(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 732 864 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.09.1996 Bulletin 1996/38

(51) Int. Cl.^{6}: **H04R 17/00**

(21) Application number: **96103044.2**

(22) Date of filing: **29.02.1996**

(84) Designated Contracting States:
DE FR GB IT

(30) Priority: **11.03.1995 GB 9505003**

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(54) Acoustic transducer

(57) An acoustic transmitter or receiver comprising a piezoelectric polymer film (10) having a pair of electrodes (12,14) deposited thereupon such that in the transmission mode an electrical signal applied to the electrodes (12,14) deforms the piezoelectric polymer film (10) thereby creating an acoustic signal and in the receive mode an incident acoustic signal deforms the piezoelectric polymer film (10) thereby creating an electrical response across the electrodes; characterized in that: the piezoelectric polymer film (10) is formed into a compliant cylinder.

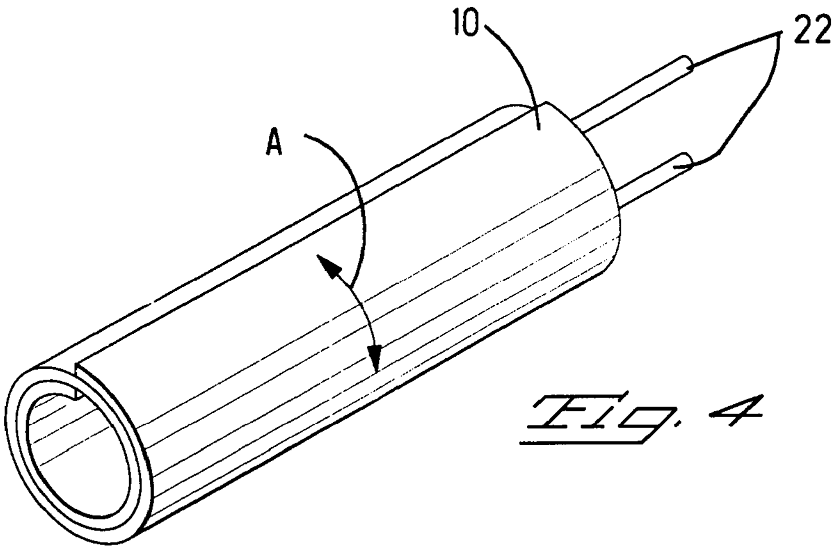

Fig. 4

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Description

This invention relates to an acoustic transducer utilising polymer piezoelectric material.

It is well known that piezoelectric polymer film may be used both to send and receive acoustic or ultrasonic signals into and from air as a transmission medium. In most cases, the piezoelectric polymer film is used in the form of a membrane where a change in applied voltage to the film electrodes (considering first a transmitter that acts similar to a loudspeaker) causes a change in length dimension, thus creating an effective change in radius of curvature and thus a perceptible radiation of acoustic energy into air, or conversely (as a microphone), where a change in sound pressure causes a change in radius of curvature and thus generates a corresponding voltage output. While the known devices function reasonably well, it is desirable to improve thereupon and especially provide a device that is usable in a cylindrical cavity or conduit where the performance of known devices is limited.

The present invention provides an acoustic device comprising a cylinder of uniaxially-oriented piezoelectric polymer film with its machine axis aligned substantially circumferentially, such that in transmission mode an applied electrical signal creates an acoustic signal radiating from one end of the cylinder, and in reception mode an incident acoustic signal arriving into one end of the cylinder creates a corresponding electrical response across the film electrodes.

The device of the present invention is formed by rolling into a compliant cylinder a piezoelectric polymer film with the predominant piezoelectric sensitivity oriented in a substantially circumferential direction. By this means, an applied varying electrical signal creates a change in diameter of the cylindrical assembly. When supported in free space, this change in diameter tends to launch an acoustic wave radiating outwards from the cylinder. Preferably, however, the transducer is mounted within a cylindrical cavity or conduit, in which case the cylindrical radiating wave is suppressed and the predominant radiation direction is along the axis of the cylinder or conduit. Some resonant phenomena are observed from such an assembly, consistent with the cylindrical form. In the preferred embodiment, the cylindrical assembly is held in place by means of an adhesive tape applied fully over one side of the piezoelectric polymer film prior to assembly. Such adhesive tape typically comprises a polyester carrier film, coated on each side with a layer of acrylic adhesive. Due to the mechanical properties of the piezoelectric polymer film and such adhesive tape, the compliance of the assembly is high, and so mechanical resonances within the assembled device are not sharply defined in frequency. This permits operation over a band of frequencies, rather than constraining operation to a single very specific frequency.

