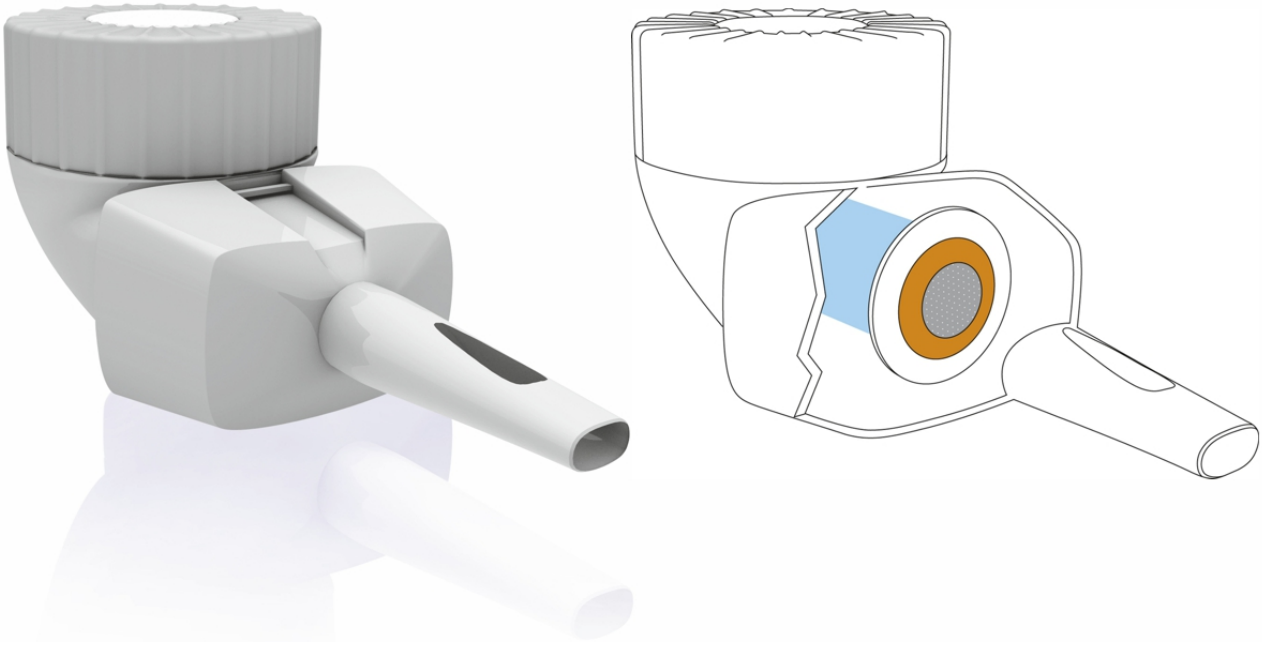
Dipl.-Phys. Steffen Arnold & Dipl.-Ing. Elmar Uhlitzsch

Piezo Actuators: Drives and Testing Aids for Inhalation Devices

Creating Oscillations – Measuring Oscillations



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Piezoelectric materials convert electrical energy directly into mechanical energy and vice versa. This presents interesting possibilities: the motion that results when an electric a.c. voltage is applied to a piezoelectric material is very important for creating oscillations, for example. Actuators exploiting this piezo effect move with resolutions in the sub-nanometer range, with high dynamics and frequencies of up to several thousand hertz.

In the application described in the following, this is of double advantage: in inhalation devices, piezoelectric elements ensure an even aerosolization of medicine, and the piezos are the driving force in function testing of the aerosol heads as well.

Fig. 1 The inhalation system eFlow®rapid works very efficiently with comparatively short inhalation times and thus meets the needs of patients very well (Image: Pari Pharma)

Oscillations manifest themselves in different ways: they can be disturbing or even destructive, e.g. in the case of imbalance, noise, friction or impact. On the other hand, they also have a positive effect, e.g. as music or in therapeutic applications, for example to treat respiratory disorders. During inhalation, liquid medication has to be aerosolized in very fine droplets, and the drug mist has to be mixed into the respiratory air as homogeneously as possible. For this purpose, Pari Pharma GmbH has developed the inhalation system eFlow®rapid (figure 1), an innovative device that works very efficiently with comparatively short inhalation times.

