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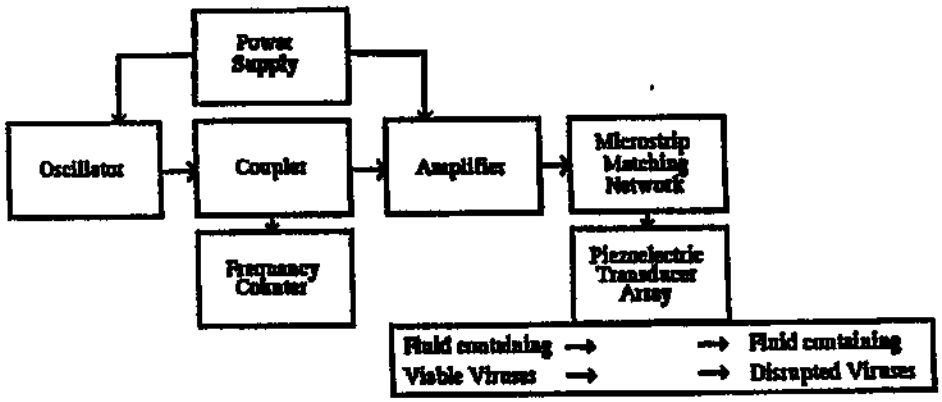

(57) Abstract

The present invention makes use of resonant acoustic and/or acousto–EM energy applied to inorganic or biologic structures for the detection and/or identification, and for augmentation and/or disruption of function within the biologic structure. In particular, the invention provides a method of generating resonant acoustic and/or acousto–EM energy in biologic structures such as virus, bacteria, fungi, worms and tumors for the detection and disruption of these structures. Moreover, the invention provides a method of augmenting functions of biologic structures such as bone through the generation of resonant acoustic and/or acousto–EM energy in the structure. Systems are also provided for the generation and detection of resonant acoustic and/or resonant acousto–EM energy.

METHODS FOR USING RESONANT ACOUSTIC AND/OR RESONANT ACOUSTO-EM ENERGY TO DETECT AND/OR EFFECT STRUCTURES

TECHNICAL FIELD

The present invention relates to detection of inorganic and biologic structures and/or disruption and/or augmentation of functions of biologic structures using resonant acoustic and/or resonant acousto-EM energy.

BACKGROUND OF THE INVENTION

The resonant acoustic frequency of a system is the natural free oscillation frequency of the system. A resonant acoustic system can be excited by a weak mechanical or acoustic driving force in a narrow band of frequencies, close or equal to the resonant frequency thereby inducing acoustic resonance in a targeted structure.

Acoustic resonance has been used to determine various properties of solid materials. For instance, Migliori et al in U.S. Patent Nos. 4,976,148 and 5,062,296 and 5,355,731 disclose a method for characterizing a unique resonant frequency spectroscopic signature for objects derived from ultrasonic excitation of objects, the use of resonant ultrasound spectroscopy for grading production quantities of spherical objects such as roller balls for bearings, and the use of resonant ultrasound spectroscopy with a rectangular parallelpiped sample of a high dissipation material to enable low amplitude resonance to be detected for use in calculating the elastic constants of the high dissipation sample. However, the Migliori patents are directed to solid materials and not to selectively targeting organic or biologic material especially when liquid systems are involved.

In addition to interacting with inanimate structures, acoustic energy also interacts with living, biologic organisms and structures. Acoustic energy has been used extensively in medicine and biology for imaging structures, by directing an acoustic wave at a biologic structure and analyzing the reflection pattern of the acoustic wave. Also, acoustic energy has been used in physical therapy medicine for delivering heat to targeted areas of injury or pain. However, all of the above applications depend on using acoustic energy that is non-selective

for the specific targeted biologic structure, and as such, may affect more than just the targeted structure.

Vago, RE., U.S. Patent No.5,048,520 and 5,178,134 discloses ultrasonic treatment of animals for topical hygiene and antiviral effects. The frequencies disclosed are in the range of 15 kilohertz to 500 kilohertz. They also report that non-enveloped viruses were refractive to the inactivating effects of the ultrasound. The mechanism cited for their antimicrobial effects is "cavitation" on the skin surface only, and they specifically avoid the use of resonant frequencies in their apparatus.

Moasser, M., U.S. Patent No.4,646,725 discloses the use of an adaptor for diagnostic ultrasound machines for treatment of skin and mucous membrane lesions caused by infectious agents including herpes virus. The method of treatment was 2.0 to 3.0 minutes at a power output of 1.5 watts per square centimeter, with no specific frequencies being cited. The use of acoustic resonance is not discussed or contemplated.

