Micro Positioning Systems for High Vacuum Applications

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Abstract

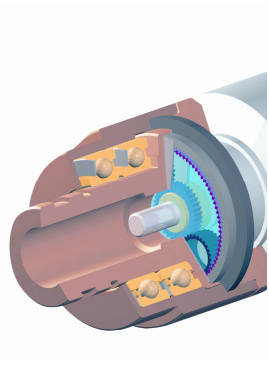
The handling of complex environmental conditions such as high and ultra high vacuum always is a big challenge for micro drive engineering. Especially in the field of micro drive systems these conditions call for high efforts in the choice of proper materials without outgassing behaviour. The systems' mechanical setup has to be adapted to the vacuum in order to avoid any gaseous inclusions while assembling. The design has to be realised regarding particular thermal expansions of variable materials. Finally high demands are made on the lubrication of micro drive systems for ultra high vacuum as beside the issue of outgassing it has to resist a wide range of temperature as given during bake-out.

1 Micro gear systems suitable for High Vacuum

Due to extreme small outer dimensions and very low masses of only some single grams the usage of micro actuators in vacuum technology opens a wide range of application based on the potential of exploiting new functionalities and basically new concepts. However the operation of drive systems vacuum applications is challenging especially for micro actuators in respect of vacuum condition and temperature range for bake out. In particular for the scope of micro actuators the limited repertory of space suitable materials causes specific problems: Materials must not outgas, should be non-corrosive and have to be suitable for temperature changes in a wide range. Beside the high needs on the material properties the demands on the conceptual design is accordant: Gas pockets have to be avoided, a compensation of thermal expansion of different materials has to be provided. The lubrication and the joining techniques of the micro systems are confronted with specific requirements, too. Especially the lubricant must not outgas, has to maintain its properties over a long period of time and so should permit a smooth positioning performance with low losses.

With respect to such ambient conditions Micro Harmonic Drive gear systems are considered as a solution [1]. Particular types of grease with extremely low vapour pressure have been qualified and dry coatings have been applied successfully matching to different qualities of vacuum as well as different temperature ranges. As a result the exposition of adapted designs of Micro Harmonic Drive gear [2] systems to a pressure of 10^{-12} mbar and a temperature range of –160°C to +150°C has been performed with success.

Table 1: adaptions for vacuum



materials	• 1.4305 stainless steel housing • 1.4305 stainless steel shafts
motor	• PRECISTEP SA • Phytron Elektronik GmbH
lubrication	• Dry lubrication (Dicronite, MoS2,) vacuum suitable grease (Fomblin)
Output bearing	• X65Cr13 high alloy steel • dry lubrication • Coated raceways • Preloaded ball bearings
Gear wheels	• Nickel-iron-alloy • Pure metallic components • Wear resistant • Corrosion resistant • Coated gear wheels • Zero backlash • UHV compatible adhesives

This development offers the possibility of a novel process control for that ambitious environmental conditions: A previous complex feed through of positioning movements from outside a vacuum chamber into it can be replaced by micro drive systems acting directly inside the vacuum chamber with smallest space and highest precision in positioning. In addition micro drive systems that are suitable for ultra high vacuum also provide new possibilities for space applications: Smallest geometrical dimensions combined with lowest masses as well as a simple and robust operating behaviour of this drive technology enable new functionalities.

2 Micro gear used in Ultra High Vacuum

An example for a successful integration of a Micro Harmonic Drive gear system into an ultra high vacuum application is the development of a micro polarimeter for BESSY, Berlin [3]. This device is used to identify the concentration of elements featured in thin magnetic coatings using the magneto-optical Kerr effect in the soft X-ray region (wavelength between 1 and 10 nm). This micro polarimeter includes a complete sub-assembly comprising two vacuum-compatible micro gearboxes used to accurately position the deflection mirror and the detector. In this application the control of the angle of incidence at the analyser mirror (a so-called multiplayer with typically 150 double layers of e.g. chromium/scandium) within +/-20 arc seconds is required. Both analyser and detector rotate relatively to the light axis. The end-effector developed by Micromotion GmbH is driven by a vacuum-compatible stepping motor combined with the two specifically adapted micro gearboxes in order to achieve the required resolution and repeatability at open loop control mode. After a bake-out of 150°C the complete drive unit was placed into a ultra high vacuum chamber at a pressure of 10-12 mbar.

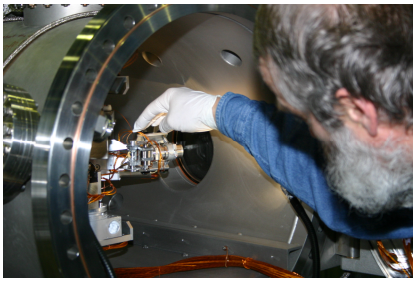


Figure 1: Application inside an vacuum chamber

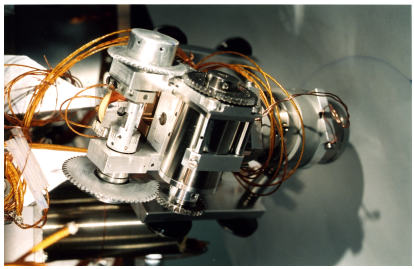


Figure 2: Micro positioning system consisting of Micro Harmonic Drive gears

3 Micro gears used in Nanolithographie

Another field of application is given by nanolithography [4]. Electron and ion beam lithography systems enable analysis and modification of samples in vacuum using an electron or ion beam. By this structures of few nanometer in dimension can be realised on surfaces or photo resist materials. In order to be able to perform a 3D analysis or modification of samples, so-called 3D modules are implemented in these

lithography systems. These 3D modules allow a free positioning of samples in the vacuum chamber with highest precision in positioning and so let the lithography systems grow to a multifunctional, nanotechnological working station. The core of already realised 3D-Modules consists out of two Micro Harmonic Drive gearboxes with a reduction ratio of 1000:1 leading to a positioning resolution of 0,0014°. By reason of an extreme flat and compact design of the micro drive systems they offer the opportunity to build up a positioning platform with several degrees of freedom and easy exchange options [5].

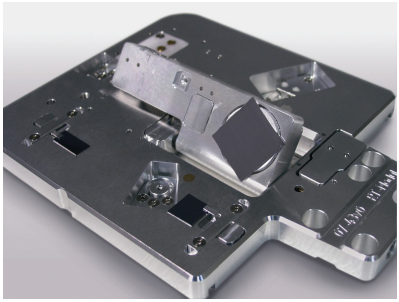


Figure 3: 3D modules consisting of Micro Harmonic Drive

Figure 4: ion beam lithography systems

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[5] brochure about ionLiNE of the company Raith GmbH about lithography and nanoengineering, download: www.raith.com