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(54) **ELASTOGRAPHY DEVICE AND METHOD**

(75) Inventors: **Laurent Sandrin**, L'Hay les Roses (FR); **Matteo Bosisio**, Paris (FR); **Cécile Bastard**, Paris (FR)

(73) Assignee: **ECHOSSENS**, Paris (FR)

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(58) **Field of Classification Search**

None  
See application file for complete search history.

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*Primary Examiner* — Long V Le

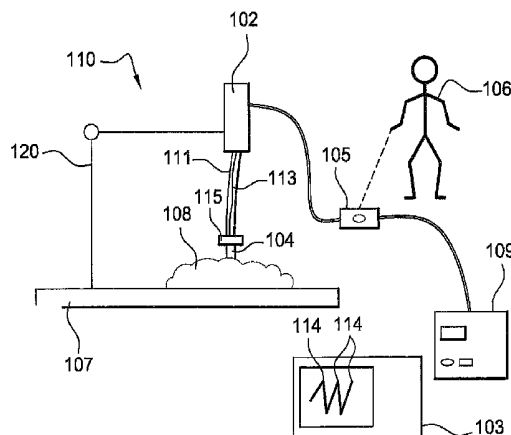
*Assistant Examiner* — Bradley Impink

(74) *Attorney, Agent, or Firm* — Pillsbury Winthrop Shaw Pittman LLP

(57) **ABSTRACT**

An elastography device for quantitatively and/or qualitatively measuring the viscoelastic properties of any medium, includes a deformable tube for positioning the ultrasonic transducer located at the end of the deformable tube and for holding it so as to ensure, during at least one measurement, perpendicularity and contact between the ultrasonic transducer and the medium.

**19 Claims, 2 Drawing Sheets**



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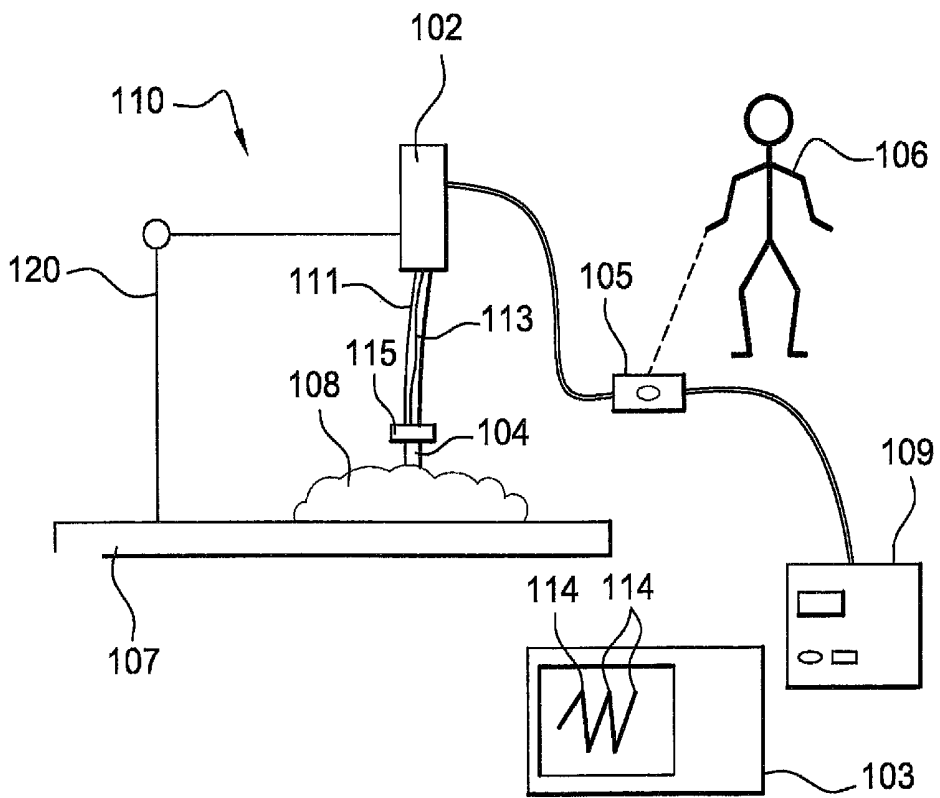
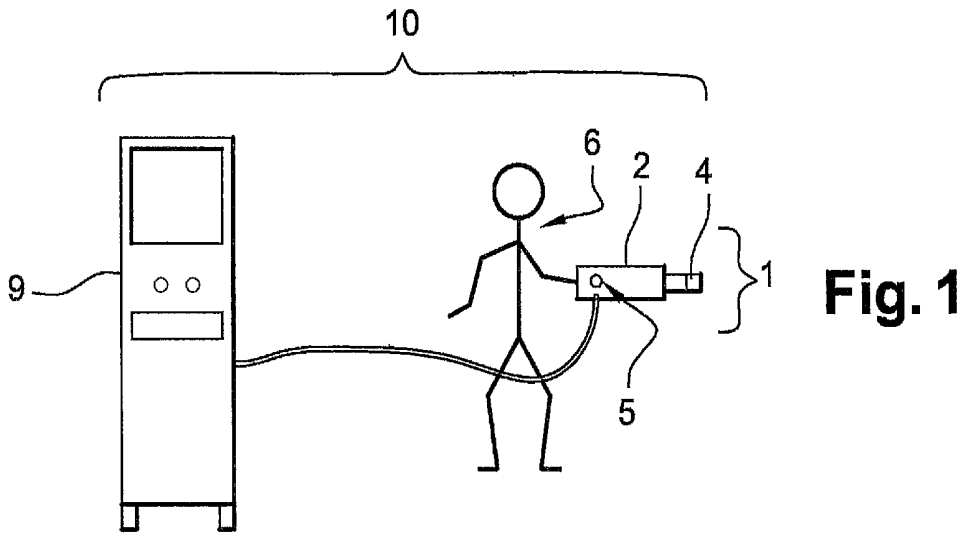


