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(71) Applicant *(for all designated States except US)*: **ULTRAN LABORATORIES, INC.** [US/US]; 1020 East Boal Avenue, Boalsburg, PA 16827 (US).

(72) Inventor; and

(75) Inventor/Applicant *(for US only)*: **BHARDWAJ, Mahesh, C.** [US/US]; 238 E. Doris Avenue, State College, PA 16801 (US).

(74) Agents: **HANSON, David, C.** et al.; Webb Ziesenheim Logsdon, Orkin & Hanson, P.C., 700 Koppers Building, 436 Seventh Avenue, Pittsburgh, PA 15219-1818 (US).

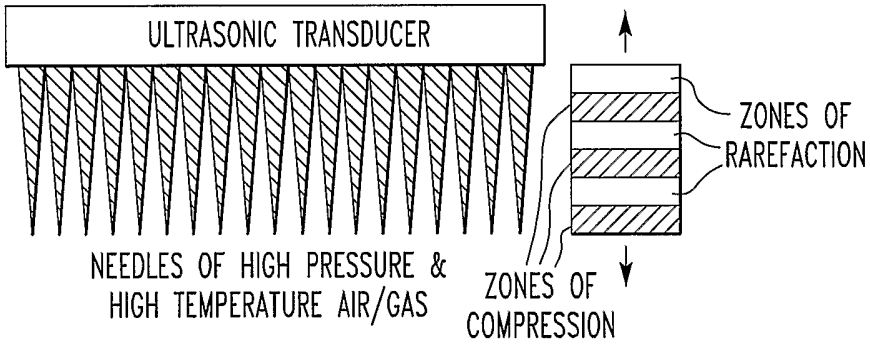
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(54) Title: METHOD OF APPLYING GAS CONTACT ULTRASOUND THERAPY, SURGERY, AND DRUG DELIVERY



(57) Abstract: A method for applying gas contact ultrasound to a specimen surface using a transducer without a carrier medium is disclosed, wherein the method of the present invention can be used to provide ultrasound therapy, surgery, and enhance drug delivery to humans, animals, and polymeric substances.

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METHOD OF APPLYING GAS CONTACT ULTRASOUND THERAPY, SURGERY, AND DRUG DELIVERY

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a method of applying gas contact ultrasound therapy.

2. Description of Related Art

[0002] High energy ultrasound is used for cell disruption, particle size reduction, welding, cleaning, and for therapeutic and surgical applications and procedures. In such applications, the ultrasonic transducer, the source of ultrasound, is either in direct or in indirect contact with the specimen to be treated. For indirect contact, the transducer is placed in a liquid, generally water or a gelatinous material, that acts as the carrier medium of ultrasound. Hence, the carrier medium acts as a conduit for ultrasound delivery to the specimen surface for treatment. In other words, it is necessary to use the carrier medium as a transducer contact for efficient transfer of ultrasound into the specimen.

[0003] However, it is highly desirable to perform certain tasks by ultrasound, such as for the treatment of human skin, wounds, destruction of malignant tissues, efficient and time-controlled delivery of drugs, etc., without using a carrier medium. However, conventional wisdom dictates that high power ultrasound without direct or indirect contact with the specimen (or a specimen surface, as used alternatively herein) to be treated is not possible. This scientific belief is based upon two major hurdles: 1) inefficient transmission of ultrasound from the piezoelectric material into air/gases; and 2) exorbitant attenuation of ultrasound by gases. The latter is a natural phenomenon about which nothing can be done, and the former requires an unconventional approach to transducer design. As described in U.S. Patent No. 6,311,573 (hereinafter "the '573 patent") entitled "Ultrasonic Transducer for High Transduction in Gases and Method for Non-Contact Ultrasound Transmission Into Solid Materials", incorporated herein by reference, it is now possible to generate high intensity ultrasound into air and other gases. The technology of the '573 patent has allowed for the successful destruction of bacterial spores using a non-contact ultrasound device. This successful destruction is described in a paper entitled, "Destruction of bacterial spores by phenomenally high efficiency non-contact ultrasonic transducers", by Kelli Hoover, Mahesh Bhardwaj, Nancy Ostiguy, and Owen Thompson in the *Journal of Materials Research Innovation*, Vol. 6, pp. 291-295 (2002). A method for the successful destruction of bacterial spores via a non-contact ultrasound device is also described in pending U.S. Patent

Publication No. 2004/0028552 entitled "Gas Contact Ultrasound Germicide and Therapeutic Treatment", the contents of which are incorporated herein. However, a need exists for the method of applying high power ultrasound to provide therapy, enhance drug delivery, or in surgery without direct or indirect contact with the specimen surface to be treated.

