Detector of Verbal Spectrum of Natural Vibrations of the Tympanic Membrane at the Threshold of Audibility Without External Stimulation ("Verbal Sensor")

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Abstract

D.T. Kemp's researches in the field of stimulated and spontaneous optoacoustic emission have corroborated reality of hopes to find a response to one of the brain neurophysiology mysteries - the "inner-voice" sensation conception. Some characteristics of the "inner-voice" sensation including an information component are similar to that of external sound images (amplitude limitation, timbre, rate etc.). This likeness puts the author on to the assumption that "inner-voice" sensation has mechanical nature.

Inner hair nerve cells of Organ of Corti are capable to be a source of “inner-voice” sound vibrations and to send them to the outward ear passage through inner and middle ear regions and tympanic membrane because there are specific reverse connections between brain's auditory parts and pilus cells of the Organ of Corti. The author considers the ear system not only as a passive receiver of outward sound oscillations, but also as their active sense selector and supposes that spectrum of own tympanic-membrane's vibrations contains **verbal** and other inner sense images at the audibility threshold.

These images as a result of intellectual brain's activity promote to recognizing outward sound stimulations which have the lowest level of energy. An optoelectronic otoendoscope as a noninvaded detector is suggested to register thinking-in words spectrum of tympanic-membrane's vibrations without an external stimulation. It is

based on the modulation of reverse radiation induced from the tympanic membrane's microregion.

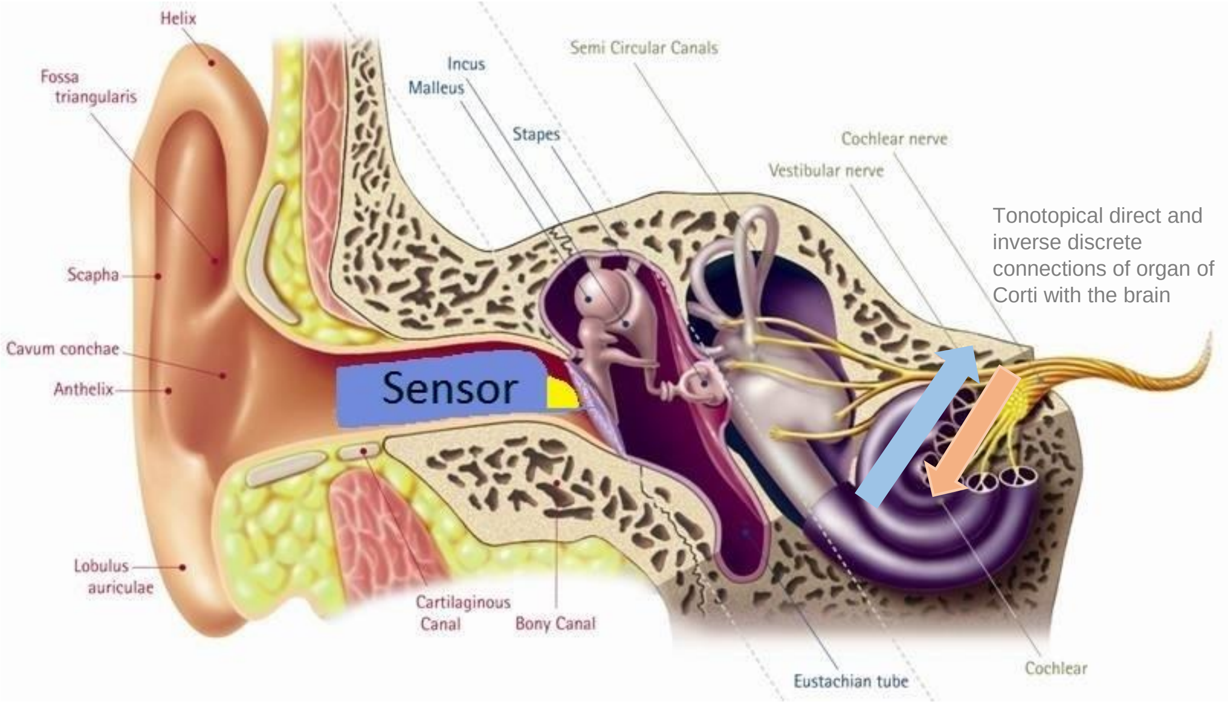
Keywords

Spontaneous otoacoustic emission, molecular kinesis, optical fiber, modulation of optical contacts, electronic microchannel multipliers, synchronous amplifiers with ultra-low noise level, microprocessor systems for SNR enhancement, standard power sources, LPCVD methods for chemical overlaying of thin membranes, metal-ceramic high vacuum connections, ultrapure manufacture, automatic spatial micromanipulators, ferroelastics, mini cryoblocks for cooling electronic devices, sound resistive elastics, ultrasonic mini topography, linear piezoelectric micromotors.

