Ultrasonic Piezo Elements have Countless Applications

From Sonar to Welding Equipment

Ultrasound is sound with frequencies above the range of human hearing frequencies starting at around 16 kHz. These high-frequency oscillations are used for many purposes in industry, medical engineering and research. The spectrum ranges from distance measurement and object recognition, filling level or flow rate measurements, ultrasonic welding or bonding, through high-resolution material tests, up to medical diagnosis and therapy. Piezoelectric ceramics offer the best prerequisites for generating and detecting ultrasonic waves. They can be cost-effectively manufactured in practically any shape and are thus suitable as tailor-made solutions for diverse applications.

Piezoelectric materials produce an electrical charge when a force is applied to them (piezo effect), and they change their dimensions when an electrical field is applied (inverse piezo effect). In other words, they convert mechanical power into electrical power and vice versa; they are also referred to as transducers. While the direct piezo effect can be used for sensor applications, the inverse piezo effect lends itself particularly to the manufacture of actuators. Their motion is exclusively based on solid state effects, and is friction- and wear-free.

Frequencies and Amplitudes

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 in the microsecond range allow for ultrasound generation with frequencies of up to 20 MHz.

The piezo elements from PI Ceramic are thus suitable for a multitude of ultrasonic applications. These can be generally classified in mainly sensor applications in the high-frequency range and power ultrasound where the energy densities are higher.

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

Design Flexibility

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 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 contacting of the elements according to customer specifications as well as mounting in provided components, 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

Application Examples from Practice

The range of applications for piezoceramic components is diverse. The direct as well as the inverse piezo effect is used in ultrasonic measurement of propagation times. A typical application for propagation time measurement is the measurement of filling levels. The piezo transducer works as a transmitter and a receiver.

It transmits an ultrasonic pulse that is reflected by the filling medium. The propagation time required is a measure of the distance travelled in the empty part of the container. Flow measurement is based on the propagation time difference during alternate transmission and receiving of ultrasonic pulses in and against the flow direction (Fig. 2).

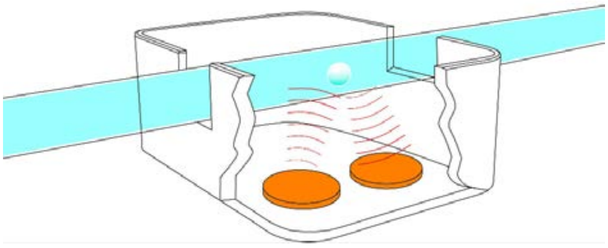

Fig. 2 The propagation time measurement is based on the alternate transmission and receiving of ultrasonic pulses in and against the direction of flow

Here, two piezo transducers operating as both transmitter and receiver are arranged diagonally to the direction of flow in an acoustic path. With the Doppler effect, the phase and frequency shift of the ultrasonic waves which are scattered and reflected by particles of liquid are evaluated.

The frequency shift between the reflected wavefront emitted and received by the same piezo transducer is proportional to the flow speed. Many other tasks can be effectively solved in a similar way, such as e.g. object recognition or high-resolution material tests.

Piezo elements have also become indispensable in medical engineering. In addition to propagation time measurements such as in air bubble detection, typical applications are in pumping and dosing.

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.

The same also applies to devices for aerosol generation (Fig. 3), in which a piezo element excites a diaphragm to ultrasonic vibrations. The frequency is approx. 35 kHz. Due to the resulting pressure changes at the diaphragm, the fluid is pressed through the holes in the diaphragm and thereby aerosolized.

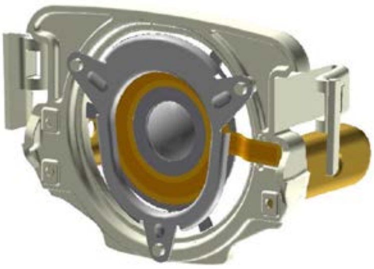

Fig. 3 The piezo ring is directly glued to the metal ring of the diaphragm. When an a.c. voltage is applied, the piezo element oscillates with a frequency of approx. 35 kHz (Pari Pharma/PI)

Further interesting applications are found in the area of power ultrasound. In industry, ultrasonic welding – primarily of plastics – and the bonding of wires in chip manufacturing are considered a cost-effective, efficient solution. Another industrial application is ultrasonic cleaning, also in microsystems technology and semiconductor manufacturing (Fig. 4).