[0004] Thus, it is an object of the present invention to provide a method for applying high power gas contact ultrasound without direct or indirect contact with the specimen to be treated.

SUMMARY OF THE INVENTION

[0005] Briefly, according to the present invention, there is provided a method for applying high power ultrasound without direct or indirect contact with the specimen to be treated comprising the steps of: providing a transducer, placing the transducer spaced apart from the specimen surface to be treated, and applying pulses of ultrasound via the transducer to the specimen surface at a distance from the specimen surface to be treated. Most importantly, a carrier medium is not necessary to transmit the pulses of ultrasound to the skin surface when using the method of the present invention. The method of the present invention can be used to provide ultrasound therapy, surgery, and enhance drug delivery to humans, animals, and polymeric substances. When used to enhance drug delivery, the human or animal epidermal surface will be initially exposed to one or more of drugs, molecules, compounds, or medicinal products before applying pulses of the gas contact ultrasound.

BRIEF DESCRIPTION OF THE DRAWING

[0006] The drawing is a schematic illustration of an intense ultrasound field emanating from the ultrasonic transducer and the needle-type oscillating wavefront.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0007] The present invention includes a method for applying high power ultrasound without direct or indirect contact with the specimen surface to be treated. The transducer emits high frequency sound waves which penetrate and infiltrate the specimen surface. The specimen surface can be human tissue, such as the dermis of the skin, or can be a polymer material. The application of high power ultrasound without direct or indirect contact with the specimen surface allows for a novel approach to ultrasound therapy, surgery, and drug delivery techniques and enhancements. An apparatus for application of high power ultrasound without contact is disclosed in the '573 patent (identified above). Ultrasound is transmitted through a gaseous medium by bonding a facing layer of fibrous material to the transmission surface of a transducer, for example, a piezoelectric transducer without substantial penetration of the bonding agent into the facing layer of fibrous material.

[0008] The observations described herein are not inconsistent with those observed when the transducers are operated in direct or indirect contact with the human body. Thus, a substantial improvement has been developed in that high power ultrasound may be applied effectively to a specimen surface without having to directly contact the specimen surface with the transducer and without having to use a carrier medium.

[0009] Based upon the observations reported herein, the following conclusions can be made: 1) high acoustic pressure and subsequent generation of heat in the air/gas surrounding the transducer is experienced with high power ultrasound without direct or indirect contact with a specimen surface. Without the intention of being bound by theory, this is likely due to friction and the possible explosion of air/gas molecules trapped within the compression and rarefaction zones of the intense ultrasound; and 2) sensational effects of ultrasound on the surface of human skin and its subsequent transmission within the body is experienced with high power ultrasound without direct or indirect contact with the specimen surface.

[0010] Using the methods of the present invention, it should now be possible to alter the physico-chemical nature of the skin and throughout the dermal tissues below by using high power ultrasound without any contact with the skin and without using a carrier medium. Additionally, as a result of the transient high pressure and temperature produced by the high power ultrasound, it also should be possible to efficiently transfer drugs, molecules, compounds, medicinal products, etc. from the epidermis of human or animal skin into the deeper parts of the human or animal body. By manipulating the transducer frequency, active area dimensions, the field of ultrasound (such as by focusing it), excitation conditions, including pulse repetition frequency (if operating in a pulsed mode), or by excitation amplitude (if operating by a continuous wave), the magnitude of ultrasonic effects and depth of their penetration into the human body can be effectively controlled.

[0011] Further, it should now be possible to efficiently transfer drugs, molecules, compounds, medicines, etc. through a polymer-based specimen surface, if one so desires, by applying high power ultrasound to the polymer specimen surface without having to directly contact the specimen surface with the transducer and without having to use a carrier medium.

[0012] The following experiment was performed in developing the method of the present invention and the following observations were made: Two transducers, nominally 150 kHz and 350 kHz according to the '573 patent, were excited with sinusoidal bursts in the pulsed mode to generate high acoustic pressure in ambient air. The details of transducers and their excitation conditions are shown in Table I.

TABLE I.

Details of transducers and their excitation for high power generation in ambient air.

