# United States Patent [19]

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[11] **3,835,340**

[45] **Sept. 10, 1974**


[54] **TRANSDUCER CORONA SHIELD**


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[22] Filed: **Feb. 15, 1973**

[21] Appl. No.: **332,716**

[52] **U.S. Cl.** ..... **310/9.8,** 310/8, 310/9.7, 310/9.6, 340/10

[51] **Int. Cl.** ..... **H04r 17/00**

[58] **Field of Search** ..... 310/9.7, 9.8, 8.3, 8.7; 340/10



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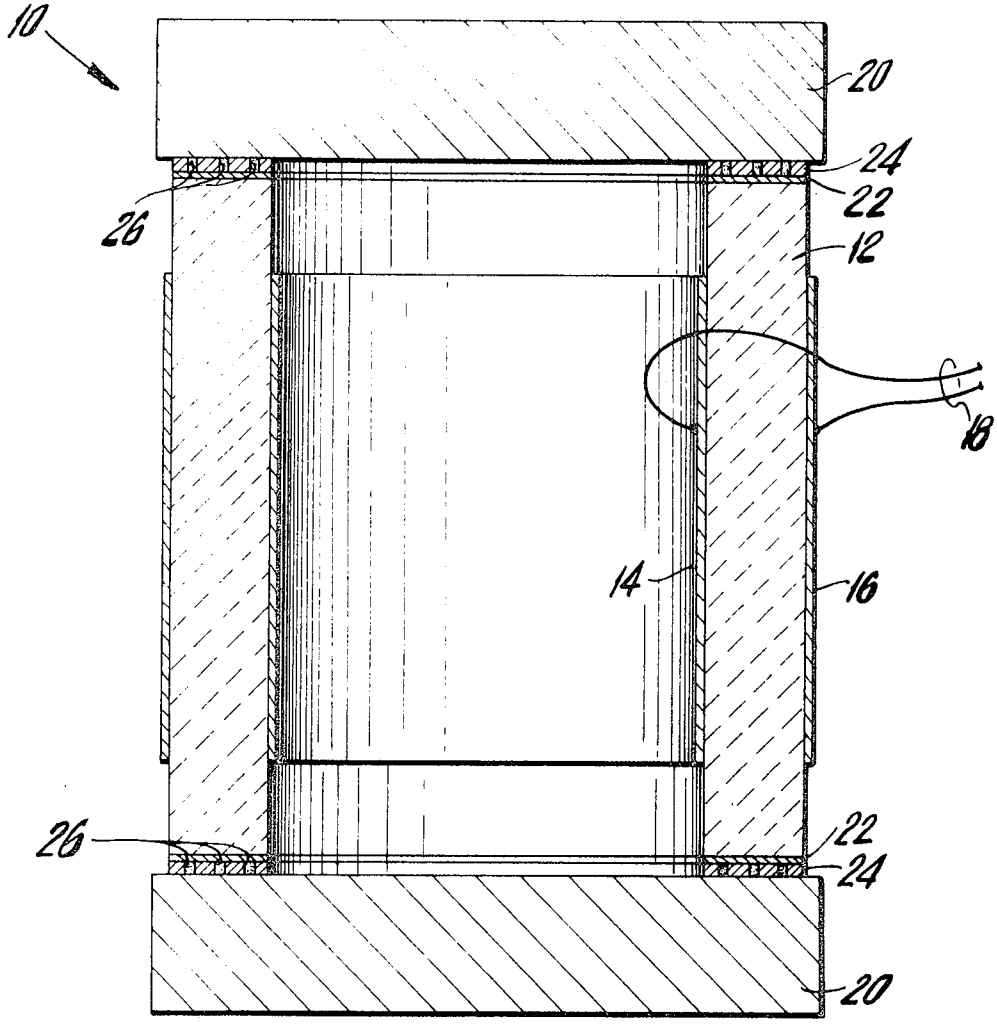
*Attorney, Agent, or Firm*—Davis, Hoxie, Faithfull & Hapgood



[57] **ABSTRACT**

In an electroacoustic transducer, corona in the interface between the ceramic transducer element and the electrically conductive transducer end mass, supporting structure, or the like, is substantially eliminated by means of a corona shield electrode on the ceramic element in the interface and electrically connected to the end mass or other conductive structure.