A device of the present invention may preferably employ a piezoelectric polymer film element having dimensions approximately 15mm x 40mm, with film thickness of 28μm and one surface bearing a layer of double-coated adhesive tape such that when the film element is wound up around a 4mm mandrel, its final diameter is in the region of 4.7mm with a length of 15mm. The electrode pattern is deposited on the film by means of screen-printing with suitable conductive ink which may preferably allow contacts to be formed thereto by means of crimped connectors. To allow such connectors to be applied without risk of forming an electrical short-circuit through the film thickness, it is necessary to design an electrode pattern which offers displaced top and bottom lead-attach pads. In the device of the present invention, such pads are allowed to project to the rear of the cylinder, parallel to its axis, thereby allowing metal contact pins to be fixed in line with the transducer. In another embodiment, the patterned film electrode pads are allowed to project beyond the cylinder, but are allowed to bend through a right angle for subsequent termination direct to a printed-circuit board by means of, for example, metal eyelets or rivets. Other forms of electrical connection are not excluded.

A preferred embodiment of the invention will now be described with reference to the drawings, in which:

Figures 1a and 1b show alternative suitable film/electrode layouts;
Figure 2 is a cross-section of a film assembly incorporating one of the layouts of Figure 1;
Figure 3 illustrates the assembly of Figure 2 at the start of wrapping on a mandrel;
Figure 4 shows in perspective the transducer produced by the wrapping of Figure 3;
Figure 5 shows the use of a plug and a reducing nozzle with the transducer of Figure 4;
Figure 6 is a schematic perspective view, partly cut away, of another application of the transducer; and
Figure 7 illustrates the transducer of Figure 3 used to propagate sound in a conduit.

Referring to Figure 1, a transducer according to the present invention is based on a piece of piezoelectric polymer film 10 which is metallised on either side with electrodes 12 and 14. The electrodes 12 and 14 have connector portions 12a and 14a brought out to one side of the transducer. The film 10 is laminated with an adhesive suitably in the form of a carrier tape 16 coated on each side with adhesive 18 and 20 as seen in Figure 2.

Referring to Figures 3 and 4, contact pins 22 are fixed to the film/tape composite described above and the film/tape composite is then wrapped around a mandrel 24 in a scroll-like manner to form the transducer of the present invention. The piezoelectric polymer film 10 is uniaxial film with the principal or machine axis aligned in the direction of the arrow A such that in the resulting transducer of Figure 4 the machine axis is circumferential.

As shown in Figure 5, the transducer may be provided with a plug or base 26 which acts as an acoustic reflecting surface. The radiation (or reception) efficiency is enhanced by the plug or base 26, with a corresponding change occurring in the frequency response of the transducer, as with the end closed off, standing waves occur at a lower frequency than when the end is open.

The transducer may optionally include a reducing nozzle 30 which further enhances radiation (or reception) efficiency by providing a reduction in diameter through which the acoustic waves are transmitted or received just in front of the transducer.

Figure 6 illustrates the transducer of the present invention mounted as part of a cartridge 32 which includes the base 26 and the reducing nozzle 30, along with a cylindrical containment 34.

Figure 7 shows the transducer of the present invention for use in propagating or detecting sound (acoustic waves) within a conduit 36.

In the case where the conduit 36 for the acoustic signal is formed of a material which is electrically conductive or semi-conductive (such as carbon-loaded rubber) and thus may carry electrical signals unrelated to the acoustic signals being generated and detected by the transducer, it may be desirable to form an independent electrical connection to this outer shell such that unwanted electrical signals may be conducted to ground. If so, additional insulation may be provided between the outermost film electrode and the inner wall of the conduit 36, possibly through the use of the shell 34. It is usually preferable in this case to allow the innermost piezo film electrode 12 or 14 (depending on the roll) to be a ground electrode, such that both inner and outer grounded cylinders are formed to surround the signal electrode (12 or 14) of the transducer.