Fig. 2

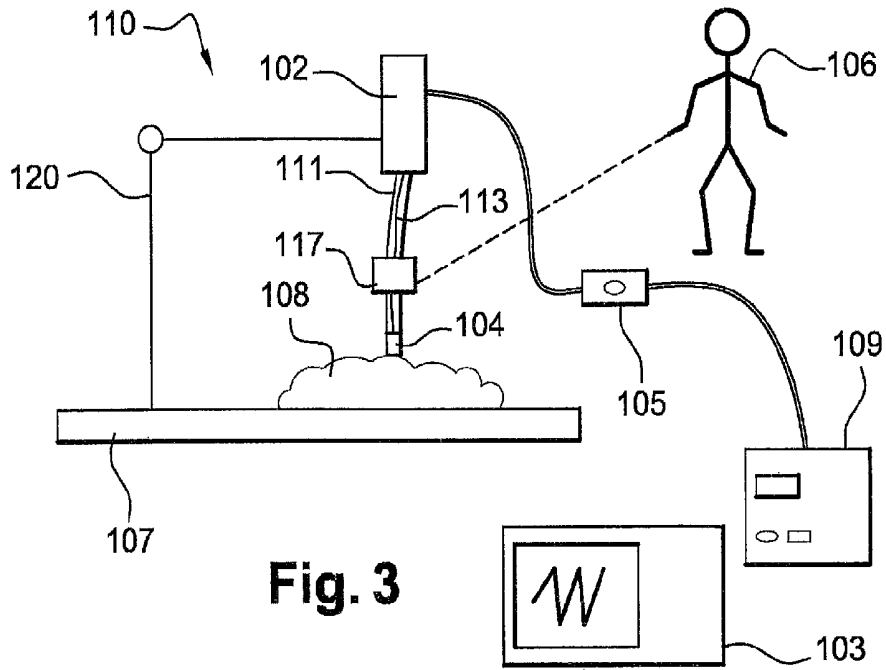


Fig. 3

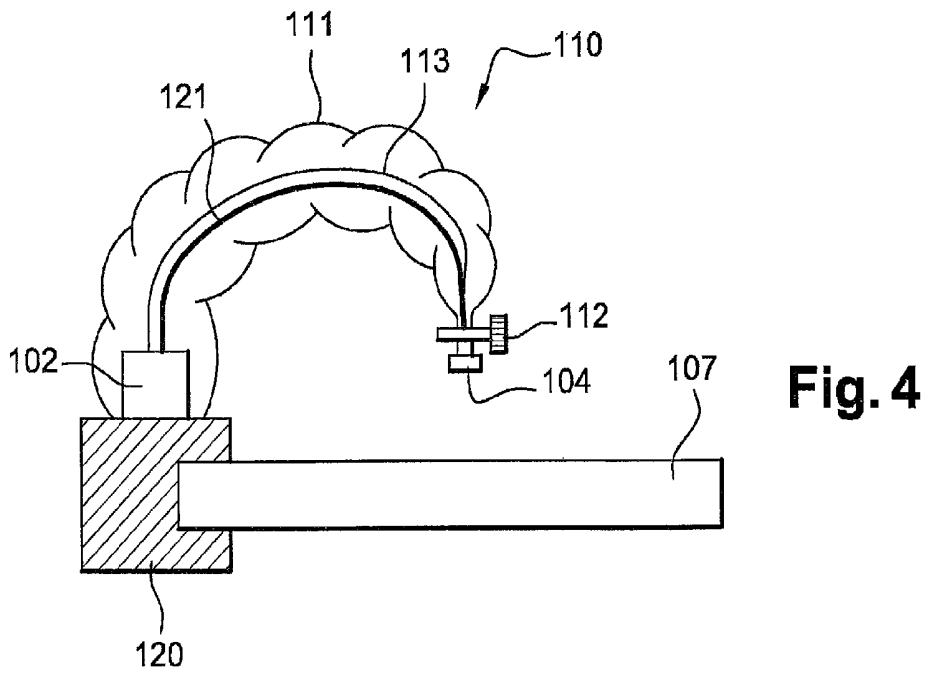


Fig. 4

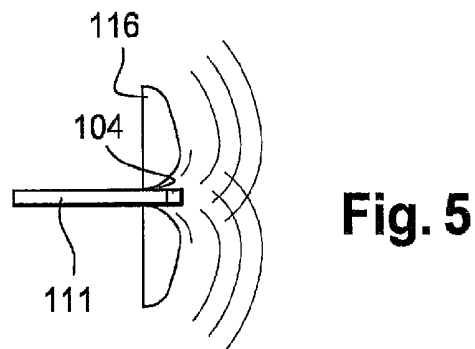


Fig. 5

## ELASTOGRAPHY DEVICE AND METHOD

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is the U.S. National Stage of PCT/FR2009/052373, filed Dec. 2, 2009, which in turn claims priority to French Patent application No. 0858278, filed Dec. 4, 2008, the entire Contents of all applications are incorporated herein by reference in their entireties.

The present invention relates to a device and a method for measuring the viscoelastic properties of any medium.

The present invention more particularly relates to a device and a method for quantitatively and/or qualitatively measuring the viscoelastic properties; such as the elasticity and/or the viscosity of a human or animal biological tissue. More specifically, such a device and such a method are suitable for measuring the viscoelastic properties of biological tissues belonging to laboratory animals or from tissue sample.

In order to measure the tissue viscoelastic properties, it is known to use the pulsed elastography, as described, for example, in patent application number FR 2843290.

This document presents an implementation of a device **10** according to the prior art (FIG. **1**). This device **10** comprises a probe **1** equipped with a vibration generator **2** generating a low-frequency elastic wave in a tissue, for example by vibration, and analyzing the propagation of this low-frequency elastic wave by means of high-frequency ultrasonic waves emitted and received by an ultrasonic transducer **4** during the propagation of the low-frequency elastic wave.

In addition, it should be noted that the user **6** positions said probe **1** manually to ensure permanent contact between the tissue and the ultrasonic transducer **4**. Said probe **1**, having the vibration generator **2** and the ultrasonic transducer **4**, also includes a trigger **5** for controlling them. The whole is connected to a computer **9**.

Such a device is suitable for measuring the viscoelastic properties of large-size organs, for example the human liver, located in the vicinity of the epidermis against which the probe **1** is positioned.