**5 Claims, 2 Drawing Figures**



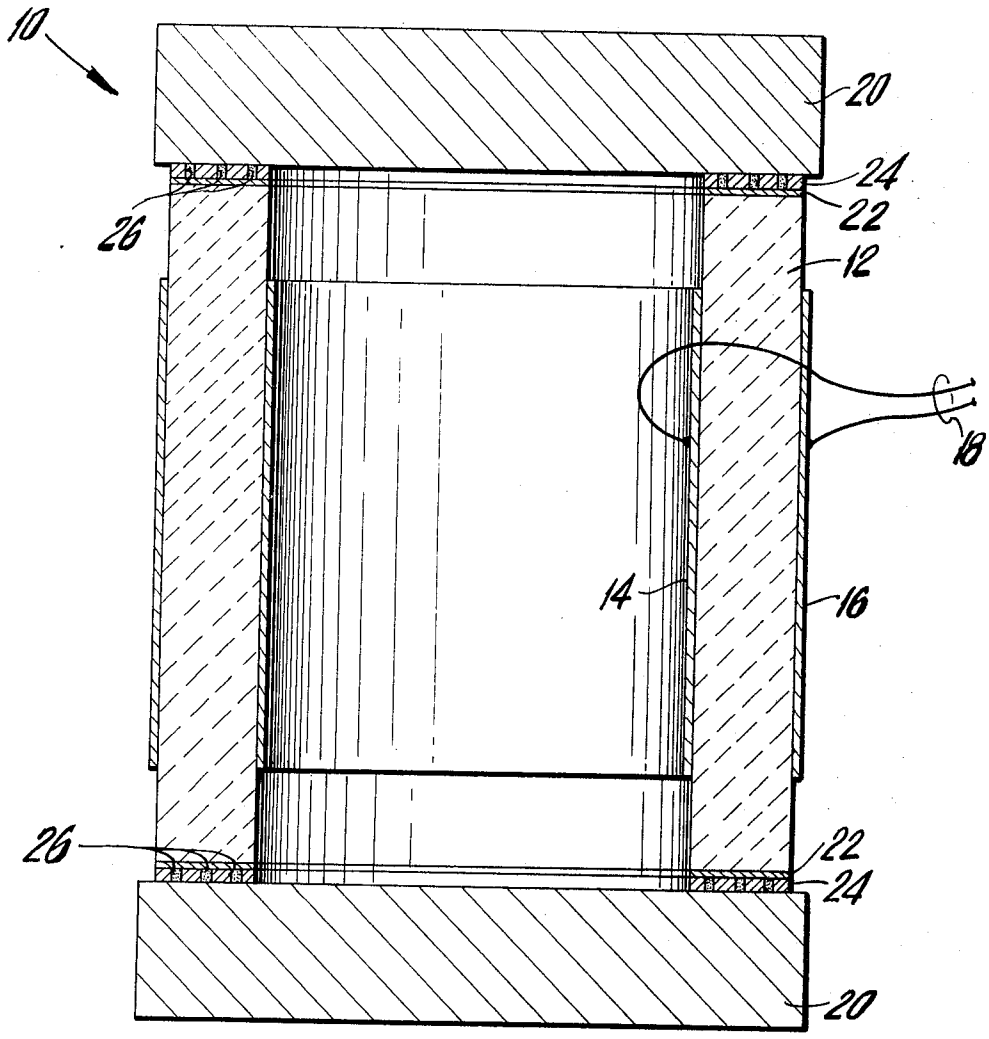



FIG. 1

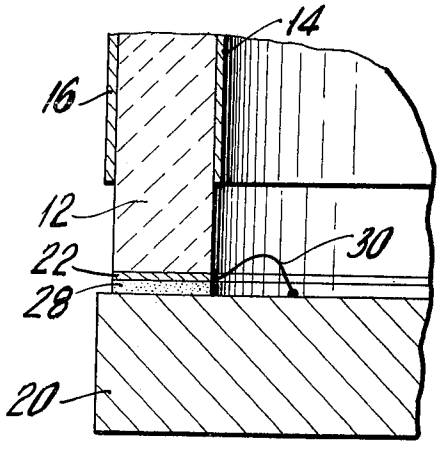



FIG. 2

# TRANSDUCER CORONA SHIELD

## BACKGROUND OF THE INVENTION

This invention relates to electroacoustic transducers and more particularly to controlling corona discharge in piezoelectric ceramic transducers.

Electroacoustic transducers are used for transmitting and receiving acoustic energy in a wide variety of applications. In underwater sonar systems, for example, an electroacoustic transducer frequently serves as a source of sound waves radiated into the water for object detection, identification, etc. Among the most frequently used types of electroacoustic transducers are those having piezoelectric ceramic elements as active components. In transducers of this type, a change in the potential applied, for example, to opposite faces of the piezoelectric ceramic element causes at least one physical dimension of the element to change. The kinetic mechanical energy represented by the changing dimension of the ceramic element is radiated into the medium surrounding the transducer as acoustic energy. This is usually accomplished by using the ceramic element to accelerate another transducer component (e.g., a metal end mass) which is contiguous with the acoustic medium.