When considering a transducer of the present invention that is designed for use as a transmitter of acoustic signals, it should be noted that suitable piezoelectric polymer film material such as uniaxially-oriented PVDF (polyvinylidene fluoride) can withstand an applied electric field strength of around 30 volts per micrometer of thickness. In the preferred embodiment, the PVDF film has a thickness of 28μm, hence the applied electrical drive signal should not exceed 840 volts. At this drive level, sound pressure levels in excess of 112dB may be detected after propagating a distance of one metre down a conduit 5mm in diameter. In receive mode, a similarly constructed transducer may show a sensitivity of -80dB (re 1 V/Pa).

The foregoing example has the machine axis of the film circumferential. Alternatively, the machine axis could be slightly out of true circumferential alignment, provided the major directional component is circumferential, for example by winding the film in a shallow helix.

A transducer according to the present invention has been found to operate successfully within certain ranges of frequency, particularly in the region of 2kHz to 25kHz when the transducer is tested in free space at close range. Since the attenuation of sound increases with frequency, the received signal after propagating some distance in air will show a corresponding reduction in signal content at high frequencies. For this reason, it is found preferable to operate such devices nearer the lower end of the range referred to above - i.e. in the region of 2kHz to 3kHz.

It is a characteristic feature of the device that a sufficiently broad and smooth frequency response is obtained that transmission of either continuous sinusoidal form, or waves modulated in frequency or amplitude, or pulse waveforms, may be transmitted and received with ease. The device thus allows transmission of acoustic waves through a duct or conduit, whereby a transducer according to the present invention could be disposed at each opposite ends of the duct or conduit with one being operated as a transmitter and the other as a receiver such that the signal could be passed therealong. A reflector could also be used at one end and electronics provided to switch one transducer between transmit and receive modes.

Claims

1. An acoustic transmitter or receiver comprising a piezoelectric polymer film (10) having a pair of electrodes (12,14) deposited thereupon such that in the transmission mode an electrical signal applied to the electrodes (12,14) deforms the piezoelectric polymer film (10) thereby creating an acoustic signal and in the receive mode an incident acoustic signal deforms the piezoelectric polymer film (10) thereby creating an electrical response across the electrodes; characterized in that: the piezoelectric polymer film (10) is formed into a compliant cylinder.

2. The acoustic transmitter or receiver of claim 1 wherein the polymer film (10) is uniaxially oriented with a machine axis (A) aligned substantially circumferentially such that in the transmission mode the acoustic signal is radiated from an end thereof and in the receive mode the acoustic signal is received in an end of the cylinder.

3. The acoustic transmitter or receiver of claim 2, wherein the electrodes (12,14) are oriented on opposite sides of the film (10) and project in the direction of the machine axis with contacts (22) connected thereto.

4. The acoustic transmitter or receiver of claim 2 wherein contacts (22) are attached to the electrodes (12,14) such that the contacts (22) extend to the side of the device.

5. The acoustic transmitter or receiver of claim 2 wherein the film is laminated with an adhesive (16,18,20) such that when the film (10) is

unwrapped in a scroll-like manner the film (10) is joined thereby into the compliant cylinder.

6. The acoustic transmitter or receiver of claim 2 wherein the film (10) is positioned within a cylindrical containment (34).

7. The acoustic transmitter or receiver of claim 6 wherein a plug or base (26) covers an end of the cylindrical containment (34), thereby acting as a reflecting surface.

8. The acoustic transmitter or receiver of claim 7 wherein a reducing nozzle (30) is disposed at an end of the cylindrical containment (34) opposite the plug or base (26).

9. The acoustic transmitter or receiver of claim 2 wherein the film (10) is formed into the cylinder with the negative electrode (12) disposed on an inner surface thereof.

10. The acoustic transmitter or receiver of anyone of claims 1-9 wherein the device is disposed within a conduit in an aligned manner.