Background

Neurophysiological version of the recognition function of human auditory structures at the audibility threshold

In biocoenosis, the factor of survival, among many factors, is also determined by informational sensitivity of its objects (including human). It furthers the evolutionary enhancement of selective capacity of their auditory organs (systems) and energy threshold of detection of information. It is done, perhaps, by means of reverse accentuation (by the nervous system) of auditory images which stimulate semantic components. Accentuation is determined and caused by the availability of specific reversible nerve connections between the respective centres of the brain and inner hair nerve cells (IHC) of the Organ of Corti, located in the cochlea of the inner ear [1, 2] (Fig. 1).



Tonotopical direct and inverse discrete connections of organ of Corti with the brain

Fig.1 Peripheral section of auditory system of a human. Position of the proposed sensor relatively to the tympanic membrane.

Research of the stimulated and spontaneous otoacoustic emission carried out by D.T Kemp et al. [3,4,5] raised the question of indirect detection of certain components of physical activity of the auditory brain structures.

Since the sensation of "inner voice" has typical physical specifications (formant-phase spectrum [6] constant volume, noise, tone and rate), it is logical to assume that this feeling is being formed and branched in auditory areas and brain memory in which certain nerve cells should send and receive not only electrical but also mechanical impulses, determined by synchronous variation of the size of neurons upon their activation (molecular kinesis).

Let us review the model from which it follows that at the threshold of audibility [7], upon detection of an external sound, auditory brain structures serve as a multichannel super generator of direct (efferent) nerve impulse flows from Organ of Corti to the brain. These flows at least partially correspond to the dynamics of conscious auditory images.

By manipulating with the structure of nerve impulses, place and time of their generation, auditory brain structures simultaneously, through the function of inner hair cells (electroacoustic conversion by way of molecular kinesis), stimulate complex movement of tectorial membrane. Thus, on the set of outer hair cells connected with it, a clearer dynamic auditory image is created (reverse mechanical link), that facilitates its recognition. It should be noted that 90-95% of the quantity of inner hair nerve cells, whose stereocilia are separated from the tectorial membrane (Figure 2), are served by afferent nerve pathways [8, 9], while inner hair nerve cells with direct piezoelectric converting function send nerve impulses to the auditory brain structures mainly by the efferent path.