Fig. 4 High-frequency ultrasonic cleaning systems offer effective support for cleaning, etching and development processes (Sonosys Ultraschallsysteme GmbH)

Today, ultrasonic instruments allow minimally invasive operation techniques as well as plaque removal (Fig. 5). Kidney stones can also be crushed with high-energy shock waves.

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

Ultrasonic Cleaning in Microsystems Technology and Semiconductor Manufacturing

For micro-level cleaning systems, it is a challenging task not to damage tiniest structures on the surface to be cleaned. Ultrasonic systems that work with operating frequencies between 700 kHz and 3 MHz are best suited for this (Fig. 6).

With these systems, dirt particles can be removed reliably in the nanometer range without damaging the sensitive surfaces by a too high pressure or too high temperatures. The functional principle is easy to understand:

The ultrasonic system consists of three components: The electronic ultrasonic generator, the ultrasonic oscillator/transducer, a piezo element, and an appropriate cleaning fluid, selected according to the cleaning task.

The ultrasonic generator converts the supplied alternating current of 50 Hz or 60 Hz respectively to a frequency that corresponds to the operating frequency of the transducer. The transducer then converts the released electric energy into mechanical acoustic oscillations causing the surrounding fluid to oscillate.

Each oscillation leads to an over-pressure phase or low-pressure phase in the fluid, depending on whether the transducer expands or contracts. During the low-pressure phase, due to the fluid's limited tensile strength, small cavities form in the fluid; these so-called cavitation bubbles implode during the over-pressure phase. When the cavitation bubbles implode at the surface to be cleaned, dirt particles are removed.

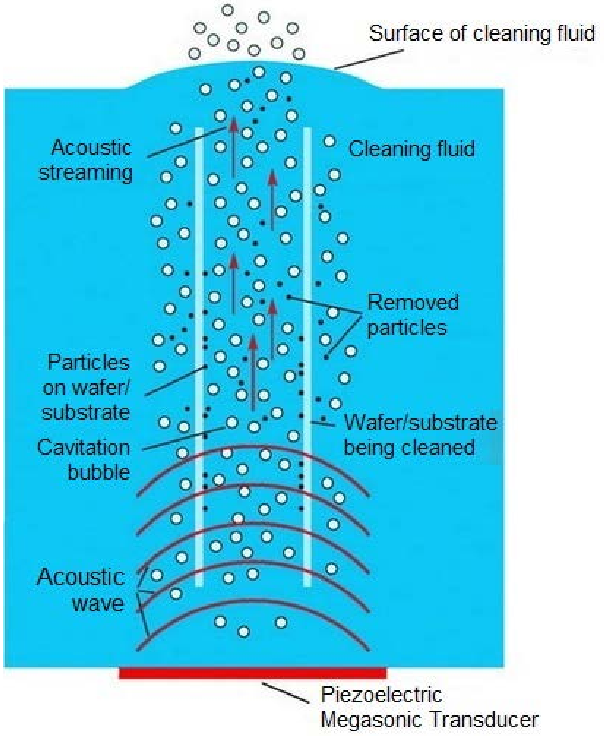

Fig. 6 Principle of Megasonic cleaning (Image: Sonosys Ultraschallsysteme GmbH)

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PI Ceramic in Brief

PI Ceramic is considered a global leading player in the field of piezo actuators and sensors. The broad range of expertise in the complex development and manufacturing process of functional ceramic components combined with state-of-the-art production equipment ensure high quality, flexibility and adherence to supply deadlines.

Prototypes and small production runs of custom-engineered piezo components are available after short processing times. PI Ceramic also has the capacity to manufacture medium-sized to large series in automated lines. PI Ceramic, a subsidiary of Physik Instrumente (PI) GmbH & Co. KG, is located in the city of Lederhose, Thuringia, Germany.

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