Vibration Isolation for Industry, Laboratory and Research

Piezo Actuators Improve Effectiveness, Reliability and Lifetime

If a disturbance knocks a system off balance, this can result in vibrations. Since every vibration is damped by the effect of its surroundings, any system will eventually come to a standstill again by itself. Many applications cannot wait this long, however, especially since what usually happens is that several disturbances temporally superimpose producing a more or less confusing vibration pattern with very different frequencies.

The vibration must then be dampened passively in a suitable way or, even better, the system must be isolated from the source of the disturbances. Active vibration isolation is particularly good at reducing the settling times significantly, the precision of measuring or production processes improves and higher throughputs are possible. Laboratory setups, laser technology, mechanical engineering and optical metrology, microscopy and micromachining, for example, all benefit from this.

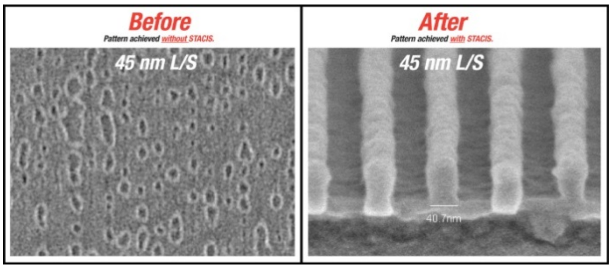

Fig. 1 Test pattern with a line width of 45 nm, without (a) and with (b) STACIS vibration isolation (image: Sematech)

The usual methods of vibration isolation used until now are no longer sufficient for many of today's technologies. Movements and jolts caused by footfall, fans, cooling systems, motors, machining processes etc. can distort patterns for micromachining, for example, to such an extent that the result is unusable. In addition, conventional pneumatic decouplers are ineffective at interference frequencies below 2 Hz. Fig. 1 shows a typical example: When a lithography device does not have sufficient vibration isolation, the 45 nm wide lines are practically not discernable (a).

The picture next to it (b) shows the result when the vibration isolation uses active methods which not only dampen the vibration but actively oppose it.

Fig. 2 Piezoelectric active STACIS vibration isolators with controller (image: TMC)

The problem solver here was an active isolation system from the STACIS range developed by TMC Technical Manufacturing Corporation (Fig. 2). It makes it possible to isolate very low oscillation frequencies starting at the sub-hertz range and thus prevents the vibrations having a detrimental effect on the machine installed on it. This not only improves the machining or testing quality but at the same time reduces the settling times (Fig. 3). The cycle times are shortened and the throughput increases.

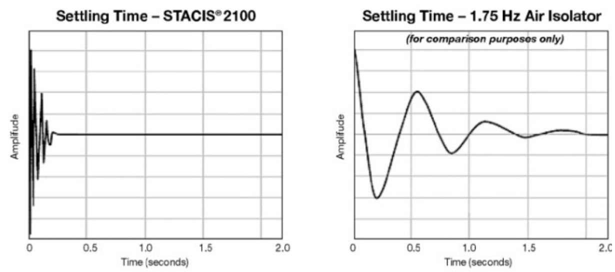

Fig. 3 Settling time as a reaction to the on-board perturbation when loading a microscopy table with the substrate (image: TMC)

Detect and Compensate Vibrations in Six Degrees of Freedom

The active vibration isolators use integrated acceleration sensors to detect vibrations occurring in six degrees of freedom. The counter-movements necessary for the compensation are generated by piezo actuators which are controlled by a real time digital signal processor. This provides the computing power required for the extremely fast calculations of the vibration compensation.

Fig. 4 STACIS isolation is also possible for smaller equipment, e.g. for scanning electron microscopes (image: TMC)

Their great stiffness, high load capacity and clean operation without compressed air make the piezo-based active isolators suitable for integration as OEM components in ultramodern tools and also for installation in isolation platforms for metrology devices or optical lithography systems, which now write with line widths in the nanometer range thanks to modern laser technology.

The isolator can also work well with existing conventional pneumatic isolators, supplement them in the lower frequency range, and can even be retrofitted with ease in many applications. Suitable versions are also available for scanning electron microscopy (Fig. 4), and their compact size means they can be integrated well in the comparably compact microscopes.

Fast, strong actuators for highly precise motion

The driving force behind the isolators is provided by piezo actuators. Their specific characteristics make them optimally suited to the application in isolators:

They operate with response times of only a few microseconds and resolutions in the sub-nanometer range. At the same time, high accelerations of more than 10,000 g can be achieved and loads up to several tonnes can be moved. Since the piezo effect is based on electric fields, piezo actuators do not generate magnetic fields, neither are they affected by them. Changing ambient temperatures do not affect the piezoelectric effect.