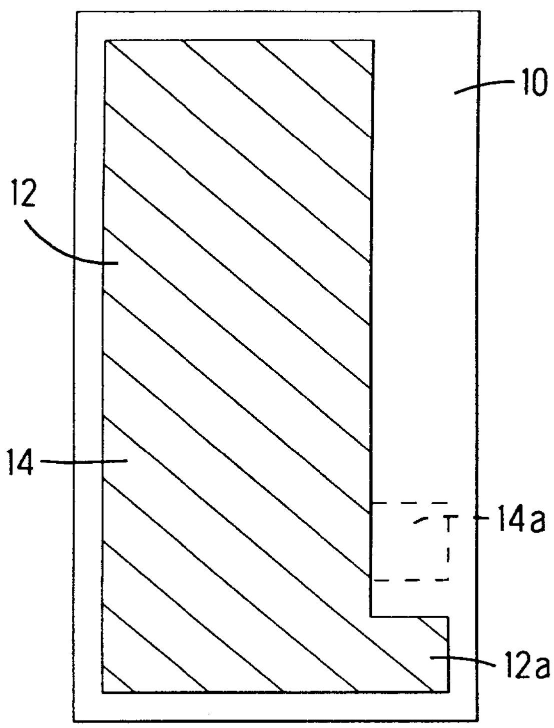

Fig. 1A

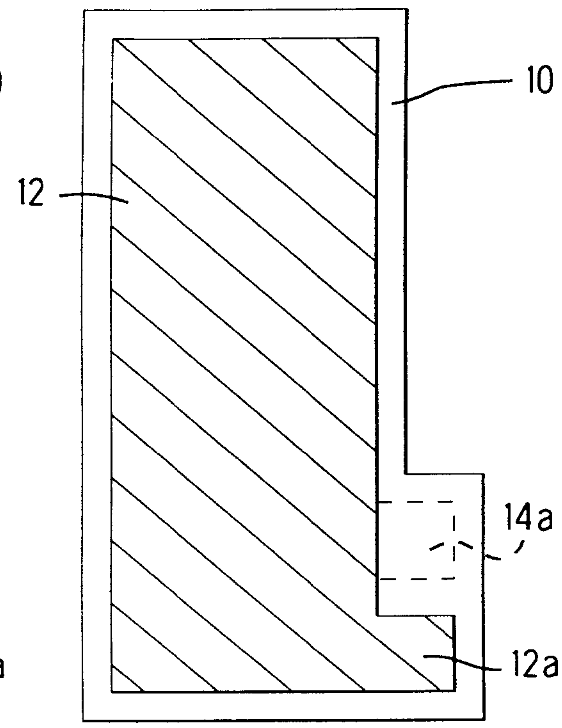

Fig. 1B

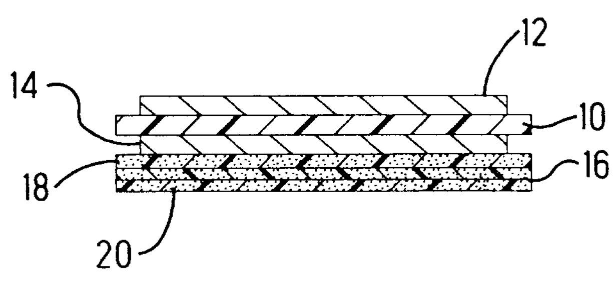