In many applications of transducers of the type described above, transducer responses of considerable magnitude must be produced. These require the application of very substantial voltages to the electrodes of the ceramic transducer element or elements. These voltages may be so high as to cause so-called corona breakdown (i.e., ionization) of the air or other gases in the transducer assembly. This problem is particularly acute with respect to air in the region of the interface between the ceramic element and the electrically conductive transducer end masses, supporting structures, or the like. Among the undesirable effects of corona may be erosion of the ceramic transducer element or so-called silver migration (i.e., attraction of electrode silver atoms to the corona area where they form structures which short-circuit or otherwise damage the transducer). Corona occuring in the adhesive joining the ceramic element and the transducer end masses or in air entrapped in that adhesive may be destructive of the adhesive bond as well as the ceramic material itself.

It is therefore an object of this invention to improve electroacoustic transducers of the type employing piezoelectric ceramic elements as active components.

It is a more particular object of this invention to provide piezoelectric ceramic transducers in which corona in the region of the interface between the ceramic element and the transducer end masses, supporting structures, or the like, is substantially reduced or eliminated.

## SUMMARY OF THE INVENTION

These and other objects of the invention are accomplished in accordance with the principles of the invention by introducing a corona shield electrode between the ceramic element and the transducer end mass, supporting structure, or the like. This corona shield electrode is intimately bonded to the ceramic element so that no air or other gases are present between the ceramic and the electrode. The ceramic element (with the corona shield electrode) may be bonded to the conductive transducer end mass, supporting structure, etc., by adhesives between the corona shield electrode and the end mass or supporting structure. The corona shield electrode is electrically connected to the conductive end mass or supporting structure so that the potential difference across the adhesive or other interface between the corona shield electrode and the end mass or supporting structure is zero. Accordingly, corona cannot occur in the interface between the ceramic element and the transducer end mass or supporting structure.



Further features of the invention, its nature and various advantages will be more apparent from the attached drawing and the following detailed description of the invention.

## BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a sectional view of an electroacoustic transducer constructed in accordance with the principles of this invention and

FIG. 2 is a partial sectional view of an electroacoustic transducer showing an alternative embodiment of the invention.

## DETAILED DESCRIPTION OF THE INVENTION

As shown in FIG. **1**, one frequently employed type of electroacoustic transducer **10** includes a hollow cylinder **12** of piezoelectric ceramic material such as barium titanate or lead zirconate titanate. Ceramic cylinder **12** (as well as the other components of transducer **10**) is shown bisected along the longitudinal axis of the transducer. Partially covering the inner and outer surfaces of ceramic cylinder **12** are concentric cylindrical electrodes **14** and **16.** Each of electrodes **14** and **16** is somewhat shorter, measured along the longitudinal axis of transducer **10,** than ceramic cylinder **12.** The thickness of electrodes **14** and **16** is exaggerated in FIG. **1** for clarity of illustration. At least one of electrodes **14** and **16** (usually inner electrode **14**) is connected to a source (not shown) of transducer driving electrical potential by way of one of leads **18.** The remaining electrode may be connected to ground by the remaining lead. Ceramic cylinder **12** responds to a change in the potential difference between electrodes **14** and **16** by changing in length.

At each end of ceramic cylinder **12** is a metal disc **20,** usually referred to as an end mass. Although transducer **10** is shown with an identical end mass at each end of ceramic cylinder **12,** it will be readily understood that this is not necessarily the case. For example, either end mass may include any arrangement of spacer rings, temperature compensating elements, mechanical impedance matching elements, frequency adjusting elements, or the like. In addition, either end mass may be part of a transducer supporting structure having any desired configuration. For convenience here, however, the term end mass will be understood to include any of these various elements and supporting structures.

Returning to the embodiment shown in FIG. **1,** end masses **20** are retained on the ends of ceramic cylinder **12** by adhesives or other mechanical means. When ceramic cylinder **12** changes in length, end masses **20** are accelerated in opposite directions along the longitudinal axis of the transducer. In the usual application, one of end masses **20** is contiguous with or mechanically coupled to an acoustic medium (e.g., air or water) and therefore acts to radiate acoustic energy into the me-

dium when accelerated as described above. The opposite end mass is the non-radiating rear end mass of the transducer. Of course, both end masses may be made radiating if desired.

