HybSi – Hybridization of Silicon Micro-Components

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Combining its expertise in the domains of precision-mechanisms and micro-fabrication techniques, CSEM shows that high performance centimeter-scale mechanisms and systems benefit from the hybridization of silicon parts with other materials. The approach to bridge the gap between MEMS and Mechatronics opens a wide range of high added value markets, ranging from the watch industry to the medical devices industry. Already the field of Scientific Instrumentation encompasses a wide variety of fields such as Life Sciences, Metrology, and Opto-Mechatronics. CSEM strategic Macro-MEMS research activitiy is targeting to implement new tools and processes to better serve these key markets in Switzerland.

The strategy of CSEM – to tackle the hybridization of macroscopic silicon parts with other materials – is twofold:

- First, wafer level assembly is investigated, paving the way for a potential low-cost, medium to large volume, automated, production of high precision mechanisms ranging in the centimetre scale;
- Second, improvement of part-level assembly techniques, involving manual and semi-automated assembly procedures, is studied. Hence addressing the prototyping and small volume production needs.

The wafer-level assembly approach presents many advantages compared to part-to-part assembly, such as enabling batch assembly (tens to thousands of components per assembly steps), high precision assembly (<5 µm), high parallelism between assembled pieces (flatness of silicon wafers), and means to unite parts without need for glue.

A wafer level technique has been developed at CSEM that consists of forming complex silicon components fully compatible with the Silinvar® process, but which cannot be made by multiple DRIE steps. This technique has been successfully applied and demonstrated for the manufacturing of a silicon hairspring with an integrated plate (Figure 1, left).

Another wafer level technique investigated in detail consists of joining metal parts to silicon components resulting in hybrid system that combines the mechanical properties of silicon (no lubrication, and high mechanical strength) with those of metals (high inertia, and press fitting capabilities). As an example, a silicon escapement wheel and a metal pinion have been manufactured and assembled together at wafer level. An improved "classical" press fitting approach has been used to assemble the metal axis on the final component, merging wafer-level and part-level assembly techniques, in a single hybrid assembly method.


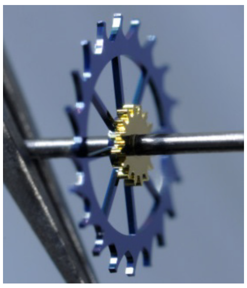

Figure 1: Silicon hairspring spiral-plate component (left), and right, a Silicon wheel with metal pinion on an axis assembled by press fitting.

Regarding the part level assembly approach, CSEM has designed, manufactured and assembled a novel centimetre scale tip-tilt-piston optical-mirror mechanism [1]. The entire assembly fits in a 40x40x42 mm^3 rectangular volume. The optical mirror can achieve ±4 ° (±70 mrad) mechanical tip/tilt rotations, or a ±0.6 mm translation in piston mode. Typical applications include: Laser Machining, Scanning Light Detection, and Ranging systems(Scanning LIDAR), as well as sub-units for multi-object spectrometers (instrumentation).

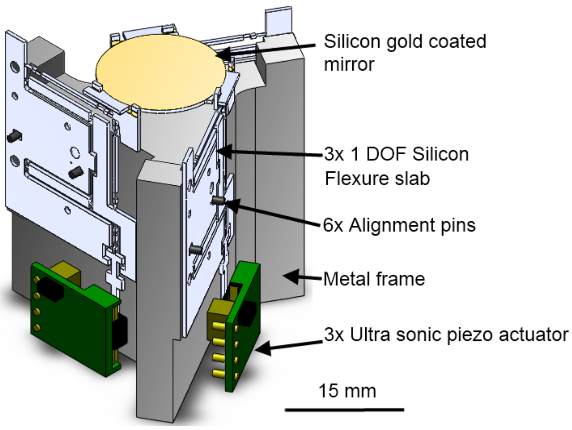

Figure 2: Tip-tilt piston mirror mechanism.

The mechanism consists of three, identical, silicon, monolithic slab structures connected to a silicon mirror. Each slab features flexure hinges to allow for a translation motion at the mirror interface. Small-size, commercial, ultrasonic piezo-actuators are used to control the mirror motion. To decouple any parasitic deviations of the actuator, the motion of the latter is decoupled through silicon rod flexures. Isostatic alignment features, included on each silicon slab, are used to enable and ease the assembly of these planar structures into a three dimensional structure. The manufacturing of the parts was done with photolithography and Deep Reactive Ion Etching.

The prototype of Figure 2 demonstrates the possibilities to create centimetre-scale 3D assembled silicon-mechanisms with 2D-parts, and novel alignment and fixation features.

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[1] J. Kruis, F. Barrot, L. Giriens, D. Bayat, R. Fournier, S. Henein, S. Jeanneret, "Design and fabrication of a novel centimeter scale three dimensional silicon tip, tilt and piston mirror mechanism", Proceeding of the 13th Euspen International Conference (2013)