CLAIMS

1. An apparatus for acoustically determining a property of a test medium, comprising:

a chamber for containment of a test medium, said chamber having at least a first side and an inlet for said test medium;

a first acoustical transformer operatively coupled with the first side of said chamber and configured to at least one of transmit and receive a pulse of acoustical energy with respect to said test medium; and

an acoustical element operatively coupled with said first acoustical transformer,

wherein said first acoustical transformer includes:

a base matching section, a first surface of said base matching section being in contact with said acoustical element;

a last matching section operatively coupled with said base matching section and having an exposed face adapted for contact with said test medium, said last matching section including a protective barrier having a first predetermined thickness disposed on a low impedance layer having a second predetermined thickness to form at least part of said exposed face, wherein the first and second predetermined thickness cooperatively reduce distortion of said at least one of transmission and receipt of said pulse of acoustical energy by tailoring a resonance frequency of said last matching section, such that the highest resonance frequency is limited to below $1.2f_C$ and the lowest resonance frequency is limited to above $0.8f_C$, wherein f_C is the center operating frequency.

2. The apparatus of claim 1, wherein said low impedance layer of said first acoustical transformer is in contact with a second surface of said base matching section, said second surface of said base matching section being opposite said first surface of said base matching section.

3. The apparatus of claim 1, wherein said acoustical element is an acoustical transmitter and said first acoustical transformer is configured to transmit said pulse of acoustical energy into said test medium.

4. The apparatus of claim 3, further comprising:

a second acoustical transformer operatively coupled with a second side of said chamber and configured to receive a pulse of acoustical energy transmitted through said test medium; and

an acoustical sensor operatively coupled with said second acoustical transformer,

wherein said second acoustical transformer includes:

a base matching section having a first surface in contact with said acoustical sensor; and

a last matching section operatively coupled with said base matching section of said second acoustical transformer and having an exposed face adapted for contact with said test medium, said last matching section including a protective barrier disposed on a low impedance layer to form at least part of said exposed face.

5. The apparatus of claim 4, wherein said low impedance layer of said second acoustical transformer is disposed on a second surface of said base matching section of said second acoustical transformer, said second surface of said base matching section of said second

acoustical transformer being opposite said first surface of said base matching section of said second acoustical transformer.

6. The apparatus of claim 5, wherein said second acoustical transformer is disposed on said second side of said chamber, said second side of said chamber being parallel to said first side of said chamber.

7. The apparatus of claim 1, wherein said protective barrier is a composite of a plurality of successive metal layers.

8. The apparatus of claim 1, wherein said low impedance layer comprises a polyimide.

9. The apparatus of claim 1, wherein said acoustical element is bi-directional and configured to transmit acoustical energy and receive acoustical energy.

10. The apparatus of claim 1, wherein said test medium is a gas.

11. The apparatus of claim 1, wherein said protective barrier comprises a material that has a carbon dioxide permeability that is less than 700 $mL/m^2 \cdot 24h \cdot MPa$ over a hypothetical thickness of 25 μm.

12. The apparatus of claim 11, wherein said low impedance layer is polyimide and said protective barrier comprises a fluoropolymer.

13. The apparatus of claim 1, wherein said low impedance layer has a modulus of elasticity that varies less than 50% over a range from 0 ºC to 400 ºC.

14. The apparatus of claim 1, wherein said acoustical element is constructed of a piezoceramic material.

15. The apparatus of claim 1, wherein said protective barrier comprises a metal.

16. A method for constructing apparatus for acoustically determining a property of a test medium, the method comprising:

establishing a predetermined thickness of a protective barrier of a last matching section of an acoustical transformer, said protective barrier being of a low permeability material for exposure to a test medium;

determining a thickness of a base matching section of said acoustical transformer for operative coupling with said last matching section of said acoustical transformer;

determining a thickness of a low impedance layer of said last matching section of said acoustical transformer for contact with said protective barrier, said thickness of said low impedance layer being selected to theoretically provide said acoustical transformer with resonance frequencies that fall within a predetermined frequency range; and

constructing said acoustical transformer having said base matching section and said last matching section, said protective barrier having said predetermined thickness, said low impedance layer having said thickness of said low impedance layer, and said base

matching section having said thickness of said base matching section, wherein said protective barrier predetermined thickness and said low impedance layer thickness cooperatively reduce distortion of at least one of transmission and receipt of a pulse of acoustical energy by tailoring a response frequency of said last matching section such that the highest resonance frequency is limited to below $1.2f_c$ and the lowest resonance frequency is limited to above $0.8f_c$, wherein f_c is the center operating frequency.