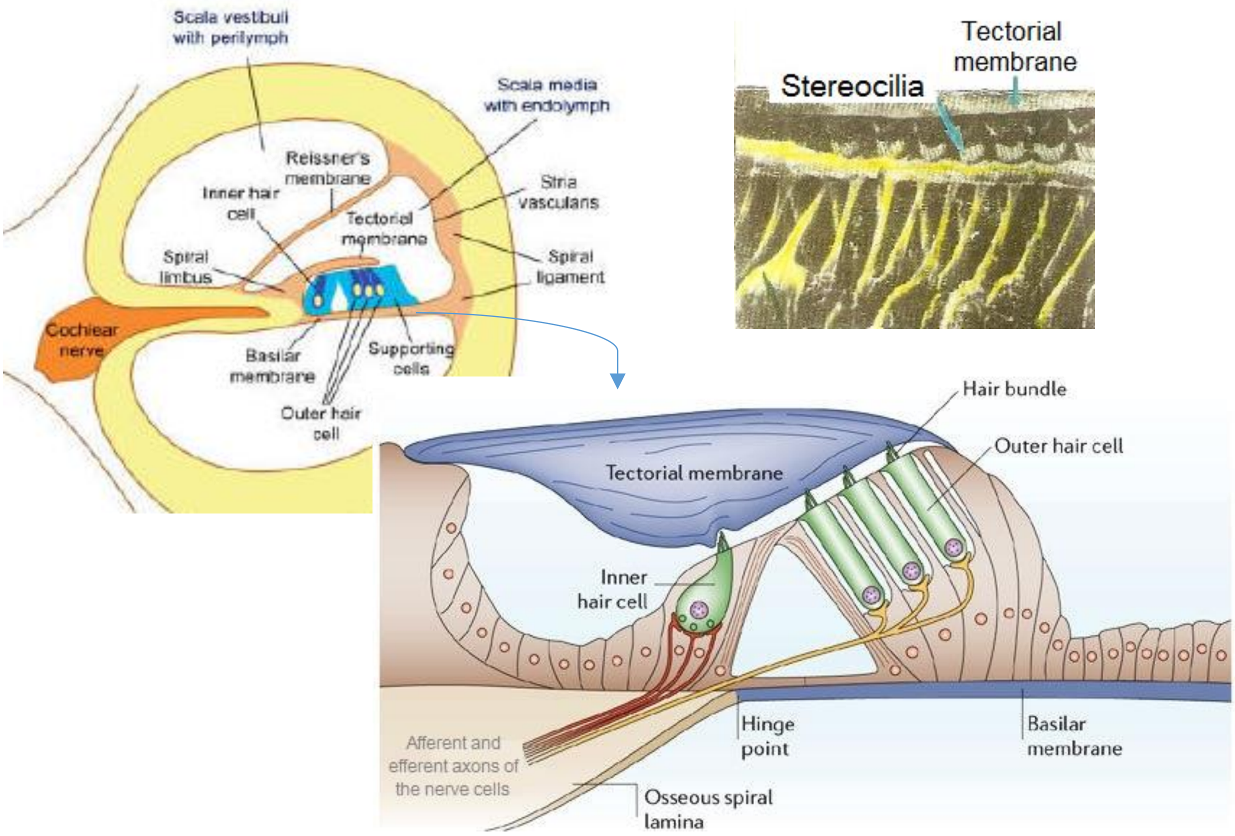


Fig. 2. Section of cochlea of the inner ear with electron micrograph fragment of a set of inner hair cells

Thus, based on the principle of functional-structural compliance, Organ of Corti can be regarded as a multichannel frequency-dispersion processor for mutual identification of auditory and semantic images due to numerous direct and reverse (temple auditory field, Wernicke's area – upper olivary bodies – olivocochlear tract (Rasmussen) - spiral ganglion) connections with the auditory brain structures. In the absence of external acoustic excitations, the tympanic membrane is in nano-vibration state [10]. Its range of vibration is stimulated by auditory brain structures through Organ of Corti and inner and middle section of the ear. It makes it easier to understand its high local sensitivity in the frequency range of 1 - 5 kHz because the sensitivity of dynamical systems to simultaneous excitation is significantly higher than to static ones.

The question is: Whether the tympanic membrane receives, in the absence of external stimulation, in the reversed direction, the acoustic vibrations determined by thought (other than in case of artefacts and pathology)? (Fig. 3).

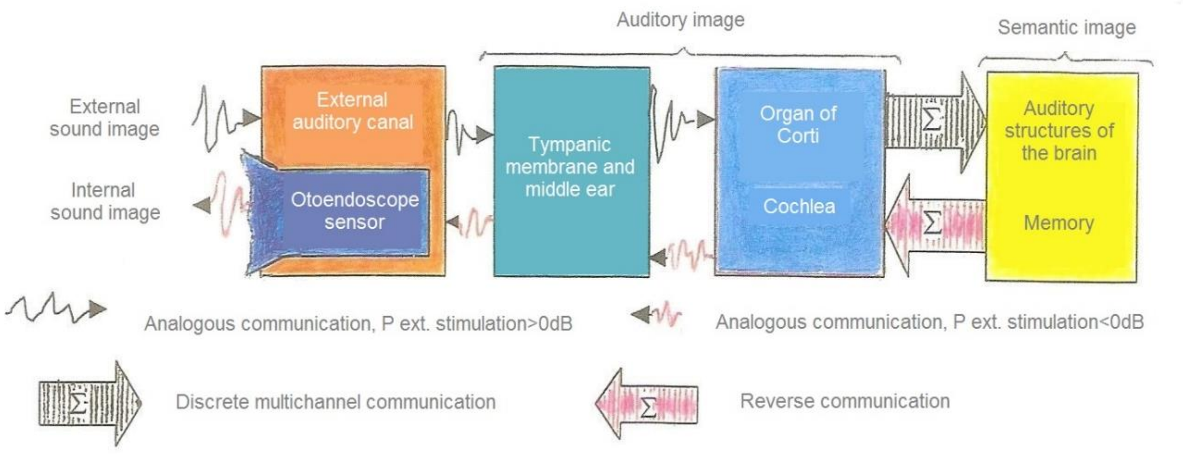


Fig. 3 Structural and functional scheme of identifying the acoustic signals emitted by the Organ of Corti.

