

METHOD OF FORMING A TRANSDUCER

This invention relates to a method of forming a transducer.

The present application is a divisional of UK Patent Application No. 88 22903.4.

There are a number of useful measurement applications that are conveniently achieved by sending and receiving ultrasonic signals in gases in the frequency range between 100KHz and 1MHz or above. At these high frequencies, the conventional construction of sound transducers employed at lower frequencies (e.g. audio frequencies) is impractical as the overall dimensions become very small.

The normal method of making high frequency ultrasonic transducers is to use a selected piece of piezo ceramic (e.g. Lead Zirconate Titanate or PZT) resonant at the required frequency. PZT is a hard, dense material of high acoustic impedance (approximately 3×10^7 in MKS units), while gases have very low acoustic impedance (of the order of 400 in the same units). PZT on its own gives very poor electro acoustic efficiency due to the large acoustic mismatch, even though this is improved somewhat by resonant operation.

Typically, the piezo ceramic element is a cylinder, whose circular end faces move in a piston-like manner in response to electrical stimulation of electrodes applied to these faces.

The normal method for reducing the acoustic mismatch to gases is to apply an acoustic matching layer to the selected operational face of the PZT disc. This layer is a material of relatively low acoustic impedance whose thickness is one quarter of an acoustic wave length in the material at the chosen frequency of operation. This dimension results in a resonant action whereby (for sending) the small movements obtained at the face of the PZT cylinder are magnified considerably, and acceptable (though still not high) efficiency can be obtained. Criteria for acoustic-electric conversion (i.e. receiving) are the same as for electro-acoustic conversion (i.e. sending) and the same transducer may be used for both.

The efficiency attainable by this technique is limited entirely by the characteristics of available materials. An ideal material would have an acoustic impedance of the order of 10^5 and very low internal losses, and also must be stable, repeatable and practical for use. There are no hitherto known materials that meet all these criteria. Some common approximations to the ideal requirements are:

1. **Silicone elastomers.** This class of materials is commonly used and gives useful performance in many applications. Acoustic losses are low. Acoustic impedances down to about 7×10^5 can be attained. A significant drawback with these materials is a large variation of acoustic wavelength with temperature (typically 0.3%/K). This

factor limits the range of operating techniques over which correct resonant matching is obtained.

2. Polymers generally. Many polymers give useful performance. Acoustic impedance is higher than for silicones down to 1.5×10^6 so overall efficiencies are lower, but reasonably stable materials can be found.
3. Liquids and gases. Examples in the literature may be found of the experimental use of multiple acoustic matching layers. Liquids have generally very low losses and acoustic impedances down to about 10^6 . If a gas is compressed, its acoustic impedance rises directly with the compression ratio, and a captive volume of liquid or highly compressed, dense gas may be used as an acoustic matching layer. Such techniques are not practical for commercial application.

According to the invention there is provided a method of forming a transducer comprising the steps of forming an acoustic matching member from a material in which a plurality of voids have been introduced by foaming the material in a molten state and casting the foamed material in a mould, the velocity of sound in the voided material being substantially less than that for the unvoided material in the direction of sound propagation of the matching member and affixing the member to a piezo element.

Such voids are preferably formed by foaming molten material with a gas.

An embodiment of the invention will now be described by way of example with reference to the accompanying drawing which shows a PZT cylinder (1) with electrical connecting wires (2), to which a matching layer (3) is affixed. The direction of sound emission is indicated by arrow (4).

Bulk acoustic impedance is the product of density and bulk acoustic velocity. Acoustic velocity in turn is a function of bulk elastic modulus. These parameters may be artificially adapted in an otherwise unsuitable material to create a material with substantially improved characteristics. A preferred starting material is C-glass (soda-lime-borosilicate glass) which is stable and low loss, but has a very high acoustic impedance. The material can also be easily formed when heated and has a predictable degree of softening with temperature. By arranging for the glass to be formed into a sponge structure with a very high proportion of voids, acoustic impedances down to 3×10^5 have been experimentally obtained.

Glass is readily available in the form of glass bubbles (hollow microspheres), used in diverse commercial applications such as syntactic foams and car body fillers and manufactured, for example, by Minnesota Mining and Manufacturing Company Inc. under the trade name 3M glass bubbles.

A very light glass sponge structure is easily achieved by heating the glass bubbles in a mould to a temperature where the glass is soft, and compressing by a specific volumetric ratio to join the bubbles together.

Acceptable processing conditions are, for example, at a temperature of 650°C approx. and a volumetric ratio of 1.5 to 2.5 to 1. With a suitable mould, the finished piece (2) is produced that may be applied to the PZT cylinder (1) without further adjustment.

For a given specification of glass bubbles and compression ratio, a repeatable result is obtained. For example glass bubbles with a starting density of 1.25g/cm³, compressed at a volumetric ratio of 2:1 produce a material having a propagation velocity (velocity of propagation of longitudinal bulk waves) of approximately 900m/s, compared with 5-600m/s for unvoided glass ($\rho = 2.5$) which has an acoustic impedance of approximately 14×10^6 .

The resultant voided material also exhibits practically no variation in acoustic wavelength or bulk elastic modulus with temperature over the range of ambient temperatures.

As much of the material structure is formed by the voids between bubbles which communicate with the external surfaces (i.e. not "closed cell"), it is usually necessary to seal the material surface against ingress of moisture etc. This can be

achieved in various ways without seriously impairing the acoustic performance - for instance a thin layer of silicone elastomer on a thin layer of low melting point glass is satisfactory.

While, in the preferred embodiment described above, the material used is G-glass, this is not to be construed as limitative and another glass or other non-crystalline material may be used.

Alternatively, a synthetic plastic material, for example a plastics resin or a metal, for example aluminium or titanium, may be employed. With resin, similar temperature dependent effects to those mentioned in the introduction will occur, although the invention does allow the velocity of sound propagation in the material to be adjusted. Furthermore, other methods of forming the acoustic matching member may be used, for example, by foaming the material to provide the necessary voids, these methods being particularly applicable for use with the plastics and metals mentioned above.

The matter contained on page 4, lines 8 to 25, page 5 and page 6, lines 1 to 8 is provided merely to facilitate understanding of the invention. The matter in question is found in our parent UK patent application No. 8822903.4 and forms the basis of the claims of that application but does not in any way form a basis for the claim of the present application.



7.

CLAIMS

1. A method of forming a transducer comprising the steps of forming an acoustic matching member from a material in which a plurality of voids have been introduced by foaming the material in a molten state and casting the foamed material in a mould, the velocity of sound in the voided material being substantially less than that for the unvoided material in the direction of sound propagation of the matching member and affixing the member to a piezo member.
-