Yet, such a device has drawbacks. In particular, it is not suitable for small-sized organs. In fact, the probe generates a tissue compression when affixed or even positioned in the vicinity or in contact with the organ (the smaller the volume of the tissue is, the higher the compression phenomenon is).

In addition, such a device is not suitable for small organs because the size of the ultrasonic transducer is very significant and the probe is approximately and randomly positioned.

An example of this is the mouse, whose epidermis surface allowing access to the liver is about 1 cm<sup>2</sup>. This dimensional limitation does not allow the user to ensure an optimal positioning which depends not only on the size of the tissue but also on the differences between individuals and/or between species.

An additional drawback is that the user has to manually hold, on the one hand, a constant and satisfactory contact between the ultrasonic transducer and the epidermis so that the ultrasounds are capable of propagating and, on the other hand, an optimal perpendicularity.

Yet, to trigger low-frequency elastic waves, the user presses the trigger **5** which brings about variations in terms of contact between the probe and the epidermis, distorting thus the perpendicularity and, de facto, leading to an overestimation of measurements close to the ultrasonic transducer.

In addition, such a movement raises problems of repeatability of the measurements. Indeed, once the position of the ultrasonic transducer has been modified, it is impossible to

position again the ultrasonic transducer at exactly the same location where the first measurements have been made. This is very detrimental for measurements that are carried out on heterogeneous tissues, such as, for example, the kidney.

Furthermore, an overestimation of the measured elasticity, due, inter alia, to a diffraction phenomenon in the field close to the low-frequency wave generation source, occurs over a thickness which depends, in particular, on the dimensions of this source, on the viscoelastic properties, on the medium, on the thickness of the fat layer, as well as on the low-frequency elastic wave.