Fig. 2 A piezo element excites the diaphragm of the nebulizer to execute ultrasonic oscillations. The fluid is pressed through the roughly 3000 fine holes in the diaphragm and thereby aerosolized (Image: Pari Pharma)

The reservoir of the inhalation device is first filled with the desired dose of medicine, and the aerosol is then created in the nebulizer (figure 2) using a perforated steel diaphragm. "A piezo element excites this membrane to execute ultrasonic oscillations at approx. 120 kHz," is how Phillip Holzmann (figure 3), Head of the Microsystems Development Group at Pari Pharma explains the functioning of the nebulizer. "Due to the resulting pressure changes at the diaphragm, the fluid is pressed through the holes in the diaphragm and thereby aerosolized. The approximately 3000 holes in the diaphragm have a diameter of roughly 2 µm. This guarantees a defined droplet size distribution."

Fig. 3 Philipp Holzmann, Head of the Microsystems Development Group at Pari Pharma (Image: Pari Pharma)

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Convincing Arguments for the Piezo Element

There were simultaneously several reasons for selecting a piezo element as the driving force in the aerosol generation. The creation of vibrations, for example, is virtually a classic piezo application because the piezo element starts to oscillate when an a.c. voltage is applied. Since the annular piezo (figure 4) is directly glued to the metal ring of the diaphragm, the diaphragm oscillates along with it. The amplitude is in the range of a few µm. "The oscillation generated by the piezo element thus perfectly suits the application in respect to frequency as well as displacement", Holzmann explains. The short response times of the piezos and the high dynamics of the motion naturally also benefit the application as a diaphragm drive.

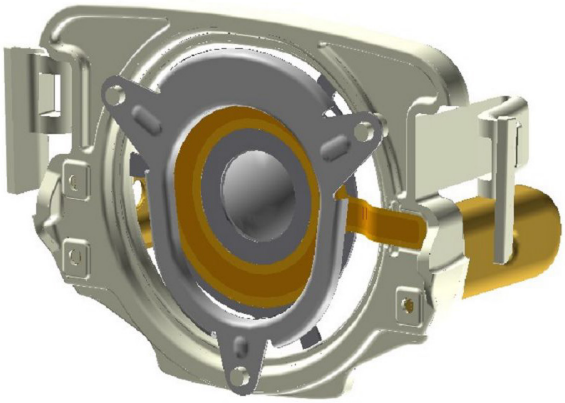

Fig. 4 The annular piezo is directly glued to the metal ring of the diaphragm. When the a.c. voltage is applied, the piezo element oscillates with a frequency of 120 kHz (Image: Pari Pharma/PI)

However, there are further arguments that speak for the use of piezos in aerosol nebulizers: Since the motion is based on crystalline solid-state effects, there is no danger of abrasion with this technology and there are no cogwheels, bearings or other mechanical parts subject to wear. Piezos do not generate any magnetic fields and are not influenced by them. Changing ambient temperatures do not interfere with the piezo effect either.

"We have also found an established and competent manufacturer in PI Ceramic (figure 5), which modifies and produces the piezo elements specifically for our application conditions", adds Holzmann.

Fig. 5 Many variants of the basic structure of piezo elements are possible, for example piezo tubes, disks, shears or translators, which makes it easy to adapt them to the actual application

Quality Assurance of the Diaphragms Directly in the Manufacturing Process

For patients to benefit from the new inhalation system, the nebulizer system must function flawlessly. For this reason, the manufacturer relies on 100% testing.

"In principle, an electrical impedance test that can detect particular oscillation characteristics of the component (figure 6) would also be possible" continues Holzmann. "In the end, however, we did not believe that this method was precise and reliable enough. Since the oscillation behavior had already been optimized with a scanning vibrometer during the development phase, we were able to use the knowledge gained from this to determine measuring points that yield quality-relevant results in oscillation measurements during production. We therefore decided to use a laser vibrometer in quality control as well."

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Deviations in the diaphragm quality, e.g. due to deformations during assembly or errors in the adhesion process, can be reliably detected with the optical oscillation analysis.

