euspen's 16th International Conference & Exhibition, Nottingham, UK, May 2016

www.euspen.eu

A three device silicon based platform for micro-assembly and characterization.

F. Cosandier[1], F. Barrot[1], J. Kruis[1,2], L. Voruz[2], G. Musy[1], S. Droz[1], L. Giriens[1], W. Glettig[1] and E. Dominé[1]

[1] *CSEM, Centre Suisse d'Electronique et de Microtechnique SA, Neuchâtel, Switzerland*
[2] *EPFL, Ecole polytechnique Fédérale de Lausanne, Switzerland*

florent.cosandier@csem.ch

Abstract

In order to improve the assembly process of microcomponents, three high precision mechanisms were developed. All of them were designed and fabricated at CSEM, through a silicon etching process (DRIE). The devices are an X-Y stage, a micro-gripper and a force sensor. The X-Y stage has ±500 µm stroke on both axes and is driven by piezo-stick-slip-actuators. The micro-gripper has two jaws symmetrically driven by one actuator. The maximal opening of the jaws is 1.5 mm and each jaw has a stroke of 300 µm. The force sensor is composed of four identical parts assembled in a square arrangement, each having a compliant translation mechanism coupled with a capacitive comb that returns an electrical signal corresponding to the force applied on the system. The stroke of the sensor is 200 µm for a maximal force of 200 mN. The weight and the position of the center of gravity of an object can be measured. These three MEMS are used to realize a unique platform to assemble and characterize small parts which are accurately positioned by the X-Y stage, taken by the gripper and sequentially measured with the force sensor. Additional actuators for rough positioning of the precision mechanisms relative to each other are required to obtain the full setup.

Keywords: MEMS, compliant mechanisms, X-Y stage, capacitive sensor, micro-gripper, micro-assembly, characterization platform

1. Introduction

In present day high precision mechanisms, flexures are widely used, especially for their sub-micron accuracy and their lack of friction, backlash, wear and need for a lubricant. At the Swiss Centre for Electronics and Microtechnology (CSEM) flexures are used in mechanisms for space [1], metrology, optomechatronics, medical devices and watchmaking [2] applications. Also centimetre-scale MEMS [3] are produced and can be used, as presented in this paper, in the case of watchmaking component adjustment. Both design and realisation are done internally, through CSEM know-how and fabrication facilities. In this paper, three examples of MEMS are detailed: an X-Y stage, a micro-gripper and a force sensor. As well as a concept platform that incorporates the three devices is shown. It is dedicated to the precision assembly and adjustment of a wristwatch balance wheel.

2. X-Y stage

A flat two axes stage was required with a 20 mm external square dimension, a sub-micronic resolution and a 1 mm travelling range. The guiding mechanism of the stage (see Fig. 1) is composed of two slabs, each having two moving parallelograms orthogonally and serially arranged. They are linked by their base and common output. Each has an actuated degree of freedom at its intermediate stage. So, each slab has two stages: one passive and one active. The motion is given by piezo actuators linked to the mobile stages with a thin wire that only transmits an axial force.

Slabs are machined by Deep Reactive Ion Etching (DRIE) through 0.5 mm thick silicon wafers. Their size is 26 x 26 mm^2. The DRIE process is multilevel in order to keep a gap between the intermediate stages, so they do not interact. Joints are prismatic hinges. Slabs are assembled by gluing and alignment is made using dowel pins. Bridges are left to hold the stages during the assembly [4]. Once done, the bridges are broken to free the moving parts, in a given order and direction, so the joints of the mechanism are not damaged.

The low level of overconstraint of the mechanism, as well as total lack of friction of the moving elements and the intrinsic precision of the piezo actuators, impart to the X-Y stage performances for ultra-high accuracy positioning on both ±500 µm stroke axes. It has a wide range of potential uses: optical components positioning, automated measurements for microscopy or accurate positioning in vacuum.

