Ultrasound Piezo Elements in Medical Technology

Tool, Therapeutic Device and Sensor

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Ultrasound is sound with frequencies above the range of human hearing frequencies starting at around 16 kHz. This range is used for many purposes in medical engineering, but also in industry, and research. The spectrum of applications in medical technology extends from pumping and dosing to diagnostics and therapy. Piezoelectric ceramics offer excellent properties for generating and detecting ultrasonic waves. They can be manufactured cost-effectively in almost any shape and thus offer tailor-made solutions for different applications.

Piezoelectric materials can produce an electric voltage when a force is applied to them (piezo effect), and they can change their dimensions when an electric field is applied (inverse piezo effect). They convert mechanical power into electrical power and vice versa; they are also referred to as piezoelectric transducers. While the direct piezo effect can be used for sensor applications, the inverse piezo effect is used for the manufacture of actuators. The motion is exclusively based on solid state effects, i.e. it is frictionless and wear-free. Piezos also do not generate any magnetic fields and are not influenced by them.

Short Response Times, High Dynamics and Flexible Designs

The creation and detection of ultrasound, for example, is a classic piezo application because the piezo element starts to oscillate when an a.c. voltage is applied. The short response times and the high dynamics of this motion naturally also benefit ultrasound generation.

The piezo elements from PI Ceramic are suitable for a multitude of ultrasonic applications. These can be generally classified in mainly sensor applications for frequencies of up to 20 MHz and power ultrasound, in which the energy densities are higher.

As a result, the piezo elements accomplish considerable mechanical work, e. g. in crushing kidney stones or removing dental plaque. The typical frequencies of power ultrasound are between 20 and 800 kHz.

With piezo components, different geometric variants and resonant frequencies can be realized in addition to the material selection for the respective application (Fig. 1); components such as disc- or plate-shaped transducers in thickness vibration mode, piezoceramic rings, piezo tubes and shear elements with standard dimensions can be delivered on very short notice on the basis of semi-finished products in stock. Geometries beyond the standard dimensions are also available upon request.

PI Ceramic furthermore ensures integration in the final product. This includes the electrical contacting of the elements according to customer specifications as well as mounting in third-party components, as well as gluing or potting of the ultrasonic transducers. To measure the flow, filling level and force or acceleration, customized sensor components are manufactured that can be easily integrated in the respective application.

Fig. 1 Many variants of piezo elements are possible, e.g. tubes, disks, benders, shear elements or transducers, which makes it easy to adapt them to the respective application

Aerosol production for respiratory therapy

There are a wide variety of application areas for piezoceramic components in medical technology. Therapeutic devices are a typical example. The treatment of respiratory diseases often involves medication being directly applied with atomizers. Conventionally, pressurized air atomizes the inhalation solution into minute droplets. An alternative method is to generate minute droplets with the aid of piezo technology. Specially shaped piezo disks act as ultrasonic transducers and excite a stainless-steel diaphragm with several thousand holes to execute ultrasonic vibrations at 35 kilohertz (Fig. 2). This produces particularly homogenous aerosols. This is advantageous for precise dosing – the administration of high-quality drugs can be better targeted allowing access to new therapeutic concepts. The risk of side effects is also reduced. Moreover, piezo technology reduces the time required to atomize medications by up to 50% compared to conventional systems. For patients with chronic respiratory diseases in particular, this means an improvement in their quality of life.

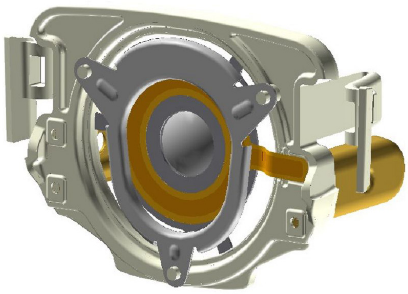

Fig. 2 The piezo ring is directly glued to the metal ring of the diaphragm. When an a.c. voltage is applied, the piezo element oscillates with a frequency of approx. 35 kHz (Image: Pari Pharma/PI)

Even the special hygiene requirements which come with medical engineering applications are mastered by piezo ceramics; the aerosol generators can be professionally sterilized in autoclaves. The ultrasonic operation is noiseless for humans, and the low power consumption of the piezo component also allows battery operation.

Propagation time measurements for bubble-free flow and patient-friendly sonography

In medical applications it is often necessary to ensure there is an undisturbed flow without air or gas bubbles, e.g. in dialysis, with transfusion pumps. This can be done with the aid of ultrasonic technology in so-called air-bubble detectors. The piezo elements in these sensors serve to generate and receive ultrasonic waves. The propagation time of the ultrasound signal is evaluated (Fig. 3).