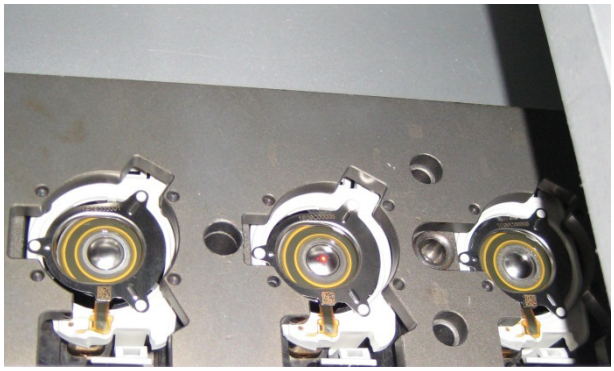

Fig. 6 View of the test items (Image: Pari Pharma)

A semiautomatic measuring station was developed for quality control in production. The main item is a laser vibrometer from the product range of Polytec, which consists of a control unit and a compact measuring head with a flexible fiber optic cable. As part of quality control, the oscillation behavior of the diaphragm is measured contact-free at each aerosol head and the frequency spectrum is determined for each diaphragm. The important measuring points for this were already obtained with the scanning vibrometer during the development phase.

Piezo as the Driving Force during Testing

The piezo also assumes a key role as the driving force during function testing: It is electrically excited in a frequency spectrum between 30 and 300 kHz. Measurements of the oscillation amplitudes within this frequency band and the position of the resonances make it possible to draw conclusions about the diaphragm quality (figure 7).

"The analysis is performed with the testing software QuickCheck from Polytec, which was adapted very well to our requirements and reliably separates good parts and rejects", adds Holzmann.

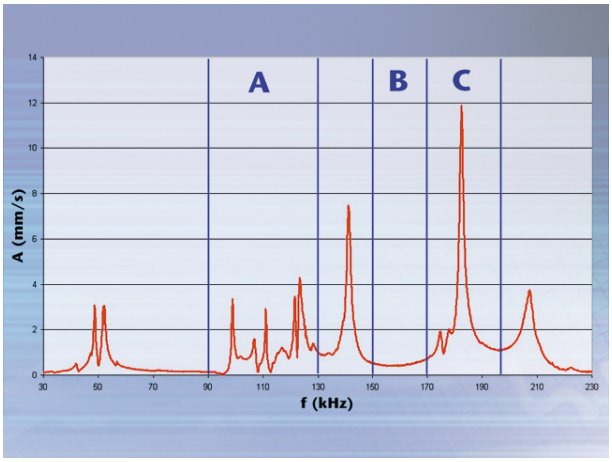

Fig. 7 Quality control with the laser vibrometer: example of the frequency spectrum of a diaphragm (Image: Pari Pharma)

"To evaluate the quality of a measurement, the signal-to-noise ratio is calculated as well." In order to ensure that the laser hits a level position between the holes of the diaphragm on each test item, the measurement is evaluated on the basis of the intensity of the reflected light. If the laser intensity is too low, the measuring point is moved by a few micrometers with a deflection unit until the full intensity is reached (figure 8).

Fig. 8 Integration of the laser vibrometer in the a bench (Image: Pari Pharma/Polytec)

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The 100 percent testing with the laser vibrometer thus ensures that the inhalation systems reliably function during practical use with patients. The piezo elements used also significantly contribute to this because they are the driving force in the aerosol generation as well as in the oscillation testing

Authors

Steffen Arnold, Head of Marketing & Products at Physik Instrumente (PI) GmbH & Co. KG, Elmar Uhlitzsch, Vibrometer Product Manager at Polytec GmbH

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.

About Polytec

As an innovative high-tech company, Polytec has been developing, producing and distributing laser-based measurement technology solutions for research and industry for over 40 years. Building on their success with distribution business, Polytec began developing and manufacturing their own laser-based measuring instruments in the 1970's. Today, the company with headquarters in Waldbronn near Karlsruhe is a worldwide leader in the field of optical oscillation measurement with laser vibrometers. Systems for surface measuring technology, analytic measuring technology as well as velocity and length measurement also belong to their now wide range of innovative products.

About Pari Pharma

For over 100 years, PARI has made a name for itself as a company specializing in treating respiratory disease, with an international reputation. Today, PARI Pharma is developing modern devices for inhalation treatment. With their own research and production, the company has repeatabily succeeded in establishing international standards in aerosol technology. Careful selection of materials, production at their own manufacturing plants and the strictest quality controls guarantee the reliability of their products, the purpose of which is to make life easier for people who suffer from respiratory diseases and those who care for them.

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