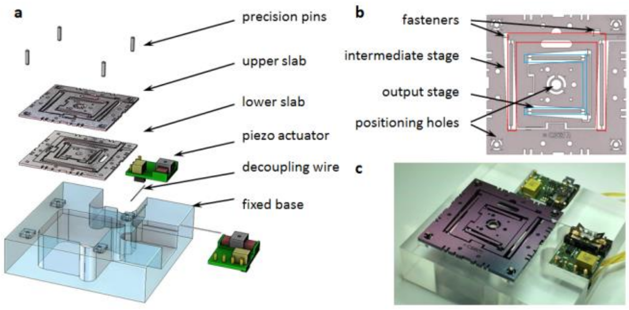

Figure 1. CAD exploded view (a), detail view (b) and photograph (c) of the X-Y stage.

3. Micro-gripper

A flat system with symmetrically actuated jaws was required to grab parts of about 1 mm. Three stacked slabs compose the guiding mechanism of the gripper (see Fig. 2). The central slab has a parallel stage that guides the input of the mechanism, while the outer slabs transform the axial motion of the input into a lateral motion of the jaws via tilted rods linking the axial input to lateral stages.

The prismatic are hinges. Similar to the X-Y stage, a multilevel DRIE process is used to produce the 22.5 x 15.4 mm^2 slabs with gaps between the moving parts. The mechanism has a height of 1.6 mm, excluding the jaws.

Two versions of the gripping interface are available. The first has jaws like fingers located in the plane of the gripper and is compatible with a vertical arrangement of the gripper (Fig. 2 right). The second version has bent jaws and is intended for a horizontal disposal of the gripper to grasp objects lying on a horizontal surface (Fig. 2 left). Moreover, the jaws are designed to catch objects either by the external faces or by the inner face of a circular opening of 1 mm in diameter.

The jaws have 0.3 mm stroke each and the initial space between them is 1.5 mm. So the minimal gap is 0.9 mm and the gripper is well suited to handle objects of 1 mm in size.

A metallic layer is deposited at the top of the elastic joints to integrate strain gauges. Thus the displacement of the jaws can be measured electrically.

To sum up, the original new kinematics of the micro-gripper allows axial actuation, resulting in symmetrical motion of both jaws. A possible improvement of the gripper could be to deposit a soft layer of polymer on the jaws to guarantee that the parts are not blemished. The gripper has possible uses in microrobotics, microassembly, and is vacuum compatible.

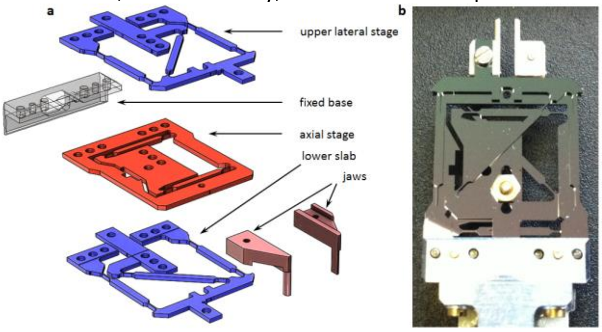

Figure 2. CAD exploded view (a) and photograph (b) of the micro-gripper.

4. Force sensor

A sensing platform was required to characterize the weight and center of gravity of parts in the 20 g range. Four lateral slabs arranged in square compose the force sensor (see Fig. 3). Each has a vertical over-constrained stage, guided by 4 flexible blades. A differential capacitive sensor is made up using overlapping comb structures, which are etched on both the moving and the fixed part of the slabs. When moving the stage, the variation in penetration depth of the two combs results in a change of the capacitance, allowing a displacement measurement. The stiffness characteristic of the stage is measured and knowing this, the force applied on the stage can be linked to the capacitance signal.