This thickness, below which measurements are not possible, is about 20 mm for a center frequency  $f$  of the low-frequency elastic wave of 50 Hz. To remedy this problem, data on this thickness are disregarded, namely 20 mm, in the calculation of the viscoelastic properties, thereby prohibiting measurements on a thickness less than 20 mm.

In this context, the aim of the invention is to provide a non-invasive device making it possible to overcome the above problems by proposing a device whereby it is possible to precisely hold and position, perpendicularly to and in contact with the tissue, an ultrasonic transducer so as to determine the viscoelastic properties thereof.

Such a device is also advantageous thanks to its design, and though it requires further knowledge and numerous developments, offers an easy to use and noninvasive device of which cost is low.

To this end, the invention provides an elastography device for quantitatively and/or qualitatively measuring the viscoelastic properties of any medium, said device comprising:

- a vibration generator for generating at least one low-frequency elastic wave;
- an ultrasonic transducer for observing the propagation of said at least one low-frequency elastic wave;
- a trigger for triggering at least one measurement;
- said at least one measurement comprising the following steps of:

- generating at least one low-frequency elastic wave in a medium;
- emitting and acquiring simultaneously to the generation of at least one low-frequency elastic wave high-frequency ultrasounds using said ultrasonic transducer to observe the propagation of said at least one low-frequency elastic wave;

said device being characterized in that it comprises a deformable tube, positioned between said vibration generator and said ultrasonic transducer, for holding said ultrasonic transducer located at the end of said deformable tube and for holding it so as to ensure, during at least one measurement, perpendicularity and contact between said ultrasonic transducer and the medium.

What is meant by deformable tube is a tube freely movable in several directions, with no angular limitation, and which holds its position in the absence of any stress applied to move it.

The medium is interchangeably referred to as tissue.

Besides the main characteristics which have been mentioned in the previous paragraph, the device according to the invention may have one or more additional characteristics listed below, whether considered individually or in all technically possible combinations:

- said elastography device includes a support spatially hold the ultrasonic transducer;
- said elastography device includes a spring system located between said ultrasonic transducer and said deformable tube;

said device includes at least one rod capable of transmitting the low-frequency elastic waves from said vibration generator to said ultrasonic transducer;

said device includes a gripping tube;

said vibration generator is formed by a vibrating table;

said vibration generator is formed by a loudspeaker-type secondary device;

said elastography device includes a fine-tuning system for rotationally and/or translationally adjust the position of said ultrasonic transducer;

said vibration generator is located at the end of said deformable tube where the ultrasonic transducer is located;

said vibration generator is located at the opposite end of the deformable tube where the ultrasonic transducer is located;

said device includes a high-frequency imaging ultrasonic array;

said device is coupled with an organic synchronization device;

said ultrasound transducer has an active diameter smaller than 3 mm.

The present invention also relates to an elastography method for quantitatively and/or qualitatively measuring the viscoelastic properties of any medium characterized in that it implements a device according to the invention; said method comprises at least the following steps of:

positioning said at least one ultrasonic transducer, by deforming said deformable tube, perpendicularly and in contact with the medium;

translationally and/or rotationally adjusting the position of said ultrasound transducer;

triggering at least one measurement;

holding said ultrasonic transducer in position and in contact during at least one measurement;

said measurement comprising the following steps of:

generating at least one low-frequency elastic wave;

emitting and acquiring simultaneously to the generation of at least one low-frequency elastic wave high-frequency ultrasonounds using said ultrasonic transducer to observe the propagation of said at least one low-frequency elastic wave;

calculating at least one parameter relating to the viscoelastic properties of the medium such as the displacement variations and/or the deformations and/or the displacement speeds and/or the deformation speeds caused in the medium or more generally any parameter relating to the viscoelastic properties;

calculating the viscoelastic properties of the medium;

An additional advantageous feature is that said ultrasonic transducer is held in position and in contact with the medium during a series of measurements, by said deformable tube.

Advantageously, the low-frequency elastic waves are randomly triggered by the user starting in a synchronized manner with a breathing and/or heart rate.

Preferably, the high-frequency ultrasonic emission is performed over a frequency range comprised between 8 MHz and 100 MHz, and preferably between 10 MHz and 50 MHz.

Similarly, the low-frequency elastic waves are generated over a frequency range between 50 Hz and 10000 Hz, said low-frequency elastic waves may be of about 400 Hz.

In addition, said at least one low-frequency elastic wave is generated by mechanical vibration and/or by mechanical compression and/or by ultrasonic focalization.

