formed of four elongate, orthogonally disposed ferroelectric elements extending from a common axis and polarized radially. The ferroelectric elements are encased by a flexible, inelastic sheath, or membrane, cooperating with a pair of traverse end members to seal the interior of the transducer from a water medium. Inserting the transducer in the medium results in an inward deflection of the membrane forming outwardly facing, concave configured surfaces enabling more efficient low frequency operation. Ambient pressure transferred by the membrane cooperates to hold the ferroelectric elements in compression to prevent their untimely self-destruction and to reduce the transducer's vulnerability to external shock.

It is an object of the invention to provide a low frequency transducer.

Yet another object is to provide a transducer having a reduced vulnerability to external shock.

A further object is to provide a transducer having a capability to allow a higher power projection of acoustic energy.

An ultimate object of the invention is to provide a low frequency, high power transducer more efficiently coupling signals representative of acoustic energy between ferroelectric materials and a water medium.

These and other objects of the invention will become more readily apparent from the drawings when taken with the ensuing description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of the invention operatively disposed.

FIG. 2 is a schematic end view of the invention showing the force components.

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2 DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, a low frequency, electroceramic sonar transducer 10 includes a single, composite electroceramic element 11 formed of our orthogonally disposed, elongate ridges 12, 13, 14, and 15. Each of the ridges is composed of a plurality of elongate, ceramic members 12a, 12b, 13a, 13b, 14a, or 15a, sandwiching conductors 12b, 13b, 14b, or 15b between adjacent members. In accordance with well-known methods, the ceramic elements are separately brought into the influence of a powerful electric field causing a discrete polarization. The ceramic elements and the interposed conductors are arranged to possess an additive polarization radially outward from a common inertial member 16 serving as a transducer axis.

An electrical lead connected to a driving source of one polarity is attached to alternate ones of the conductors in each stack, and an electrical lead reaching from a driving source of the opposite polarity is connected to the other alternate conductors in a parallel relationship. This parallel electrical connection of ceramic stacks is widespread within the hydroacoustic transducer art, and, for that purpose, has been schematically depicted by pairs of bus bars 17 and 18 and 17' and 18' joined to pairs of electrical leads 17a and 17'a and 18a and 18'a extending to remote driving or monitoring circuitry.

Thusly configured, driving signals fed to the bus bars 17, 17', 18, and 18' cause reciprocable travel of each of the elongate ridges, radially, outwardly from the centermost axial member 16 in response to the driving signals.

Superior coupling between the ferroelectric element and the water medium is provided by including a flexible, inelastic sheath 20 laterally enveloping the stacks. The lateral peripheral length of the sheath is greater than a straight line peripheral dimension and it sags or defines concave surfaces between adjacent ridges the purpose of which will be covered later. The sheath is optionally a transparent membrane, a polyester fibrous glass sheet, or similar high tensile strength material, having the characteristics of being flexible while being inelastic. However, since plastic-like materials tend to sacrifice either flexibility of elasticity, especially when operated under pressure and under colder temperatures, a membrane is preferably employed.

Resiliently sealing the opposite ends of the sheath to a pair of laterally extending end members 21 and 22, the latter being shown in phantom for purposes of simplicity of the drawings, forms four distinct compartments which make up the interior of the transducer. With the ambient water pressure exerting a converging, inward force, as shown by sub arrows 23, each quadrature component 20a, 20b, 20c, and 20d of the sheath assumes a concave, cross-sectional configuration. Empirically, an optimum configuration for efficient operation is one having a "sag height" equal to one-tenth the length of the span between adjacent elongate ridges.

Because ceramic stacks exert a considerable force over a short distance, the concave configured sheath maximizes the energy transfer between the transducer and the water as explained below.

By noting FIG. 2, applying a driving potential via the electrical leads 17a, 17'a, 18a, and 18'a causes simultaneous, oppositely directed, radial extensions and contractions of elongate ridges 12, 13, 14, and 15 with respect to the common axial member 16.