17. The method of claim 16, wherein said protective barrier in the step of establishing said predetermined thickness of said protective barrier is metallic.

18. The method of claim 16, wherein said predetermined thickness in the step of establishing said predetermined thickness of said protective barrier is 0.05λ or less, where $\lambda = C/f_C$, C being the speed of sound in the material of said protective barrier, and f_C being a desired center operating frequency.

19. The method of claim 18, wherein said predetermined thickness of said protective barrier is 0.01λ or less.

20. The method of claim 16, wherein said predetermined frequency range in the step of determining said thickness of said low impedance layer is $0.75 \cdot f_C$ to $1.25 \cdot f_C$, where f_C is a desired center operating frequency.

21. The method of claim 20, wherein said a lowest predicted resonance frequency is proximate $0.8 \cdot f_C$ and a highest predicted resonance frequency is proximate $1.2 \cdot f_C$.

22. The method of claim 16, wherein said low impedance layer in the step of determining said thickness of said low impedance layer is polyimide.

23. The method of claim 16, wherein said test medium in the step of establishing said predetermined thickness of said protective barrier is a gas.

24. The method of claim 16, wherein said base matching section in the step of determining said thickness of said base matching section is in physical contact with said last matching section of said acoustical transformer.

25. The method of claim 16, wherein said acoustical transformer is a transmitting acoustical transformer.

26. The method of claim 25, further comprising:

establishing a predetermined thickness of a protective barrier of a last matching section of a receiving acoustical transformer, said protective barrier of said receiving acoustical transformer being of a low permeability material for exposure to said test medium;

determining a thickness of a base matching section of said receiving acoustical transformer for operative coupling with said last matching section of said acoustical transformer; and

determining a thickness of a low impedance layer of said last matching section of said receiving acoustical transformer for contact with said protective barrier of said receiving acoustical transformer,

wherein said thicknesses of said low impedance layer of said transmitting acoustical transformer and said low impedance layer of said receiving acoustical transformer are selected to theoretically provide both said transmitting acoustical transformer and said receiving acoustical transformers with resonance frequencies that fall within a predetermined frequency range.

27. An apparatus for determining a property of a test medium, the apparatus having an acoustical transformer with a last matching section including a low impedance layer and a protective barrier, said protective barrier being arranged for contact with a test medium, the acoustical transformer being prepared by a process comprising:

providing a low impedance layer having a first surface and a second surface separated by a predetermined thickness;

disposing a protective barrier on said second surface of said low impedance layer, said protective barrier being of a predetermined thickness, wherein said protective barrier predetermined thickness and said low impedance layer predetermined thickness cooperatively reduce distortion of at least one of transmission and receipt of a pulse of acoustical energy by tailoring a response frequency of said last matching section such that the highest resonance frequency is limited to below $1.2f_c$ and the lowest resonance frequency is limited to above $0.8f_c$, wherein f_c is the center operating frequency;

providing a base matching section having a first surface and a second surface separated by a predetermined thickness;

operatively coupling said first surface of said low impedance layer to said second surface of said base matching section; and

attaching one of an acoustical sensor and an acoustical driver to said first surface of said base matching section.