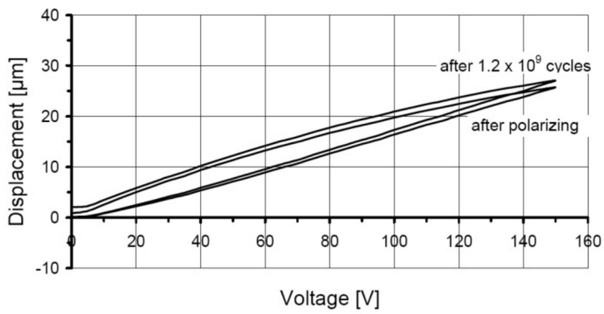

Fig. 5 PI piezo actuators have gone through several billion cycles in endurance tests without measurable changes in their behavior (image: PI)

The technology does not suffer from wear and tear either, because there are no gearwheels, bearings or other mechanical parts. The motion is based on crystalline solid-state effects. Piezo actuators from PI Ceramic/Germany have gone through several billion cycles in endurance tests without measurable changes in their behavior (Fig. 5).

At the same time, piezos can also score in terms of energy consumption: In static mode they require almost no energy, even if heavy loads are held permanently. The behavior can be compared to that of an electrical capacitor.

Piezos for Active Vibration Isolation

The piezo actuators used by TMC are from the PICA series (Fig. 6) and originate from PI Ceramic, a subsidiary of Physik Instrumente (PI), the Karlsruhe specialist for precision positioning. The actuators are manufactured in a high-tech production plant and supplied in a large range of diameters and overall lengths.

They can be used for almost all actuator applications and are optimally suited to the isolators as well, because they are suitable for high loads and resonant frequencies above 10 kHz, at scanning ranges of more than 100 µm and a blocking force of more than 75 kN.

Fig. 6 Different standard and special versions of PICA piezo stack actuators (image: PI)

In principle these actuators consist of a stack of piezo ceramic disks separated by metal electrodes. For the PICA versions the layers are around 5 mm thick. The thinner the individual layers in the stack, the lower the drive voltage.

Multilayer actuators, where the thickness of the individual layers is only around 60 µm, are thus very attractive for industrial applications (Fig. 7). These actuators already achieve their nominal displacement at operating voltages significantly below 150 V. They are also considered to be very robust. The full-ceramic encapsulation protects them from humidity and failure caused by an increase in the leakage current.

Fig. 7 Patented technology for maximum operating hours and life time: PICMA (Image: PI)

The so-called piezo stepping drives (Fig. 8) are also of interest for applications in the field of vibration isolation. They can cover large travel ranges for adjustment, on the one hand, and on the other can act like conventional piezo actuators, i.e. they can isolate vibrations thanks to their high stiffness of a few micrometers. In the semiconductor industry they are therefore used in conjunction with lithographic methods to fabricate structure widths of only a few 10 nm without interference and reproducibly. Piezo actuators thus open up interesting possibilities for active vibration isolation in a large variety of application fields.

Fig. 8 In the semiconductor industry, piezo step actuators are therefore often used in conjunction with lithographic methods to manufacture structure widths of only a few 10 nm without interference and with high reproducibility (Image: PI)

About TCM

TMC Technical Manufacturing Corporation was established in 1969. Its headquarters are in Peabody, Massachusetts and the company is now considered to be the technology leader for products in the field of vibration isolation. Isolation devices from TMC were already in place when the first transistors were manufactured at Western Electric.

The spectrum now ranges from simple, low-cost desktop microscopes with vibration-isolated base right through to the active vibration systems of the STACIS range, which are equipped with sensors, piezo actuators and digital controllers and are supplied in a large variety of sizes. Customers include large research centers, OEM and end users in the field of semiconductor manufacture and many companies working in the field of nanotechnology, e.g. in microscopy and microbiology.

About PI

In the past four decades, PI (Physik Instrumente) with headquarters in Karlsruhe, Germany has become the leading manufacturer of nanopositioning systems with accuracies in the nanometer range. With four company sites in Germany and fifteen sales and service offices abroad, the privately managed company operates globally. Over 850 highly qualified employees around the world enable the PI Group to meet almost any requirement in the field 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 its subsidiary PI Ceramic in Lederhose, Germany, one of the global leaders for piezo actuator and sensor products.

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

Author

Dipl.-Phys. Steffen Arnold, Head of "Marketing and Products" at PI (Physik Instrumente)