

ULTRASONIC TRANSDUCER

Technical Field

This invention relates to ultrasonic piezoelectric transducers, processes of constructing an ultrasonic piezoelectric transducer, a system for transmitting ultrasonic vibrations, a system for detecting ultrasonic vibrations, systems for transmitting and detecting ultrasonic vibrations, a method for transmitting ultrasonic vibrations, a method for detecting ultrasonic vibrations and methods for transmitting and detecting ultrasonic vibrations.

Background Art

Occasionally situations arise that demand the use of an ultrasonic transducer in the 100-200 kHz range with minimal power requirements and operating into air or other gases. The low power requirement rules out a large number of existing transducers - whether their sensitivities are so poor that they need a large stimulating voltage or whether they need a large bias voltage which is difficult to achieve in a low power D.C. system. For example, piezoelectric ultrasonic transducers (commonly used underwater) operating into air or other gases are typically of low sensitivity or narrow bandwidth.

These characteristics result from the immense acoustic impedance mismatch between air or other gases and the transduction materials (the latter being able to create large forces but with only small deflections). Either one puts up with the small deflections (low acoustic output) or one brings the material into a resonant state at one particular frequency. For echo sensing or information transmission applications a single frequency is useless and as broad a range of frequencies as possible is desirable. Some low-bias-voltage (30V) electrostatic transducers have been developed but, by and large, these are expensive and time-consuming to produce.

Summary of the Invention

It is an object of the present invention to ameliorate one or more disadvantages of the prior art.

Disclosure of Invention

The present inventors have discovered that a piezoelectric material having an appropriate profile can be driven in a mode that is referred to in the specification and claims as a dilational mode which is alternatively referred to as a quasi-longitudinal mode. A tentative explanation of what is meant by a transducer being driven in a dilational mode is as follows. When a piezoelectric material having a curved profile is driven it will bulge out when it is lengthened and contract in when it is shortened. Where it is not curved no transverse motion results. Thus, if the material is gently curved but contains no point of inflection and thus no change in the sign of its curvature, it will undergo

transverse vibration of the same phase along its whole length. If, on the other hand, the curve includes a point of inflection the transverse displacement changes in phase at this point. If this curvature having the point of inflection also possesses the appropriate radiation geometry there is a resultant effective coupling of piezoelectric excitation to transverse displacements whereby the out of phase transverse vibrations constructively interfere to give high output and when this occurs the piezoelectric material is being driven in a dilational mode. In this way a transducer possessing a high effective radiating area can be designed for ultrasonic frequencies having wavelengths are of the order of a few millimetres.

According to one aspect of the present invention there is provided an ultrasonic piezoelectric transducer capable of transmitting and receiving ultrasonic vibrations in a dilational mode, comprising a piezoelectric foil operatively associated with means supporting and tensioning said foil wherein: said foil is profiled and tensioned by said means to form three curved segments wherein each curved segment has an opposite sign of curvature to an adjacent curved segment and is not fixed to said means, and wherein said foil is freestanding between each of said segments and is anchored to said means on either side of said three curved segments.

According to another aspect of the present invention there is provided an ultrasonic piezoelectric transducer capable of transmitting and receiving ultrasonic vibrations having a vibrational peak, in the frequency range of 10kHz - 200kHz, comprising a piezoelectric foil operatively associated with means supporting and tensioning said foil wherein: said foil is profiled and tensioned by said means to form three curved segments wherein each curved segment has an opposite sign of curvature to an adjacent curved segment and is not fixed to said means, and wherein said foil is freestanding between each of said segments and is anchored to said means on either side of said three curved segments.

Brief Description of the Drawings

Fig. 1 is an exploded perspective view of an ultrasonic piezoelectric transducer of the invention together with a forming block and cross bar;

Fig. 2 is a block diagram of a circuit for detecting ultrasonic signals using an ultrasonic piezoelectric transducer of the invention;

Fig. 3 is a block diagram of a circuit for transmitting ultrasonic signals using an ultrasonic piezoelectric transducer of the invention;

Fig. 4 is an exploded perspective view of an alternative ultrasonic piezoelectric transducer of the invention;

CLAIMS

1. An ultrasonic piezoelectric transducer capable of transmitting and receiving ultrasonic vibrations in a dilational mode, comprising a piezoelectric foil operatively associated with means supporting and tensioning said foil wherein:

said foil is profiled and tensioned by said means to form three curved segments wherein each curved segment has an opposite sign of curvature to an adjacent curved segment and is not fixed to said means, and wherein

said foil is freestanding between each of said segments and is anchored to said means on either side of said three curved segments.

2. The transducer of claim 1, wherein said transducer is capable of transmitting and receiving ultrasonic vibrations having a vibrational peak, in the frequency range 10kHz - 200kHz.

3. An ultrasonic piezoelectric transducer capable of transmitting and receiving ultrasonic vibrations having a vibrational peak, in the frequency range of 10kHz - 200kHz, comprising a piezoelectric foil operatively associated with means supporting and tensioning said foil wherein:

said foil is profiled and tensioned by said means to form three curved segments wherein each curved segment has an opposite sign of curvature to an adjacent curved segment and is not fixed to said means, and wherein

said foil is freestanding between each of said segments and is anchored to said means on either side of said three curved segments.