Method

The principle of detection of natural vibrations of the tympanic membrane and the requirements for its construction

Conceptually, let us think of the necessity to determine by touch the dynamics of a movable object and its vibration in a dark place. In case of accidental short touch, the result is likely to be uncertain. The task is simplified when the hand follows the object without violating the trajectory and mode of movement. A similar mechanical analogy may be extended to the principle of recognition of structures and acoustic vibrations of the membrane by an appropriate sensor (e.g., based on micro light-conductor) that moves at a certain distance from the centre of the surface of the tympanic membrane.

Necessity in detector's extremely high sensitivity to the amplitude of vibration of the surface of the tympanic membrane (atomic scale) and at the same time sufficiency of its dynamic range for compensation of large amplitudes of non-informative acoustic excitations from processes of respiration, cardiovascular activity, gastric activity and other spontaneous sound reactions of the surface of the tympanic membrane is determined by the main principles of the design of the detector:

- converting physical parameters of the sensor must be mechanical and optical to avoid significant bioelectronical noise in the zone of location of converting element of the detector;
- end of the micro light-conductor should be covered with a translucent mirror layer of metal;
- micro-volume of the body of the tympanic membrane directly in the zone of thorium and the interval between them during vibration of the surface of the tympanic

membrane should create an environment modulating a light beam, i.e. micro-volume of the body on the surface of the tympanic membrane in its centre should comprise "design element" of the converter.

Physical process in the optical micro contact is based on the natural modulation of energy of the induced emission by the vibration of the tympanic membrane surface in the quasi-resonator comprised of the semi-translucent mirror of the end of the micro light-conductor and a volume of the surface of the tympanic membrane reflecting a part of the light beam.

A proper instrumental implementation of such principle will make it possible to create a microoptical contact with the necessary degree of modulation of light reflected from the surface of the tympanic membrane. The proposed modulation principle was tested on an experimental model to identify sound mode 2168 Hz at the threshold of audibility.

The optimal mode of work of the microoptical contact will be defined by the threshold level of automatic stabilization of its parameters and value of the intensity of the reference beam without the risk of destruction of micro contact area of the surface of the tympanic membrane.

It should be noted that the proposed detector should be an integral part of a multiprocessor system of processing and recognition of dynamic images with critical quality of specifications.

Pilot scheme of the otoendoscope detector design

The otoendoscope on the inlet comprises a pair of detectors of natural vibrations of the tympanic membrane surface, which should be symmetrically positioned on the sound-absorbing headband according to the previously obtained topograms of external auditory canals (EAC) in the head of the patient.

The following adjustment process involves putting detectors (Fig. 4) in a position against the outer tympanic membrane surface 1, in which a microoptical contact between them should occur.