Johnston, RG., U.S. Patent No.5,426,977 discloses ultrasonic measurement of the acoustic resonances in eggs to provide a technique for establishing the presence of *Salmonella* bacteria. Johnson characterizes the eggs and determines the difference between the egg with and without Salmonella bacteria. As such, this method does not detect the actual micro-organism, but instead characterizes the vibrational modes of an eggshell, which are modified by the physical presence of a bacteria.

The prior art has failed to suggest a satisfactory method or system for affecting functions of a biologic structure without also affecting near-by tissue. Furthermore, the prior art does not provide for a method that allows precise detection of biologic or inorganic structures using acoustic resonance to produce a signature with high signal to noise ratio, while producing little effect in nearby structures. Still further, use of non-resonant acoustic energy in the prior art affects targeted and non-targeted structures equally.

SUMMARY OF THE INVENTION

For purposes of this invention, the terms and expressions below, appearing in the specification and claims, are intended to have the following meanings:

"Acoustic energy" as used herein is defined as energy that is produced when a

physical structure vibrates and the vibrational energy of motion is transferred to the surrounding medium which includes air, liquid, or solid.

"**Detect**" as used herein is defined as determining the presence or absence of a structure, and if present identifying the structure.

"**Electromagnetic (EM) properties and/or fields**" as used herein includes direct and alternating currents, electric and magnetic fields, electromagnetic radiation, and fields which include but are not limited to waves, current, flux, resistance, potential, radiation or any physical phenomena including those obtainable or derivable from the Maxwell equations, incorporated by reference herein.

"**Electromagnetic (EM) energy pattern**" as used herein represents the electromagnetic energy produced by a structure as acoustic energy interacts with the structure and is manifested as electromagnetic properties and/or fields.

"**Biologic structure**" as used herein and used interchangeably with organic includes anything from the smallest organic or biochemical ion or molecule, to cells, organs, and entire organisms.

"**Disruption**" as used herein refers to deleterious effects on a biologic structure.

"**Acoustic Signature**" as used herein means a unique acoustic pattern that is produced by the structure when in acoustic resonance that may take the form of amplitude of signal.

"**Resonant acoustic frequency**" as used herein includes frequencies near or at the natural resonant frequency of the structure including harmonic and subharmonic frequencies of the natural resonant frequency to induce acoustic resonance therein.

"**Acousto-EM signature**" as used herein is defined as an EM energy pattern of an object in acoustic resonance and/or an EM energy equivalent in frequency to the resonant acoustic frequency.

"**Acousto-EM spectroscopy**" as used herein is defined as detecting a unique EM signature for a structure that is in acoustic resonance or detecting a unique acoustic signature that is in resonance due to the introduction of electromagnetic energy, both of which can be used to detect and/or identify the structure in resonance.

"**Living transducer**" as used herein is defined as a biologic piezoelectric or semiconductor structure that converts electromagnetic energy or fields into mechanical

energy and/or mechanical energy into electromagnetic energy or fields.

"Cavitation"as described herein is defined as the formation of vapor-filled cavities in liquids, i.e. bubble formation in water when brought to a boil.

"Mechanical" as described herein include mechanisms such as compression and rarefaction which are thought to take place in the intensity/duration threshold region between the thermal and cavitation regions.

"Non-resonant electromagnetic signature" as used herein is defined as an EM energy pattern produced by an object stimulated by a non-resonant acoustic field.

"Resonant acousto-EM energy" as described herein means electromagnetic energy or field that induces acoustic resonance in a structure.

The present invention addresses the shortcomings of the prior art by inducing acoustic resonance in a targeted structure with select frequencies that affect the specific targeted structure but have virtually no effect on nearby, non-resonating structures. Furthermore, acoustic energy power intensities can be reduced by introducing a source of electromagnetic (EM) energy that augments the acoustic energy thereby reducing the destructive nature of high power acoustic energy. The interaction between EM energy and acoustic resonance allows for precise detection of a structure in acoustic resonance by producing a signature with high signal to noise ratio, while producing little effect in other structures.

The present invention provides methods to selectively detect, identify and/or affect an inorganic or biologic structure by using resonant acoustic and/or acousto-EM energy which can transfer useful energy to targeted structures while leaving nearby structures, which are not in resonance, virtually unchanged.

Therefore, it is an object of the present invention to provide a method of identifying or detecting an inorganic or biologic structure using its resonant acoustic and/or acousto-EM energies.

It is an object of the present invention to provide a method using resonant acoustic and/or acousto-EM energies to augment and/or disrupt the growth and/or function of biologic structures.

It is another object of the invention to provide a method for determining resonant frequencies of a biologic structure.

It is also an object of the invention to provide a method using resonant acoustic