Fig. 2

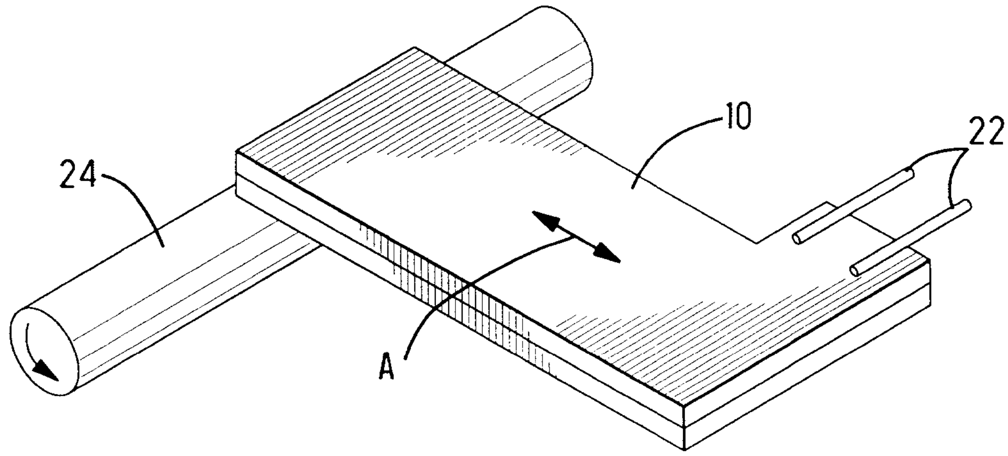

Fig. 3

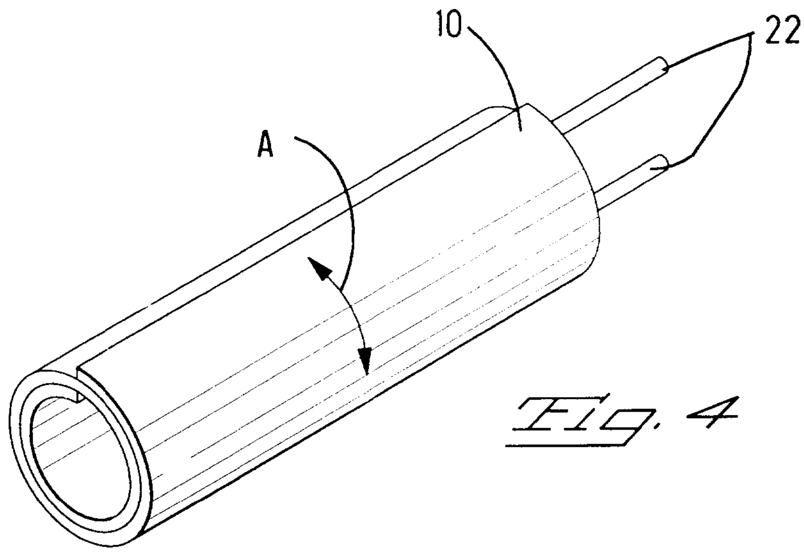

Fig. 4