These and other features and advantages of the present invention will become more apparent from the following

description of different embodiments of the invention, illustrated only by way of non-limitative example in the accompanying drawings, in which:

FIG. 1 is a simplified schematic representation of a device **10** according to the prior art.

FIG. 2 is a simplified schematic representation of a device according to the invention for ensuring the positioning of at least one ultrasonic transducer.

FIG. 3. is a simplified schematic representation of device according to the invention equipped with a gripping tube

FIG. 4. is a simplified schematic representation of a device according to the invention equipped with a vise-like support

FIG. 5 is a simplified schematic representation of an ultrasonic array for imaging that may be part of the elastography device

For reasons of clarity, the same elements have been designated by similar references. Similarly, only the elements useful for understanding the invention have been illustrated schematically the scale not being taken into consideration.

For the remainder of the description, what is meant by elastography is a technique for measuring the viscoelastic properties wherein a vibration generator generates, by direct or indirect contact with a tissue, one or more low-frequency elastic waves propagating in this tissue.

The temporal shape of such a low-frequency elastic wave may be arbitrary, but more generally of pulsed type, transient or periodic (continuous monochromatic).

This vibration is generally obtained in a mechanical manner but may also be obtained by radiation pressure, by ultrasonic hyperthermia or by internal vibrations of the body (heartbeat, pulse, etc. . . .)

In addition, different types of one membered or multi membered ultrasonic transducers may be used. It can for example be, in a non limitative way, a ring-type, annular, 2D matrix, linear or convex array transducer, a one membered, three-membered, star-type transducer, etc. . . .

In addition, laboratory animals refer particularly, in a non-limitative way, to amphibians, fish, reptiles and mammals, such as mice, rats, rabbits, cats, dogs and monkeys.

FIG. 1 shows the prior art devices.

In FIG. 2 are shown a user **106**; an organic synchronization device **103**, a table **107**, a laboratory animal **108** and an elastography device **110** according to the invention, the device **110** according to the invention comprises:

a deformable tube **111**;

at least one ultrasonic transducer **104**;

a support **120**;

a vibration generator **102**;

a trigger **105**;

a coaxial wire **113** for the transmission and the reception of ultrasonic signals;

a spring system **115**;

an analysis, processing and computation system **109**.

The deformable tube **111** ensures the positioning and the holding of at least one ultrasonic transducer **104** and ensures the transmitting of low-frequency elastic waves. More particularly, this tube **111** holds its position when it is deformed

The support **120** ensures the holding:

of the deformable tube **111**

of the vibration generator **102** for generating low-frequency elastic waves;

of at least one ultrasonic transducer **104** for the ultrasonic emission and acquisition

The support **120** makes it possible to hold the above mentioned components without requiring any intervention from the user **106**.

The trigger **105** makes it possible to trigger measurements.

The spring system **115** located, for example, between the end of the deformable tube **111** and the ultrasonic transducer **104** makes it possible to compensate the stress exerted on the tissue upon contact between the ultrasonic transducer **104** and said tissue. Thus, no compressive stress is generated on the tissue. This makes it possible to avoid any modification of the viscoelastic properties of the tissue.

In the following, the operation of the device **110** will be described according to the invention.

The first step is to position the ultrasonic transducer **104** in contact with the tissue to be measured or in contact with the tissue surrounding said tissue.

To this end, the user **106** deforms the deformable tube **111** which is held by the support **120** so as to bring the ultrasonic transducer **104** as close as possible to the tissue.

This deformable tube **111** is advantageous thanks to its structure which allows, on the one hand, to easily move the ultrasonic transducer **104** in space without any angular limitation, and on the other hand, to hold the desired position without deforming the deformable tube **111** thanks to its ductility.

Thus, the deformable tube **111** makes it possible to adjust the position of the ultrasonic transducer **104** so as to respect the perpendicularity and the contact of said ultrasonic transducer **104** with the tissue to be measured.

The structure of the deformable tube **111** may be formed by:

- multiple elements connected by a ball joint; in other words, the deformable tube **111** in this case is formed by an articulated tube;

- an elastically deformable tube, or

- more generally, any other type of tube which can:

- retain its shape when no stress is applied; and

- change its shape when a stress is applied.

Moreover, according to a possibility provided by the invention, the device is coupled to a surgical navigation system, not illustrated, of:

- first, locating the area of interest to be measured using a medical imaging device, of x-ray magnetic resonance imaging type or of any other imaging type enabling the sight of the biological tissues;

- then, positioning the ultrasonic transducer **104** in an electro-mechanic, electro-hydraulic, electro-pneumatic or in a manual way.

Therefore, such a positioning enables the user **106** to perform measurements of viscoelastic properties.