The ceramic material of cylinder **12** is an insulator of high dielectric constant (typically on the order of 1,000 times the dielectric constant of air). Typically, ceramic cylinder **12** can support a potential difference of considerable magnitude between electrodes **14** and **16.** At the interface of ceramic cylinder **12** and either of end masses **20,** however, there are almost inevitably materials of lower dielectric constant. For example, some air or other gases are usually present in the interface. When adhesives are used in the interface, air or other gases may be entrapped in the adhesive layer. Moreover, the adhesive itself may be a material of a low dielectric constant. Since each of end masses **20** is electrically conductive, a potential difference will also exist between the end mass and at least one of electrodes **14** and **16,** i.e., across the unpoled length of ceramic cylinder **12** (the portion not covered by electrodes **14** and **16**) and the interface between the cylinder and the end mass. Voltage gradients across dielectric materials of differing dielectric constants are inversely proportional to the respective dielectric constants of the materials. With respect to the potential difference between electrodes **14** or **16** and either of end masses **20,** the gradient is therefore greatest in the interface between ceramic cylinder **12** and the end mass, particularly in any air or other gases in that interface. If transducer **10** is operated at high potentials, the potential gradients in the interfaces between ceramic cylinder **12** and end masses **20** may be great enough to cause so-called corona (i.e., ionization) in gases in these interfaces. Such corona is damaging to the components of the transducer, particularly the ceramic and adhesive materials.

In accordance with the principles of this invention, the corona described above is eliminated by rendering the potential gradient across the interfaces of ceramic cylinder **12** and end masses **20** effectively zero. This is accomplished by introducing an electrode **22** at each end of ceramic cylinder **12** and electrically connecting each of these electrodes to the adjacent end mass. Each of electrodes **22** has the shape of an annular ring completely covering one end of ceramic cylinder **12.** Like electrodes **14** and **16,** electrodes **22** are intimately bonded or joined to the material of cylinder **12** so that no air or other gases are present between the material of cylinder **12** and the electrodes. Electrodes **22** may be conductive paint, conductive epoxy, conductive adhesive, fired-on silver, or the like. Electrodes **22** may also be made of a semiconducting material such as carbon impregnated paint, powdered copper, powdered silver, or the like. As in the case of electrodes **14** and **16,** electrodes **22** are shown in FIG. **1** with exaggerated thickness.

In the embodiment shown in FIG. **1** each of electrodes **22** is electrically connected to the adjacent end mass by a metallic grounding spacer **24** of brass or the like. Each of grounding spacers **24** has the shape of an annular ring and may in addition include a plurality of perforations **26** aligned with the longitudinal axis of transducer **10.** Adhesive material in these perforations may be used to secure end masses **20** to electrodes **22** and thus to ceramic cylinder **12.**

In the embodiment shown in FIG. **2,** grounding spacer **24** is omitted and electrode **22** is electrically connected to end mass **20** by lead **30.** End mass **20** may be bonded to ceramic cylinder **12** by an adhesive layer **28** between end mass **20** and electrode **22.** As in the case of the embodiment shown in FIG. **1,** the potential gradient across this adhesive is zero, thereby preventing the occurrence of corona in the interface.

It is to be understood that the embodiments shown and described herein are illustrative of the principles of this invention only, and that various modifications may be implemented by those skilled in the art without departing from the scope and spirit of the invention. For example, whereas the invention has been described in its application to electroacoustic transducers having hollow cylindrical piezoelectric elements, the invention is equally applicable to transducers having a wide variety of other configurations and in which corona in the interfaces between piezoelectric elements and end masses or supports is a problem.

What is claimed is:

**1.** In a transducer including a first electrode connected to a first insulator of relatively high dielectric constant, a conductive end mass positioned adjacent a surface of said first insulator and insulated from said first electrode, and a second insulator of relatively low dielectric constant in at least some portions of the interface between said end mass and said surface of said first insulator, the improvement comprising:

a second electrode substantially covering the surface of said first insulator adjacent said end mass so as to separate said first and second insulators and

means for conductively connecting said second electrode to said conductive end mass.

**2.** The apparatus defined in claim **1** wherein said second electrode is a layer of fired-on metal.

**3.** The apparatus defined in claim **1** wherein said second electrode is a layer of electrically conductive paint.

**4.** The apparatus defined in claim **1** wherein said means for conductively connecting comprises a perforated metal plate between said second electrode and said conductive end mass.

**5.** The apparatus defined in claim **1,** wherein said first insulator is a piezoelectric ceramic.

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