Applying Extremely Thin Layers in a Vacuum Chamber: Hexapods Proven and Tested in Particle Accelerators

Hexapods of Physik Instruments (PI) allow individual positioning in all six axes. Their parallel-kinematic structure is considerably more compact and stiffer than that of serially stacked multi-axis systems. Moreover, there is no accumulation of guiding errors and tilt errors of the individual axes. The pivot point can be selected as desired via software commands and remains independent of the motion.

This is why Hexapods are often the method of choice for high-precision positioning tasks. With their different designs, they cover a wide range of applications and, when designed accordingly, their use in high vacuum does not present a problem either.

Hexapods are very versatile (Fig. 1), since, depending on design, they can position loads ranging from a few kilograms to a few hundred kilograms or even to several tons in any desired orientation in space, that is, independently of their mounting direction, at high precision. Since only one platform is moved, which usually also has a large aperture, the mass moved by the parallel-kinematic Hexapods is much less lower than that of serial, stacked multi-axis systems. This results in a much quicker response and significantly improved dynamics. Furthermore, no cables have to be moved, which would reduce accuracy due to additional forces and torques. Hardly surprising, then, that Hexapods have now opened up fields of application in many industrial sectors, ranging from mechanical engineering and tool machining to semiconductor manufacturing, astronomy, biotechnology, life sciences or material research.

Keywords
high precison multi-axis system, pulsed laser deposition system, piezo actuators

Suitable solutions for a wide range of tasks

Physik Instrumente (PI), based in Karlsruhe/DE, offers, for example, a wide range of Hexapods, which cover almost all possible areas of application. The Hexapods are based on electromechanical drives, thus making them much more accurate than hydraulic Hexapods, known from flight or driving simulators. Depending on the application requirements, they are driven by high-precision drive screws and precisely controllable DC motors or directly by linear motors, e.g. based on piezo actuators. Matching digital controllers (Fig. 2) and extensive software support make it easy for the user to solve each positioning task without great effort.

An example of a particularly compact Hexapod, which has been tested and proven, for example, also in high-vacuum applications, is the H-811 (Fig. 3). At a diameter of only 130 mm and a height of 115 mm, it provides travel ranges of up to 35 mm in the XY plane and up to 13 mm in the Z direction. It is in particular the large tilting angles of up to 20° around the X and Y axes and of up to 40° around the vertical axis that make this Hexapod so versatile. In doing so, it can position loads of up to 5 kg and achieve velocities of up to 10 mm/s. Each individual strut has a positioning resolution of 40 nm, and positioning can be done at a repeatability of better than 1 µm.

Development of functional thin-layer materials

This compact Hexapod has found an interesting application in a PLD system (Pulsed Laser Deposition System), in which it is used in a synchrotron beamline. In particle

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Fig. 1
Hexapods are very versatile, since, depending on design, they can position loads ranging from a few kilograms to a few hundred kilograms or even to several tons in any desired orientation in space, i.e. independently of their mounting direction, at high precision (source: PI)

Fig. 2
Powerful digital controller with open software architecture (source: PI)

Fig. 3
The compact Hexapod is available in a version for vacuum environment of up to 10^{-6} hPa (source: PI)

accelerators of this type, X-ray diffraction and reflections of the synchrotron radiation can be used to investigate the structural properties of thin films as part of modern material research under high-vacuum conditions. To this end, high-energy and short-wave (UV) light is used to take the starting material, a so-called solid target, to the gas phase and then deposit it as a layer on the substrate.