CLAIMS

1. An apparatus for acoustically determining a property of a test medium, comprising:

a chamber for containment of a test medium, said chamber having at least a first side and an inlet for said test medium;

a first acoustical transformer operatively coupled with the first side of said chamber and configured to at least one of transmit and receive a pulse of acoustical energy with respect to said test medium; and

an acoustical element operatively coupled with said first acoustical transformer,

wherein said first acoustical transformer includes:

a base matching section, a first surface of said base matching section being in contact with said acoustical element;

a last matching section operatively coupled with said base matching section and having an exposed face adapted for contact with said test medium, said last matching section including a protective barrier having a first predetermined thickness disposed on a low impedance layer having a second predetermined thickness to form at least part of said exposed face, wherein the first and second predetermined thicknesses are configured to cooperate to produce a predicted transfer function of the apparatus that is within 70% of a predicted transfer function of an apparatus without a protective barrier, and tailor a resonance frequency of said last matching section, such that the highest resonance frequency is limited to below $1.2f_C$ and the lowest resonance frequency is limited to above $0.8f_C$, wherein f_C is the center operating frequency, thereby reducing drift of the first acoustical transformer over time by inhibiting an accrual of a portion of the test medium on the last matching

section, while reducing distortion of the at least one of transmitting and receiving of the pulse of acoustical energy caused by the protective barrier.

2. The apparatus of claim 1, wherein said low impedance layer of said first acoustical transformer is in contact with a second surface of said base matching section, said second surface of said base matching section being opposite said first surface of said base matching section.

3. The apparatus of claim 1, wherein said acoustical element is an acoustical transmitter and said first acoustical transformer is configured to transmit said pulse of acoustical energy into said test medium.

4. The apparatus of claim 3, further comprising:

a second acoustical transformer operatively coupled with a second side of said chamber and configured to receive a pulse of acoustical energy transmitted through said test medium; and

an acoustical sensor operatively coupled with said second acoustical transformer,

wherein said second acoustical transformer includes:

a base matching section having a first surface in contact with said acoustical sensor; and

a last matching section operatively coupled with said base matching section of said second acoustical transformer and having an exposed face adapted for contact with said test medium, said last matching section including a protective barrier disposed on a low impedance layer to form at least part of said exposed face.

5. The apparatus of claim 4, wherein said low impedance layer of said second acoustical transformer is disposed on a second surface of said base matching section of said second acoustical transformer, said second surface of said base matching section of said second acoustical transformer being opposite said first surface of said base matching section of said second acoustical transformer.

6. The apparatus of claim 5, wherein said second acoustical transformer is disposed on said second side of said chamber, said second side of said chamber being parallel to said first side of said chamber.

7. The apparatus of claim 1, wherein said protective barrier is a composite of a plurality of successive metal layers.

8. The apparatus of claim 1, wherein said low impedance layer comprises a polyimide.

9. The apparatus of claim 1, wherein said acoustical element is bi-directional and configured to transmit acoustical energy and receive acoustical energy.

10. The apparatus of claim 1, wherein said test medium is a gas.

11. The apparatus of claim 1, wherein said protective barrier comprises a material that has a carbon dioxide permeability that is less than 700 $mL/m^2 \cdot 24h \cdot MPa$ over a hypothetical thickness of 25 μm.

12. The apparatus of claim 11, wherein said low impedance layer is polyimide and said protective barrier comprises a fluoropolymer.

13. The apparatus of claim 1, wherein said low impedance layer has a modulus of elasticity that varies less than 50% over a range from 0 ºC to 400 ºC.

14. The apparatus of claim 1, wherein said acoustical element is constructed of a piezoceramic material.

15. The apparatus of claim 1, wherein said protective barrier comprises a metal.

16. A method for constructing apparatus for acoustically determining a property of a test medium, the method comprising:

establishing a predetermined thickness of a protective barrier of a last matching section of an acoustical transformer, said protective barrier being of a low permeability material for exposure to a test medium;

determining a thickness of a base matching section of said acoustical transformer for operative coupling with said last matching section of said acoustical transformer;

determining a thickness of a low impedance layer of said last matching section of said acoustical transformer for contact with said protective barrier, said thickness of said low impedance layer being selected to theoretically provide said acoustical transformer with resonance frequencies that fall within a predetermined frequency range; and