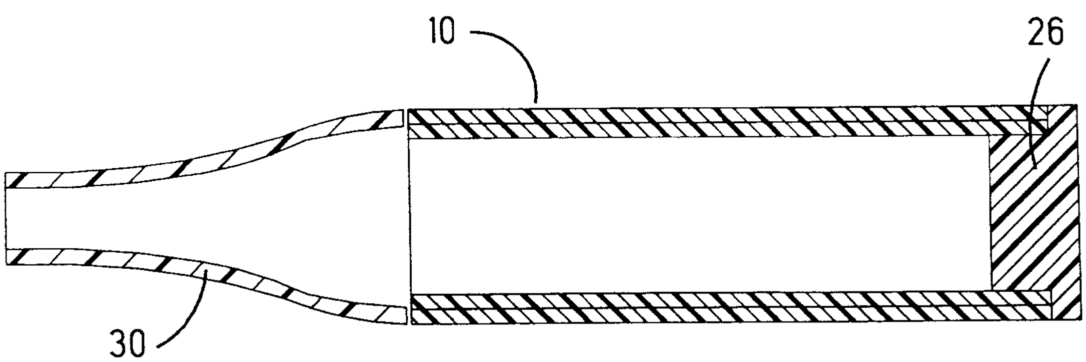

Fig. 5

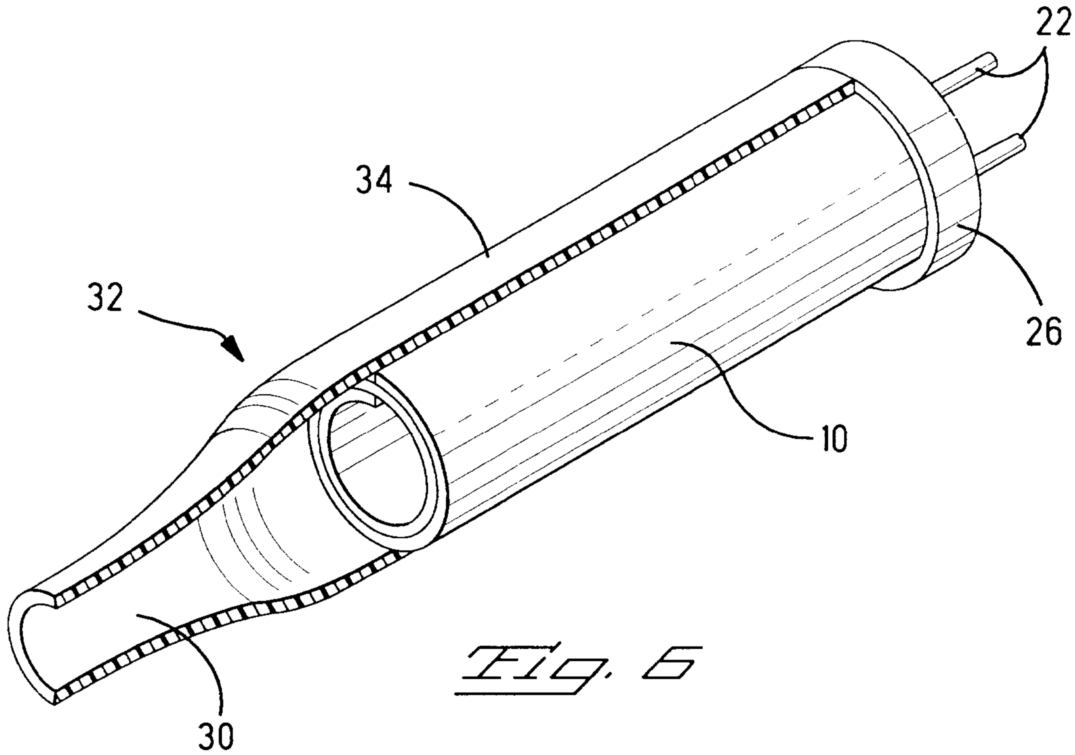

Fig. 6

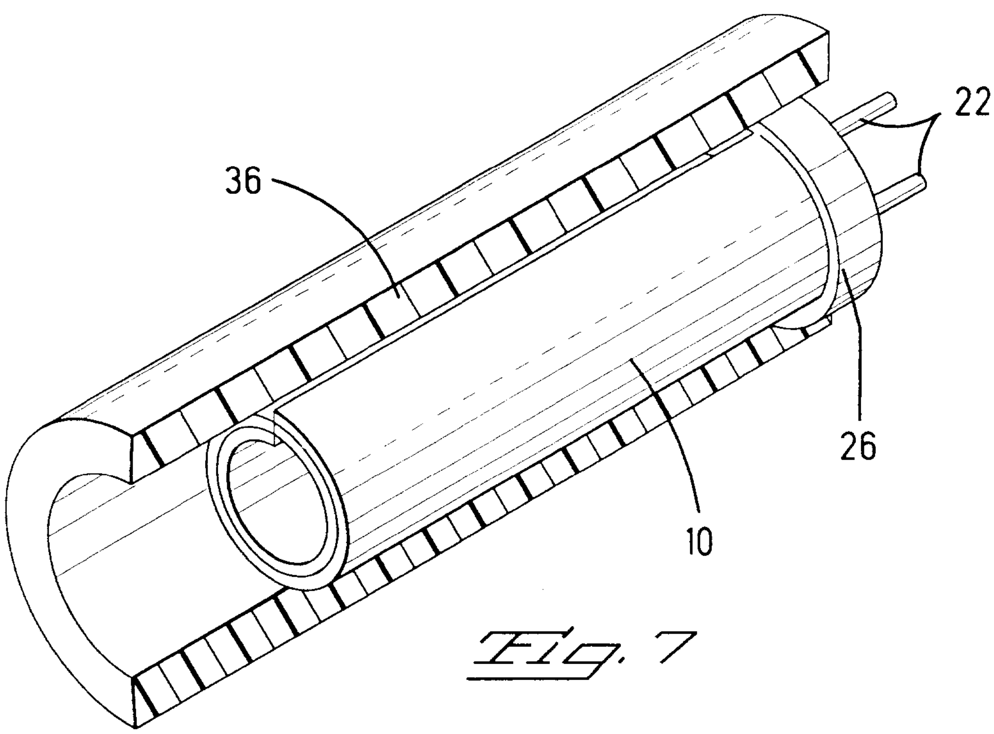

Fig. 7