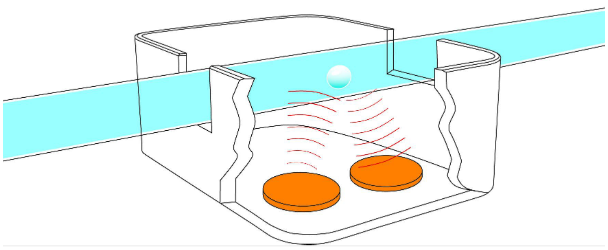

Fig. 3 The propagation time measurement is based on the alternate transmission and receiving of ultrasonic pulses in and against the direction of flow

The sensors are mounted on the outside of flexible tubes and operate without coming into contact with the medium to be transported; they therefore do not interfere with the flow rate, nor is there any danger of contamination. The nonmagnetic piezo technology means that, when the electronics are shielded appropriately, it is even possible to operate in an extreme environment, such as in the vicinity of magnetic resonance tomographs.

Sonography, whose advantages derive mainly from the harmlessness of sound waves, is likewise based on the principle of propagation time measurement. The ultrasonic transmitter contains a piezo element, which generates ultrasonic waves and also detects them again. It emits short, directional sound wave pulses which are reflected and scattered by the tissue layers to different degrees. By measuring the propagation time and the magnitude of the reflection an image of the structure under investigation can be produced.

In addition to propagation time measurements, typical applications for piezo elements are in pumping and dosing (Figure 4). The dosing amounts range from the microliter and nanoliter range to the picoliter range. Here, piezo-based microdosing systems stand out due to their very small dimensions, their low energy consumption and low costs.

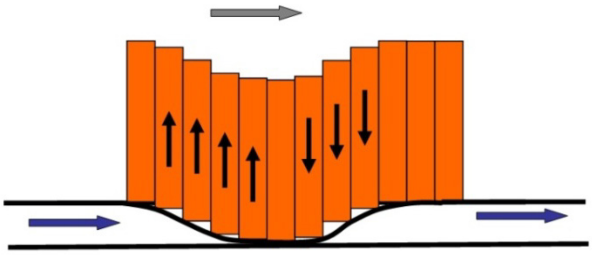

Fig. 4 In addition to propagation time measurements, typical applications for piezo elements are in pumping and dosing; the picture shows a tube pump

Tools and therapy methods with ultrasound

Further interesting applications are found in the area of power ultrasound. Nowadays, instruments with ultrasonic drives allow minimally invasive surgical techniques in eye and oral surgery. Devices based on ultrasound are frequently used for liposuction and removing dental plaque (Fig. 5) and they have been using piezo elements as sound generators for quite some time.

Fig. 5 Instrument for ultrasonic plaque removal (OEM product); the piezo disks can be clearly seen

Therapeutic methods working with ultrasound methods involve irradiating the tissue with ultrasonic waves by means of an ultrasonic transmitter. Mechanical longitudinal waves generate mechanical vibrations in the tissue, which can promote healing processes, for example. A part of the ultrasound energy is simultaneously converted into heat. Typical working frequencies for the piezo elements are in the range 0.8 to over 3 MHz, both continuous wave and pulsed wave ultrasonic techniques being used in the application.

Different effects can be achieved depending on the energy of the waves. High-energy shock waves are used to destroy kidney stones, for example. Low-energy shock waves effect a type of micro-massage, and are used for the treatment of bones and tissue in physiotherapy among other things.

In cosmetic applications ultrasonophoresis, i.e. the introduction of drugs into the skin, is becoming increasingly important.The field of applications for piezo elements in medical technology is thus constantly expanding.

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About the PI Group

Over the last four decades, PI (Physik Instrumente) with headquarters in Karlsruhe, Germany, has developed into the leading manufacturer of positioning systems with accuracies in the range of only a few nanometers.

With four company sites in Germany and ten sales and service offices abroad, the privately managed company operates globally. More than 700 highly qualified employees all over the world enable the PI Group to fulfill almost any requirement from the area of innovative precision positioning technology.

All key technologies are developed in-house. This allows the company to control every step of the process, from design right down to shipment: precision mechanics and electronics as well as position sensors. The required piezoceramic elements are manufactured by our subsidiary PI Ceramic in Lederhose, Germany, one of the global leaders for piezo actuator and sensor products.

The PI miCos GmbH in Eschbach near Freiburg, Germany, is a specialist for positioning systems for ultrahigh vacuum applications and parallel-kinematic positioning systems with six degrees of freedom and custom-made designs.

PI headquarters in Karlsruhe, Germany: More than 350 employees work on high-resolution drive systems and positioning systems