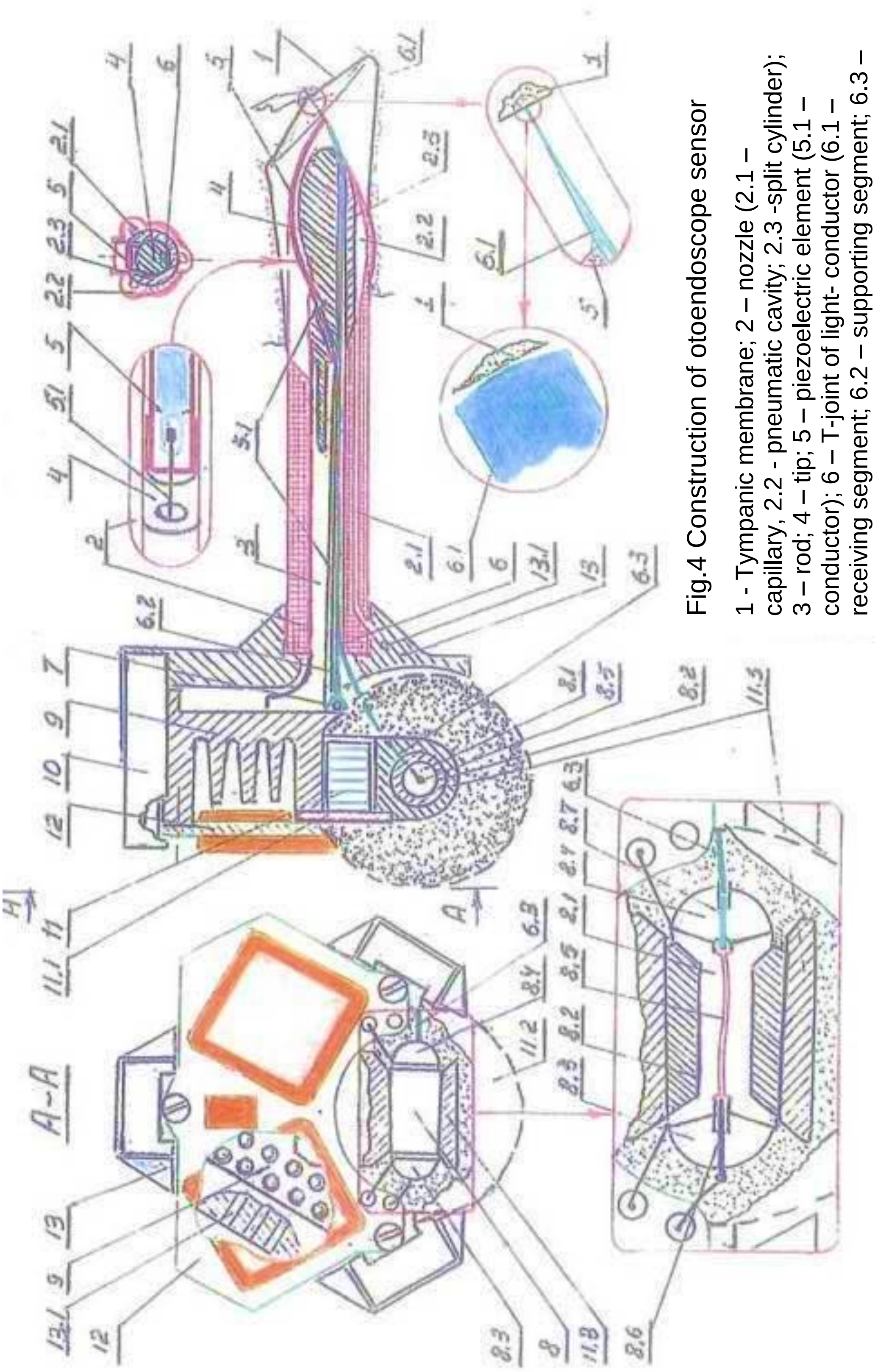


Fig.4 Construction of otoendoscope sensor

1 - Tympanic membrane; 2 – nozzle (2.1 – capillary, 2.2 - pneumatic cavity; 2.3 -split cylinder); 3 – rod; 4 – tip; 5 – piezoelectric element (5.1 – conductor); 6 – T-joint of light- conductor (6.1 – receiving segment; 6.2 – supporting segment; 6.3 – informative segment); 7 – light emitting diode;

8 – dynode (8.1 – central part; 8.2 – metal ceramic soldered joint; 8.3 – anode section; 8.4 cathode section; 8.5 – microchannel; 8.6 – collector of electrons; 8.7 – segment of light-conductor); 9- radiator; 10- piezoelectric linear engine; 11- mini-cryoblock (11.1 - switchoard panel; 11.2 – external heat isolator; 11.3 – collector of cool joints); 12 - VLSI- processor board; 13 - frame-conductor (13.1 – capillaries)

A flexible sound-absorbing nozzle 2 is entered into the EAC with three capillaries 2.1 and pneumatic cavities 2.2 at their ends formed by platinum-iridium cut cylinder with anti-friction finish inside its surface 2.3, affixed to the nozzle 2, and unattached sections of the material of the nozzle 2 at the end of each capillary 2.1. Thus, at the end of the nozzle 2 pneumatic cavities are formed. These pneumatic cavities are individually height-adjustable which allows to fit the nozzle 2 into the necessary position in accordance with parameters of EAC.