4. The transducer of any one of claims 1 to 3, wherein said means includes support posts operatively associated with two of said three curved segments to support said two segments, said two segments being of the same sign of curvature.

5. The transducer of any one of claims 1 to 3, wherein said means includes a support block on which said foil is mounted, said block having support posts operatively associated with two of said three curved segments to support said two segments, said two segments being of the same sign of curvature.

6. The transducer of claim 4 or 5, wherein said support posts are wedge shaped.

7. The transducer of claim 4, wherein said means supporting and tensioning said foil includes a tensioning bar operatively associated with one of said curved segments to tension said one of said curved segments, said one of said segments being of the opposite sign of curvature to said two segments.

8. The transducer of claim 7, wherein said piezoelectric foil is shaped in cross-section as depicted in Fig. 9 of the accompanying drawings, where d_2 is the cross-sectional diameter of said tensioning bar, points A and C are points of anchor of said piezoelectric foil, x is the length of the profile of said piezoelectric foil between points A and C via Point B, d_1 is the distance between points A and C, d_3 is the distance between

the tops of said two curved segments, h_1 is the height of the piezoelectric foil to the top of the left hand curved segment of said two curved segments from a line joining points A and C, h_r is the height of the piezoelectric foil to the top of the right hand curved segment of said two curved segments from a line joining points A and C, h_{21} is the height of the left hand curved segment of said two curved segments and h_{2r} is the height of the right hand curved segment of said two curved segments, and wherein:

$$\begin{aligned} 1.5*d_1 &\leq x \leq 2.3*d_1; \\ 0.5*d_1 &\leq h_r \leq 0.9*d_1; \\ 0.5*d_1 &\leq h_1 \leq 0.9*d_1; \\ 0.1*d_1 &\leq h_{21} \leq 0.2*d_1; \\ 0.1*d_1 &\leq h_{2r} \leq 0.2*d_1; \\ 0.05*d_1 &\leq d_2 \leq 0.2*d_1; \text{ and} \\ 0.6*d_1 &\leq d_3 \leq 0.8*d_1. \end{aligned}$$

9. The transducer of claim 8, wherein:

$d_1 = 10\text{mm}$ and $x, h_r, h_1, h_{21}, h_{2r}, d_2$, and d_3 are within the ranges therefor in claim 8.

10. The transducer of claim 8 wherein:

$$\begin{aligned} d_1 &= 10\text{mm}; \\ x &= 20\text{mm}; \\ h_r &= 7.5\text{mm}; \\ h_1 &= 7.5\text{mm}; \\ h_{21} &= 1.5\text{mm}; \\ h_{2r} &= 1.5\text{mm}; \\ d_2 &= 1.0\text{mm}; \text{ and} \\ d_3 &= 6.9\text{mm}. \end{aligned}$$

11. The transducer of any one of claims 1, 2 or 3, wherein said foil comprises a poled polyvinylidene polymer or a poled copolymer of vinylidene fluoride and trifluoroethylene.

12. The transducer of any one of claims 1, 2 or 3, wherein said foil comprises a poled polyvinylidene polymer foil.

13. The transducer of any one of claims 1, 2 or 3, wherein said foil comprises a poled polyvinylidene polymer foil which is $9\mu\text{m}$ to $35\mu\text{m}$ thick.

14. The transducer of any one of claims 1, 2 or 3, wherein said foil comprises a poled polyvinylidene polymer foil which is $25\mu\text{m}$ thick.

15. The transducer of any one of claims 1, 2 or 3, wherein the width of said foil is $1\text{mm} - 500\text{mm}$.

16. The transducer of any one of claims 1, 2 or 3, wherein the width of said foil is 5mm - 20mm.

17. The transducer of any one of claims 1, 2 or 3, wherein the width of said foil is 10mm.

18. The transducer of any one of claims 1, 2 or 3, wherein said transducer is capable of transmitting and receiving ultrasonic vibrations having a vibrational peak, in the frequency range 80kHz - 120kHz.

19. The transducer of any one of claims 1, 2 or 3, wherein said transducer is capable of transmitting and receiving ultrasonic vibrations having a vibrational peak, in the frequency range 15kHz - 60kHz.

20. The transducer of any one of claims 1, 2 or 3, wherein said transducer is capable of transmitting and receiving ultrasonic vibrations having a vibrational peak, in the frequency range 15kHz - 30kHz.

ULTRASONIC TRANSDUCER

ABSTRACT

Ultrasonic piezoelectric transducer comprising a piezoelectric material (10) having a profile whereby the transducer transmits and/or receives ultrasonic vibrations in a dilational (quasilongitudinal) mode. The profile is curved and includes a point of inflection. Possesses a vibrational peak in the frequency range 10 kHz - 200 kHz. Construction is performed via profiling and tensioning the piezoelectric material.

Fig. 1.