Said measures consisting in:

- generating at least one low-frequency elastic wave using the vibration generator **102**;

- emitting and acquiring simultaneously to the generation of at least one low-frequency elastic wave high-frequency ultrasounds using said ultrasonic transducer **104** to observe the propagation of said at least one low-frequency elastic wave.

To this end, the ultrasonic transducer **104** should, during the measurements:

- stay in contact with the tissue so as not to lose the ultrasonic signal and to make at least one series of measurements at the same location. This is ensured by the specific structure of the deformable tube **111** allowing it to retain its shape.

- be positioned perpendicularly to avoid an overestimation of the measurements. This feature being achieved by the deformable structure, free of any angular limitation, of the deformable tube **111**.

Specifically, small organs or organs whose accessibility is reduced require such a positioning precision.

This difficulty of access is frequently encountered in small laboratory animals such as mice, for instance, the adult wild mice usually 8 cm long has a liver with a volume of about 1.5 cm<sup>3</sup>, yet, much of it is located behind the ribcage, hence forcing the user **106** to carry out measurements over a skin area between 10 mm<sup>2</sup> and 1 cm<sup>2</sup> and more specifically, on a depth generally between 1 mm and 20 mm below the dermis and preferably 2 to 6 mm.

To this end, during the generation of at least one low-frequency elastic wave, the vibration generator **102** transmits the vibration to the ultrasonic transducer **104** via the flexible tube **111**. As shown in FIGS. **2**, **3** and **4**, the vibration generator **102** is separated from the ultrasonic transducer **104** by the deformable tube **111**. The ultrasonic transducer **104** has an active diameter less than or equal to 3 mm, This small diameter allows, firstly, to position the ultrasonic transducer **104** on a small area and, secondly, to avoid the diffraction zone encountered by the prior art devices.

In addition, measurements over a depth of less than 20 mm require the generation of low-frequency elastic waves having centre frequency between 50 and 10000 Hz and preferably, between 100 and 3000 Hz, this frequency may be typically of about 400 Hz.

Then, to observe the propagation of the low-frequency elastic waves, the ultrasonic transducer **104** of the one membered or multi-membered type adapted for generating high-frequency ultrasounds for example ranging between 8 and 100 MHz and preferably, between 10 and 50 MHz.

Such measurements are triggered by the user **106** via the trigger **105**, said trigger is connected to the vibration generator **102** and to the ultrasonic transducer **104** by a wire, by a computer network of WIFI type or by any other device allowing the transfer of data.

Thus, the vibration generator **102** generates at least one low-frequency elastic wave, which can be transmitted by the ultrasonic transducer **104** itself or by a non-illustrated secondary device, such as, for example, a loudspeaker.

In addition, it should be noted that the cardiac and the respiratory rates naturally generate low-frequency elastic waves of the monochromatic type. Therefore, there are three types of low-frequency elastic waves in the tissue interfering with each other, typically these waves can be generated by:

- the device according to the invention

- the cardiac system

- the respiratory system

The devices according to the prior art ignore interferences generated by the respiratory and/or cardiac rate. However, these biological phenomena generate movements of the reference frame highly altering the measurement of the viscoelastic properties or making it even impossible.

During inhalation, air enters the lungs, which increase in size, and then, inversely, the lungs volume decreases during exhalation. This phenomenon of inflation and deflation can lead to large displacements and thus distort measurements.

Thus, an elastography device according to the prior art restricts the field of use. This measurement inability is considerable in small animals, because unlike humans, whose respiratory rate is low, namely 16 pulses per minute, the respiratory rate of laboratory animals is very high. More specifically, while the rabbit is at almost 60 pulses per minute, the mouse is at about 220 pulses per minute.

Advantageously, the device **110** according to the invention offers the possibility to synchronize the generation of low-frequency elastic waves with the biological frequency using an electrocardiogram and/or a pulmonary synchronizer **103** more commonly known as organic synchronization.

Indeed, the respiratory cycle is composed alternately of an inspiration during which the air enters the lungs then inversely of an expiration during which air is expelled from said lungs causing strong tissue displacements and tissue extensions and compressions.

Therefore, it is important to initiate measurements repeatedly at a determined time so as each obtained measurement or series of measurements is representative of a similar area of interest.

To this end, the device of the invention can be coupled to an organic synchronizing device **103** making it possible to synchronize the measurements with the respiratory rhythm.

This implementation is necessary and advantageous in mice whose liver has 6 lobes (middle lobe, left lobe, 2 right lobes and 2 caudal lobes), which liver may have not only an organic heterogeneity but also a tissue heterogeneity requiring the user **106** to perform the measurements at a precise location for at least a series of measurements.