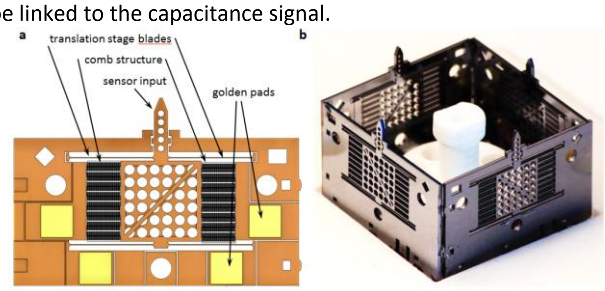

Figure 3. CAD detailed view (a) and photograph (b) of the force sensor.

The space between the moving and the fixed fingers is 10 µm. The overall volume of the sensor is 22 x 22 x 16.5 mm^3. The vertical stages have a maximal stroke of 200 µm, corresponding to a force of 200 mN. The assembly of the slabs is made according to the principles of kinematic couplings [5] (a new publication is coming up), leading to a perfect orthogonality of the faces and very low stress in the structure of the device.

30 µm wires are bonded onto golden pads, made at wafer level, in order to measure the capacitance of the combs. Each of the slabs can move independently, so the sensor perceives a force as a common signal and also two tip-tilt torques as differential signals between the facing slabs. So the mass of an object can be measured, but also the in plane coordinates of its centre of gravity.

5. Concept platform

A concept of combined use of the three presented MEMS devices is presented (see Fig. 4). It is a bench for adjusting watch balance wheels. The force sensor is also used to locate the centre of gravity of a measured object.

First, the gripper which is mounted on a long stroke x-axis stage takes a part from a tray. Then, the part is released on the X-Y stage. A feedback vision system is used with the X-Y stage to precisely centre the part over the force sensor. In accordance with the force sensor, a high-power laser is pointed on the rim of the wheel and corrects the unbalance of the wheel by means of ablation. The piece is then tested and corrected again if needed. A secondary application is developed where elements are accurately positioned and laser micro-welded.

All developed and presented MEMS are used in this concept by exploiting their own performances and by creating a synergy to solve a concrete problem.

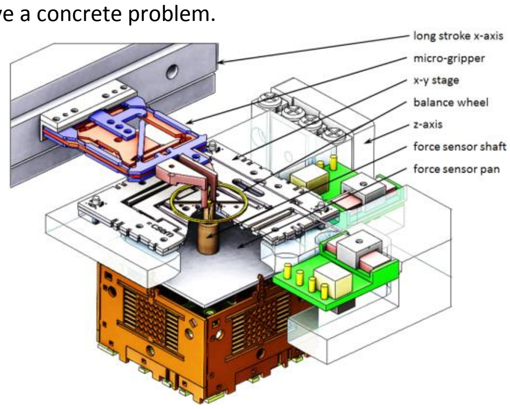

Figure 4. CAD view of the concept platform.

6. Conclusion and acknowledgements

Combining several techniques and know-how, three precision devices are assembled to create a platform. It also gives a good illustration of competences of CSEM, through the key advanced microtechnologies linked to MEMS: flexure kinematics, silicon fasteners for safe release, kinematic assembly, wafer level thermo-compression, multi-level DRIE, sensor integration (strain gauge and capacitive comb) and wire bonding.

This work is part of HiMiSHo project funded by the Swiss confederation and republic and canton of Neuchâtel.

[1] Spanoudakis P et al. 2010, Design and Development of the Point Ahead Angle Mechanism for the Laser Interferometer Space Antenna Actuated by PiezoLEGS® Actuators, *Proc. of Actuator*

[2] Henein S et al. 2009, Silicon Flexure-Based Micro-Balance for Batch Weighing Processes, *Proc. of the EUSPEN Int. Conf.*

[3] Henein S et al. 2011, Silicon flexures for the sugar-cube delta robot, *Proc. of the EUSPEN Int. Conf.*

[4] Barrot F et al 2013. Method for Freeing a Micromechanical Part and a MM Part Comp. Sacrificial Fasteners, *WO 2013/093108 A1*.

[5] Kruis J et al. 2015, 6 DOF repeatability measurement setup for measuring position of assembled silicon parts with nanometric resolution, *Proc. of the EUSPEN Int. Conf.*