For direct use in such a beamline, *SURFACE* has now developed a new all-in-one system, which impresses in particular with its compact design (Fig. 4) and has already been tested and proven in a first project, offering scientific and commercial users the opportunity to further develop innovative technologies. The transfer mechanism integrated into this PLD system enables it to be installed on a goniometer in the synchrotron beam within a few minutes. This allows the entire system to be moved, without changing the position of the sample. Accordingly, PLD growth processes can be optimized ex situ, while the synchrotron is only occupied during the actual in situ analysis. Further characteristics of the beamline PLD system are the laser heating, which can heat the substrates up to 1200 °C, and the simple loading. *Wolfgang Stein* (Fig. 5), Managing Director and owner of SURFACE, underlined the user friendly design of the system. "The vacuum chamber can be opened, for example for maintenance work, without changing the alignment of the sample to the goniometer. Another

Fig. 4
New beamline PLD system for in situ synchrotron diffraction (source: SURFACE)

Fig. 5
Dipl.-Ing. Wolfgang Stein,
Managing Director of SURFACE:
"The Hexapod, designed by PI for use in high vacuum, positions the sample, relative to the incident X-rays"
(source: SURFACE)

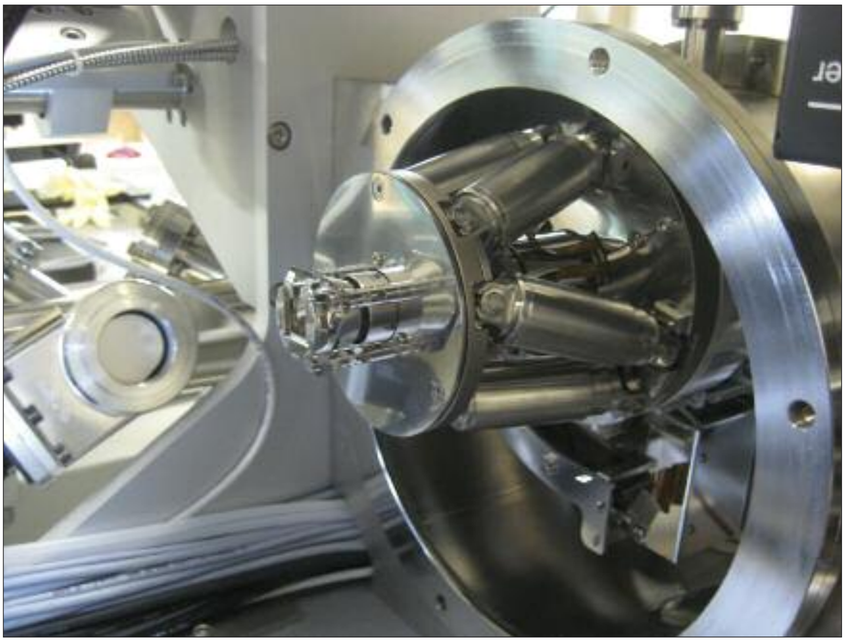

Fig. 6
The sample manipulator allows a wide angle range of the X-rays due to its small size even at low substrate heights (source: SURFACE)

special feature is the sample manipulator, which allows due to its small size a wide angle range of the X-rays even at low substrate heights."

Hexapod in the sample manipulator

The sample manipulator (Fig. 6) holds the 10 mm × 10 mm substrates. The Hexapod, designed by PI for use in high vacuum, positions the sample, relative to the incident X-rays. This allows the sample to be tilted by ±5° around the X and Y axes at a resolution of 0,001°. In addition, to compensate for different layer thicknesses, it can be moved in the direction of the Z axis, i.e., vertically to the sample surface, by up to 3 mm. Motions of ±6 mm in the X and Y directions allow scans at different positions of the sample surface. The Hexapod is mounted on a rotary stage, which can perform further positioning tasks if required, for example, in order to carry out so-called RHEED measurements (Reflection High-Energy Electron Diffraction) during the growth process or orienting the sample holder towards the lock chamber when preparing a sample change.

To give the appropriate commands to the Hexapod system, the Hexapod controller communicates with the superior control of the PLD system. All motion commands are specified in Cartesian coordinates, while all transformations to the single drives are effected by the controller. Any desired point in space can be set as center of rotation via software commands. This freely definable pivot point is maintained independently of the motion, thus allowing the motion of the Hexapod platform to be tuned precisely to each positioning task.