With reference to FIG. 2 the user **106** may for instance trigger a series of measurements synchronized with an organic synchronization system **103** adapted to trigger low-frequency elastic waves to each peak **114** representative of the maximum wave front corresponding to a maximum inhalation.

Thus, the measurements are triggered by the user but only start when the peak **114**, representative of the maximum wave front, is reached.

Then, to observe the propagation of these low-frequency elastic waves, high-frequency ultrasonic waves are emitted and acquired simultaneously by the ultrasonic transducer **104**.

These high-frequency ultrasonic waves generally range between 8 and 100 MHz and preferably between 10 and 50 MHz.

These data are then transmitted to a data processing, computation and analysis system **109**, informing the user **106** of the viscoelastic properties of the area of interest in real time.

According to an embodiment of the invention shown in FIG. 3, the elastography device **110** is provided with a gripping tube **117**.

Thus, the low-frequency excitation generated by the vibration generator **102** is transmitted to the ultrasonic transducer **104** via the deformable tube **111** located inside the gripping tube **117**.

Such an implementation is advantageous thanks to its workability, since the user **106** manually positions the ultrasonic transducer **104** without altering the transmission of the low-frequency elastic waves performed by the deformable tube **111**, from the vibration generator **102**, to the ultrasonic transducer **104**. The latter, in addition to its ultrasonic emission and acquiring function, serves as a probe.

Furthermore, the support **120** can be of the vise type as illustrated in FIG. 4.

The minimum size of this support facilitates the handling and the transport of the elastography device.

As shown in FIG. 4, the elastography device may include a fine-tuning system **112**, to rotationally and/or translationally adjust the position of the ultrasonic transducer **104** without deforming the deformable tube **111**.

According to an alternative provided by the invention shown in FIG. 4 the low-frequency elastic waves are transmitted to the probe **104** via a rod **121** located within the deformable tube **111**.

In addition, according to an additional alternative of a device **110** according to the invention shown schematically in FIG. 5, the device **110** is provided with an echograph type

ultrasonic imaging array **116**, allowing the user to ensure that the ultrasonic transducer **104** is positioned in the axis of the area of interest.

To this end, the device of the invention may comprise at least one ultrasonic imaging array **116** and at least one elastography-specific ultrasonic transducer **104**.

The ultrasonic transducer **104** moves in a direction perpendicular or substantially perpendicular to the imaging array plan so as to transmit at least one low-frequency elastic wave from the vibration generator **102** in the medium. According to a non-illustrated alternative the ultrasonic transducer can be moved along x, y, and/or z axis and/or in rotation.

The high-frequency echographic array **116**, informs the user about the spatial location and the movement of organs, allowing it therefore to position the probe **104** in the axis of said organ of interest. Thus, the ultrasonic transducer **104** located at the end of the deformable tube **111** and in contact with the epidermis is used to observe the propagation of low-frequency ultrasonic waves indicative of the viscoelastic properties of the biological tissue.

In addition, as shown in FIG. 5, the high-frequency ultrasonic array **116** has a specific shape the purpose of which is to cover an optimal area. For this purpose, said shape may be curved, circular, oval, rectangular, triangular or be any other geometric shape leading to the same result, namely the coverage of an area by high-frequency ultrasounds.

The possible steps for implementing a device according to the invention illustrated in FIG. 5 include:

imaging the tissue with a high-frequency ultrasonic imaging array **116** to determine the spatial location of the area of interest;

positioning the ultrasonic transducer **104** in the axis of the area of interest using the deformable tube **111**

generating at least one low-frequency elastic wave; simultaneously emitting and acquiring high-frequency ultrasounds using the elastography transducer **104** to measure the viscoelastic properties.

According to an advantageous non-illustrated alternative of the invention, said high-frequency ultrasonic array **116** is composed of multiple elements, said elements can be used, on the one hand, to image the environment, and, on the other hand, to generate at least one low-frequency elastic wave.

The array may generate at least one low-frequency elastic wave in the medium in a way which is:

mechanical, by displacing at least one element;

mechanical, by displacing said array

electronic, by ultrasonic focalization.

According to an additional alternative provided by the invention, the vibration generator may be formed by the table **107** on which the tissue to be measured seats. In such an implementation, the user **106** shakes the table **107** then follows the movement of the ultrasonic waves generated by said table **107** via ultrasonic transmission and acquisition of the ultrasonic transducer **104**.

It should be noted that the application field of the invention relates to laboratory animals. Such an application may of course be extended to the pharmaceutical, food, chemical, or to the medical fields to determine the viscoelastic properties of human or animal tissue samples or cell samples from in vivo, ex-vivo, in vitro cell cultures.