Inside the nozzle 2 along its axis there is a moving probe which consists of a flexible electrically conductive sound absorbing rod 3 connected to the platinum-iridium tip 4; piezoelectric element 5 [11], fixed by electrically conductive cement in cam slot of the tip 4; and optical fibrous T-joint 6 of the light-conductor [12]. Rod 3 and tip 4 have matching canals, which contain T-joint 6 of the light-conductor as well as the isolated conductor 5.1 for power supply to the piezoelectric element 5. Segment 6.1 of the T-joint fixed to piezoelectric element 5 has a conical shape and radial gradient of refractive index [13], and then changes into a short segment of a fiber light-conductor, the end of which is covered with a layer of half-transparent mirrored layer of metal. Microoptical contact is created between the end of the segment 6.1 of the T-joint and the EAC.

The segment 6.2 of the T-joint is connected to the emitting diode 7 fixed in the canal of the rod 3, and the informative segment 6.3 of the T-joint is fixed to the microchannel photoelectron multiplier - dynode 8 (hereinafter referred to as dynode 8) [14]. Rod 3 and light emitting diodes 7 are glued to the needle fin 9 which is moved by three reversible piezoelectric linear micro engines 10. Thus, the probe is shifted from the operating point to non-operating and vice versa in the nozzle 2 like in the fuse case protecting the segment 6.1 of the T-joint from damage.

The radiator 9 serves as a heat spreader of the thermoelectric minicryoblock 11 which cools dynode 8 built into the collector 11.3 of cool soldered-joints. On radiator 9 a metal plate 12 is fixed with two-sided assembling of shielded micro powerful VLSI- processors servicing the sensor. Piezoelectric linear microengines 10 are glued into the frame-conductor 13 with three capillaries 13.1 compatible with capillaries 2.1.

Dynode 8 in its central part 8.1 has a metal-ceramic soldered joint 8.2 to limit temperature (in technological sense). Place of soldering of ceramic anodic 8.3 and cathodic 8.4 parts of dynode 8 to the central section 8.1 is respectively anode and cathode which are connected electrically with each other by the surface of the microchannel 8.5. Collector of electrons 8.6 is electrically isolated from the anode 8.3. The light-conductor 8.7 is soldered into the cathode part 8.4.

Photocurrent amplification coefficient of the dynode 8 should not be made too high in comparison with usual photoelectron multipliers. It should be sufficient for its operating in the modulation mode, the so-called "fat zero", corresponding to the level of noise of the synchronous amplifier entry which is connected to the collector 8.6. Thus, the radiator 9 is an automatically movable platform that brings the part 6.1 of the T-joint into microoptical contact with tympanic membrane surface and necessarily the moment before the maximum displacement of the working area of the tympanic membrane surface to the EAC.

Maintainance of the operating microoptical contact during natural vibrations of the tympanic membrane surface should be achieved by means of piezoelectric element 5 (segnetoelastic class) as actuator of reverse communication loop "microoptical contact - photoelectron transformer - correcting filter - microoptical contact parameter regulator."

Offers on technology of manufacturing

Making of the dynode 8 is seen as the most labour-consuming process since it requires the use of ultrapure materials and premises with the high-vacuum technological equipment [15].

Coating of the microchannel 8.5 needs to be applied using a LPCVD-method in non- hydrogenous environment in the form of an ultra-thin film; structure of the latter is modified during the process of coalescence in an island one while a monoatomic oxide layer is formed on the surface. For deposition of the said coating, the reagents should be supplied directly into the microchannel 8.5 through the capillary nozzle by means of reversing injection.

Making of an electric dynode 8 should be carried out upon limiting the temperature of the coating of a microchannel 8.5 in order to prevent its destruction. The final operations in making the sensor of a detector of an otoendoscope shall be gluing the tip 4 to the piezoelectric element 5 to which, in their turn, a conductor 5.1 and a receiving end 6.1 of a T-joint 6 of a light-conductor are attached.

Conclusion

The author supposes that the natural spectrum of otoacoustic noise contains a verbal component corresponding to thinking brain activity, and proposes a technical otoendoscopy means to test this assumption.

It is necessary to emphasize that implementation of the proposed ideas is quite possible and falls within the scope of current achievements in the scientific and technical fields, namely medical instrument engineering, photo- and optical electronics, microelectronics, digital technology for pattern recognition (SNR enhancement), cryogenic technique, technology of production of ferroelectric and sound resistant elastics and ultra-pure materials.

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