The radial extensions, shown schematically with respect to elongate ridge 12, are vector Δ12 and with respect to elongate ridge 13 are Δ13. These vectors, when broken into x and y components, allow a schematic investigation of the transfer of forces from these two elongate ridges to quadrature portion 20b of the flexible, elastic sheath. The effect of the two y force components, Δ12y and Δ13y, to quadrature portion 20b is obvious since this portion of the sheath is, laterally displaced as a plane front in the arrow direction of, and a distance equal to the length of the y components.
However, a much greater excursion of portion 20a is attributed to the oppositely directed $\Delta 1_{12z}$ and $\Delta 1_{12y}$ force components. By analyzing portion 20a to a sagging rope, it is apparent that a forceful, but relatively small, oppositely directed displacement of the two ends of the rope causes a magnified lateral displacement of the sagging portion of the rope.

Similarly, the forceful, but relatively short opposite displacement attributed to the $\Delta 1_{12z}$ and $\Delta 1_{12y}$ force components causes a magnified lateral excursion by portion 20a. Elaboration on the resulting improved hydroacoustic coupling and on the theory involved is set forth in the above-cited patent, "Broad Band Electroacoustic Transducer" also issued to Dr. Frank R. Abbott.

The length of the elongate ridges 12, 13, 14, and 15 is merely a matter of choice and is optionally of much greater length than depicted in the drawings to handle higher acoustic energy transfer levels and to provide increased sensitivity to impinging acoustic energy.

Mounting a capping element 25, 26, 27, 28 on a separate elongate ridge 12, 13, 14, or 15, respectively makes the transducer less susceptible to injury from outside shock. In addition, securing the inner surface of the flexible, inelastic sheath onto the outer surfaces of the capping elements provides a uniform bearing surface for transferring compressional loading radially, inwardly on each of the elongate ridges. This compressional loading helps overcome one of the inherent limiting features of piezoelectric (ferroelectric) elements, in particular barium titanate, that being, when being driven at high levels the ceramics tend to tear themselves apart and self-destruct. Having a compressional loading, minimizes this possibility.

Thus, using the elongate, flexible sheath gives the transducer a low frequency range of response by providing a large water loading surface, provides a vehicle for projecting high level acoustic power, and provides compressional loading to prevent the elongate ridges from tearing themselves apart. Furthermore, the elongate configuration allows use of the transducer in confined places, or narrow places, where conventional, bulky, ring-shaped transducers cannot fit.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings, and, it is therefore understood that within the scope of the disclosed inventive concept, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In transducers having surfaces configured for transferring acoustic signals to and from a water medium, an improvement therefor is provided comprising: ferroelectric means shaped with four orthogonally disposed elongate ridges secured to and extending from a common axis and each being individually polarized for deformation radially outwardly and inwardly from said common axis;

a pair of end members resiliently mounted across opposite ends of said ferroelectric means enabling an unimpeded said radial deformation; and

inelastic, flexible sheath means secured to said end members and laterally enveloping said ferroelectric means sealing the transducer's interior from said water medium, upon being immersed in said medium, the ambient pressure forces said sheath means to bear against the outwardmost surface of all said ridges transferring a compressional force in-line opposed to said radial deformation thereby minimizing the possibility of self-destruction of said transducer, and said sheath means has a sufficient lateral peripheral length to form concave panels reaching between juxtaposed said outwardmost extensions when immersed in said medium to provide an increased impedance enabling improved broadband operation.

2. A transducer according to claim 1 further including:

an elongate cap member mounted on each said outwardmost surface each secured to the inside surface of said sheath means for equally distributing said compressional force laterally across each said ferroelectric means.

3. A transducer according to claim 2 in which said ferroelectric means, said end members and said sheath means mechanically cooperate to form four coaxially disposed internal chambers having a lower pressure than the said water medium creating a pressure differential across said sheath and said compressional force.

4. A transducer according to claim 3 in which said four orthogonally disposed elongate ridges are each formed of a plurality of ceramic strips separated by conductors impressing a radial electric field in-line with said radial deformation of each separate elongate ridge.

5. A transducer according to claim 4 in which said sheath means is a transparent membrane.

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