constructing said acoustical transformer having said base matching section and said last matching section, said protective barrier having said predetermined thickness, said low impedance layer having said thickness of said low impedance layer, and said base matching section having said thickness of said base matching section, wherein said protective barrier predetermined thickness and said low impedance layer thickness are configured to cooperate to produce a predicted transfer function of the apparatus that is within 70% of a predicted transfer function of an apparatus without a protective barrier, and tailor a response frequency of said last matching section such that the highest resonance frequency is limited to below $1.2f_c$ and the lowest resonance frequency is limited to above $0.8f_c$, wherein f_c is the center operating frequency, thereby reducing drift of the first acoustical transformer over time by inhibiting an accrual of a portion of the test medium on the last matching section, while reducing distortion of the at least one of transmitting and receiving of the pulse of acoustical energy caused by the protective barrier.

17. The method of claim 16, wherein said protective barrier in the step of establishing said predetermined thickness of said protective barrier is metallic.

18. The method of claim 16, wherein said predetermined thickness in the step of establishing said predetermined thickness of said protective barrier is 0.05λ or less, where $\lambda = C/f_C$, C being the speed of sound in the material of said protective barrier, and f_C being a desired center operating frequency.

19. The method of claim 18, wherein said predetermined thickness of said protective barrier is 0.01λ or less.

20. The method of claim 16, wherein said predetermined frequency range in the step of determining said thickness of said low impedance layer is $0.75 \cdot f_C$ to $1.25 \cdot f_C$, where f_C is a desired center operating frequency.

21. The method of claim 20, wherein said a lowest predicted resonance frequency is proximate $0.8 \cdot f_C$ and a highest predicted resonance frequency is proximate $1.2 \cdot f_C$.

22. The method of claim 16, wherein said low impedance layer in the step of determining said thickness of said low impedance layer is polyimide.

23. The method of claim 16, wherein said test medium in the step of establishing said predetermined thickness of said protective barrier is a gas.

24. The method of claim 16, wherein said base matching section in the step of determining said thickness of said base matching section is in physical contact with said last matching section of said acoustical transformer.

25. The method of claim 16, wherein said acoustical transformer is a transmitting acoustical transformer.

26. The method of claim 25, further comprising:

establishing a predetermined thickness of a protective barrier of a last matching section of a receiving acoustical transformer, said protective barrier of said receiving acoustical transformer being of a low permeability material for exposure to said test medium;

determining a thickness of a base matching section of said receiving acoustical transformer for operative coupling with said last matching section of said acoustical transformer; and

determining a thickness of a low impedance layer of said last matching section of said receiving acoustical transformer for contact with said protective barrier of said receiving acoustical transformer,

wherein said thicknesses of said low impedance layer of said transmitting acoustical transformer and said low impedance layer of said receiving acoustical transformer are selected to theoretically provide both said transmitting acoustical transformer and said receiving acoustical transformers with resonance frequencies that fall within a predetermined frequency range.

27. An apparatus for determining a property of a test medium, the apparatus having an acoustical transformer with a last matching section including a low impedance layer and a protective barrier, said protective barrier being arranged for contact with a test medium, the acoustical transformer being prepared by a process comprising:

providing a low impedance layer having a first surface and a second surface separated by a predetermined thickness;

disposing a protective barrier on said second surface of said low impedance layer, said protective barrier being of a predetermined thickness, wherein said protective barrier

predetermined thickness and said low impedance layer predetermined thickness are configured to cooperate to produce a predicted transfer function of the apparatus that is within 70% of a predicted transfer function of an apparatus without a protective barrier, and tailor a response frequency of said last matching section such that the highest resonance frequency is limited to below $1.2f_c$ and the lowest resonance frequency is limited to above $0.8f_c$, wherein f_c is the center operating frequency, thereby reducing drift of the first acoustical transformer over time by inhibiting an accrual of a portion of the test medium on the last matching section, while reducing distortion of the at least one of transmitting and receiving of the pulse of acoustical energy caused by the protective barrier;

providing a base matching section having a first surface and a second surface separated by a predetermined thickness;

operatively coupling said first surface of said low impedance layer to said second surface of said base matching section; and

attaching one of an acoustical sensor and an acoustical driver to said first surface of said base matching section.