The invention is described above by way of example. It is understood that a man skilled in the art is capable of producing different alternatives of the device and of the method for measuring the elasticity of a human or animal tissue, particularly with regard to the disposition or arrangement of the various elements composing said device or the order as well

as the importance of the steps of said method without departing from the scope of the patent.

The invention claimed is:

1. An elastography device for quantitatively and/or qualitatively measuring the viscoelastic properties of any medium, said device comprising:

a vibration generator configured to generate at least one low-frequency elastic wave;

an ultrasonic transducer configured to observe a propagation of said at least one low-frequency elastic wave;

a trigger configured to trigger at least one measurement, said at least one measurement being performed by generating the at least one low-frequency elastic wave in a medium, and

emitting and acquiring simultaneously to the generation of the at least one low-frequency elastic wave high-frequency ultrasounds using said ultrasonic transducer to observe the propagation of said at least one low-frequency elastic wave;

a deformable tube positioned between said vibration generator and said ultrasonic transducer, the deformable tube being freely movable to spatially move without angular limitation the ultrasonic transducer and having a ductility that allows the deformable tube to hold the ultrasonic transducer in position after movement of the deformable tube, wherein the deformable tube is configured to hold said ultrasonic transducer located at the end of said deformable tube so as to ensure, during at least one measurement, perpendicularity and contact between said ultrasonic transducer and the medium, and a support attached to the vibration generator and configured to spatially hold the ultrasonic transducer.

2. The device according to claim 1, comprising a spring system located between said ultrasonic transducer and said deformable tube.

3. The device according to claim 1, comprising at least one rod capable of transmitting the low-frequency elastic waves from said vibration generator to said ultrasonic transducer.

4. The device according to claim 1, comprising a gripping tube.

5. The device according to claim 1, wherein said vibration generator is formed by a vibrating table.

6. The device according to claim 1, wherein said vibration generator is formed by a loudspeaker-type secondary device.

7. The devices according to claim 1, wherein said device includes a fine-tuning system configured to rotationally and/or translationally adjust the position of said ultrasonic transducer.

8. The device according to claim 1, wherein said vibration generator is located at the end of said deformable tube where the ultrasonic transducer is located.

9. The device according to claim 1, wherein said vibration generator is located at the opposite end of the deformable tube

where the ultrasonic transducer is located so that said vibration generator is directly connected to said opposite end of the deformable tube.

10. The device according to claim 1, wherein said device includes at least one high-frequency ultrasonic imaging array.

11. The device according to claim 1, wherein said device is coupled to an organic synchronization device.

12. The device according to claim 1, wherein said ultrasonic transducer has an active diameter of less than 3 mm.

13. An elastography method for quantitatively and/or qualitatively measuring the viscoelastic properties of any medium, said method comprising:

providing the elastography device of claim 1;

positioning said at least one ultrasonic transducer, by deforming said deformable tube, perpendicularly and in contact with the medium;

translationally and/or rotationally adjusting the position of said ultrasound transducer;

triggering at least one measurement;

holding said ultrasonic transducer in position and in contact during the at least one measurement; said at least one measurement comprising:

generating at least one low-frequency elastic wave;

emitting and acquiring simultaneously to the generation of the at least one low-frequency elastic wave high-frequency ultrasounds using said ultrasonic transducer to observe the propagation of said at least one low-frequency elastic wave;

calculating at least one parameter relating to viscoelastic properties of the medium such as the displacement variations and/or the deformations and/or the displacement speeds and/or the deformation speeds caused in the medium or more generally any parameter relating to the viscoelastic properties; and calculating the viscoelastic properties of the medium.

14. The method according to claim 13, wherein said ultrasonic transducer is held in position and in contact with the medium during a series of measures, by said deformable tube.

15. The method according to claim 13, wherein said low-frequency elastic waves are randomly triggered by the user starting in a synchronized manner with a breathing and/or heart rate.

16. The method according to claim 13, wherein said high-frequency ultrasonic transmission is performed over a frequency range comprised between 8 MHz and 100 MHz.

17. The method according to claim 13, wherein said low-frequency elastic waves are generated over a frequency range comprised between 50 MHz and 10000 MHz.

18. The method according to claim 13, wherein said low-frequency elastic waves are of about 400 Hz.

19. The method according to claim 13, wherein said at least one low-frequency elastic wave is generated by mechanic vibration, and/or by mechanic compression and/or by ultrasonic focalization.

\* \* \* \* \*

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[标]发明人	SANDRIN LAURENT BOSISIO MATTEO BASTARD CECILE		
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摘要(译)

一种用于定量和/或定性测量任何介质的粘弹性的弹性成像装置，包括可变形管，用于定位位于可变形管末端的超声换能器并用于保持它，以便在至少一次测量期间确保垂直度。超声换能器和介质之间的接触。

