APPLICATION ACCEPTED AND AMENDMENTS
ALLOWED 27.11.90

607085

FORM 1
REGULATION 9

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952-1973

APPLICATION FOR A PATENT

We BRITISH GAS plc.

of Rivermill House, 152 Grosvenor Road, LONDON SW1V 3JL, ENGLAND

hereby apply for the grant of a Patent for an invention entitled:

A MATCHING MEMBER

which is described in the accompanying complete specification. This Application is a Convention Application and is based on the Application numbered: 88 22903.4 for a Patent or similar protection made in United Kingdom on 29 September 1988.

Our address for service is:

GRIFFITH HACK & CO.
71 YORK STREET
SYDNEY N.S.W. 2000
AUSTRALIA

DATED this 26th day of September 1989

BRITISH GAS plc.
By their Patent Attorneys

J.H. Abel

GRIFFITH HACK & CO.

TO: THE COMMISSIONER OF PATENTS
COMMONWEALTH OF AUSTRALIA

S010392 26/09/89

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AUSTRALIA

PATENTS ACT 1952

B

APPLICATION BY ASSIGNEE OF INVENTOR

DECLARATION IN SUPPORT OF AN APPLICATION FOR A PATENT

NAME OF APPLICANT

In support of an application made by:
British Gas plc

TITLE

for a patent for an invention entitled:
A Matching Member

FULL NAME AND ADDRESS OF SIGNATORY

I, Walter Wallace
of Sherwood Cottage, Dunsumer Hill, Didcot, Oxfordshire, England

do solemnly and sincerely declare as follows:

1. I am authorised by the above mentioned applicant for the patent to make this declaration on its behalf.

FULL NAME AND ADDRESS OF INVENTOR(S)

2. The name and address of each actual inventor of the invention is as follows:
Michael John Gill, The Willows, Lymore Valley, Milford on Sea Hampshire SO4 OTW England

SEE NOTES OVER

3. The facts upon which the applicant is entitled to make this application are as follows:
By virtue of an assignment between the applicant and the inventor for the said invention

DELETE PARAGRAPHS 3 AND 4 FOR NON-CONVENTION APPLICATION

4. The basic application(s) as defined by Section 141 of the Act was (were) made as follows:

Country UK on 29 September 1988

in the name(s) Michael John Gill

and in on

in the name(s)

PLACE AND DATE OF SIGNING

5. The basic application(s) referred to in the preceding paragraph was (were) the first application(s) made in a Convention country in respect of the invention the subject of this application.

Declared at London, England

this 8th day of September 19 89

Signed W Wallace

Position W. Wallace, Head, Patents, Licensing & Commercial Development

(12) PATENT ABRIDGMENT (11) Document No. AU-B-42329/89
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 607085

(54) Title
A MATCHING MEMBER

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(56) Prior Art Documents
AU 58004/86 H04R 17/00
EP 119855

(57) Claim

1. An acoustic matching member for a transducer, the member comprising a matrix of hollow spheres of a non-crystalline material in which adjoining spheres are bonded together at their points of contact but otherwise voids are left between the spheres.

3. A member as claimed in claim 1 or claim 2 in which the glass is C-glass.

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COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952 Form 10

COMPLETE SPECIFICATION

FOR OFFICE USE

Short Title:

Int. Cl:

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Complete Specification-Lodged:
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Priority:

This document contains the amendments made under Section 49 and is correct for printing.

Related Art:

TO BE COMPLETED BY APPLICANT

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Actual Inventor: Michael John Gill

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Complete Specification for the invention entitled:

A MATCHING MEMBER

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

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A matching member

This invention relates to a transducer and more particularly to an acoustic matching member therefor.

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 (eg 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 (eg 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 now high) efficiency can be obtained. Criteria for acoustic-electric conversion (ie receiving) are the same as for electro-acoustic conversion (ie 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 x 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 temperatures over which correct reasonant 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 in a first aspect there is provided an acoustic matching member for a transducer, the member comprising a material having a plurality of voids formed therein, the velocity of sound in the voided material in the direction of sound propagation of the member being substantially less than that for unvoided said material.

According to the invention in a second aspect, there is provided a method of forming an acoustic matching member for a transducer comprising the steps of forming the member from a material in which a plurality of voids have been introduced whereby the velocity of sound in the voided material is substantially less than that of the unvoided material in the direction of sound propagation of the member.

Such voids are preferably formed by compressing hollow microspheres under the application of heat to form an "aerated" material structure or 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 artifically 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 0.25g/cm^3, 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 5-6000m/s for unvoided glass. This gives an acoustic impedance of 4.5×10^5 compared with unvoided glass (ρ = 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 (ie. 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 imparing the acoustic performance - for instance a thin layer of silicone elastomer or a thin layer of low melting point glass is satisfactory.

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

Alternatively, a synthetics 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 CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS

1. An acoustic matching member for a transducer, the member comprising a matrix of hollow spheres of a non-crystalline material in which adjoining spheres are bonded together at their points of contact but otherwise voids are left between the spheres.

2. A member as claimed in claim 1 in which the material is glass.

3. A member as claimed in claim 1 or claim 2 in which the glass is C-glass.

4. A member as claimed in any one of claims 1 to 3 in which the bulk elastic modulus of the material remains substantially constant with respect to the normal range of ambient temperatures.

5. A member as claimed in any one of the preceding claims in which the member comprises a moisture sealing layer enclosing the material.

6. A member as claimed in claim 5 in which the sealing layer comprises a silicone elastomer.

7. A member as claimed in claim 5 or claim 6 in which the sealing layer comprises a layer of glass.

8. A method of forming an acoustic matching member for a transducer, the method comprising bonding together adjoining spheres in a matrix of hollow spheres of a non-crystalline material at the points of contact of the spheres in such a way that otherwise there are voids left between the spheres.

9. A method as claimed in claim 8 in which the non-crystalline material is glass.

10. A method as claimed in claim 9 in which the glass is C-glass.

11. An acoustic matching member substantially as hereinbefore described with reference to the accompanying drawing.

12. A method of forming an acoustic matching member substantially as hereinbefore described with reference to the accompanying drawing.

13. An assembly comprising a transducer to which is affixed an acoustic matching member as claimed in any of claims 1 to 7 and 11.

14. An assembly substantially as hereinbefore described with reference to the drawing.

DATED this 9th day of NOVEMBER 1990

BRITISH GAS plc
By their Patent Attorneys
GRIFFITH HACK & CO.

42329/89