Nominal Frequency (kHz)	Peak Frequency (kHz)	Active dimensions (mm)	Number of Bursts (#)	Pulse Repetition Rate (ms)	Excitation Volts & Amplification (v)	Acoustic Pressure In Air (Est. Pa)
150	135	76x76	2000	50	0.5 x 50 dB	2,000,000
350	330	38x38	2000	20	0.5 x 50 dB	3,000,000

[0013] After about 5 minutes of excitation, the transducers became slightly warm due to heat generation in the transducer. No appreciable increase of temperature was felt in the air directly in front of the transducer. Under these conditions, a human hand was placed approximately 10 mm away from the transducer in ambient air. After approximately 10 to 20 seconds, a strange sensation in the treated hand was felt by the study subject. The sensation was described as being impregnated and pounded (forged) by sharp needles. Subsequently, the study subject felt the simultaneous effects of high pressure and high temperature within the irradiated area of the hand. Within a matter of 10 to 20 seconds, the sensation spread throughout the exposed region of the hand and with longer exposure it spread all the way up to the shoulder. After removing the hand from the ultrasonic field, the sensation continued for several hours. Three other test subjects had identical observations when exposed to the same experiment.

[0014] The sensation described herein is not analogous to the continuous effect of either very hot air or the continuous effect of air under high pressure alone. The sensation is the feeling of short-lived pressure and temperature. Furthermore, this sensation, while felt in the area corresponding to that of the transducer or that of the exposed body part, is not flat and constant over the exposed region. The sensation appears as if a very large number of needles, capable of emitting high pressures and temperatures simultaneously, act upon the specimen surface being irradiated. It is thought, without the intention of being bound by this theory, that the diameter of each so-called needle corresponds to that of the wavelength of ultrasound in air. For example, for 150 kHz and 350 kHz, it is 2.3 mm and 1.0 mm, respectively.

[0015] It is important to note that the intense pressures and temperatures felt are transient in nature. They last for very short durations of time which can be controlled by increasing or decreasing the pulse repetition rates by which the transducer is activated. Additionally, the magnitude of the effects reported herein will also depend upon the displacements within the

irradiated parts of the human body. For example, at lower frequencies where the displacements are relatively large, the effects of pressure and temperature may be more intense and may last longer. For example, at 350 kHz, the sharpness of the effect was more intense and uniform relative to the same at 150 kHz.

[0016] It is proposed that the application of gas contact ultrasound, as discussed herein, will be beneficial in providing ultrasound therapy in surgery and in enhancing drug delivery through a specimen surface.

[0017] The present invention has been described with reference to specific details of particular parameters thereof. Obvious modifications, combinations and alterations will occur to others upon reading the preceding detailed description. It is intended that the invention be construed as including all such modifications, combinations and alterations insofar as they come within the scope of the appended claims or equivalents thereof.

THE INVENTION CLAIMED IS:

1. A method of applying gas contact ultrasound comprising the steps of:

a) providing a transducer;

b) placing the transducer spaced apart from a specimen surface to be treated; and

c) applying pulses of ultrasound via the transducer to the specimen surface at a distance from the specimen surface to be treated,

wherein a carrier medium is not needed to transmit the pulses of ultrasound to the specimen surface.

2. The method according to claim 1, wherein the transducer is excited for a time of approximately five minutes before the applying step c).

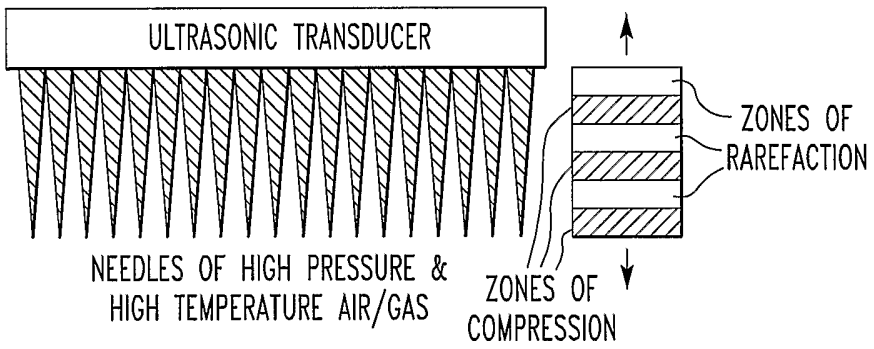
3. The method according to claim 1, wherein the applying step c) is of a duration from between 10 to 40 seconds.

4. The method according to claim 1, wherein the specimen surface to be treated is a human epidermal surface.

5. The method according to claim 1, wherein the gas contact ultrasound transducer transmits a frequency range of about 135 kHz to 350 kHz.

6. The method according to claim 1, wherein the transducer has a facing layer of fibrous material bonded thereto.

7. The method according to claim 4, wherein the human epidermal surface has been initially exposed to an agent selected from the group consisting of drugs, molecules, compounds, and medicinal products.


ULTRASONIC TRANSDUCER
ZONES OF RAREFACTION
NEEDLES OF HIGH PRESSURE & HIGH TEMPERATURE AIR/GAS
ZONES OF COMPRESSION