SILOSCAPE—Flexure-based Oscillators for Mechanical Watches

F. Barrot, F. Cosandier, G. Musy, L. Giriens, S. Droz, Y. Petremand

For the past ten years, CSEM has demonstrated that, using micro-manufacturing techniques inherited from the microelectronics industry, it is possible to batch process with a micrometric precision, centimeter scale silicon parts featuring fine mechanical functions. High precision mechanical watch parts can particularly benefit from this approach. CSEM, combining its expertise in the domains of precision mechanisms and micro-manufacturing techniques, is a pioneer and aims at becoming the Swiss Competence Center for the design, manufacturing, assembly, and characterization of hybrid silicon based innovative watch micro-mechanisms.

Silicon is characterized by an ideal elastic behavior, a high fracture strength and a low density. It is amagnetic and corrosion free; using microfabrication techniques inherited from the microelectronic industry, it can be batch processed in 2.5D with a micrometric precision for the production of large quantities of centimeter scale mechanical parts comprising fine mechanical functions such as flexure blades. Silicon has opened up new opportunities for the design and production of novel and innovative watch mechanisms.

Figure 1: Overview of flexure based mechanical oscillators invented, designed and produced at CSEM over the past ten years.

CSEM was a precursor in this field [1], paving the way for a new trend that is now followed by several key players in the Swiss watch industry. The oscillator, together with the escapement, is one of the most delicate and high added-value parts of a mechanical watch. For the past ten years, CSEM has proposed several original designs of mechanical watch oscillators [2,3] while, at the same time, carrying on its pioneering work by pushing back the frontiers of silicon micromechanical structuring and improving its mastering of the production of such delicate parts [4].The CR4 is the last watch mechanical oscillator designed and produced by CSEM (Figure 1).

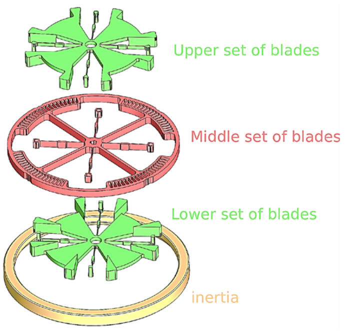

Figure 2: The CR4 mechanical oscillator – exploded view.

Like the Butterfly and Wittrick oscillators (Figure 1), the CR4 is guided by a set of flexure blades combining the restoring function of a hair spring together with the guiding function of a pivot. The CR4 is made of the stacked assembly of three silicon slabs comprising 2 pairs of blades, featuring a total 3x4 blades dispatched on three levels (Figure 2). Characterized by a better isochronism than its predecessors, the CR4 features a low displacement of its center of rotation alike the Wittrick, and is also characterized by a high quality factor.

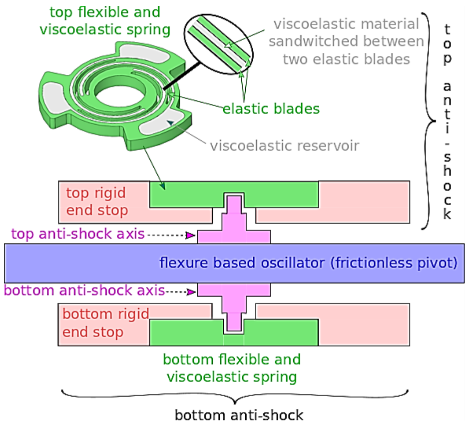

Figure 3: Anti-shock for flexure based mechanical watch oscillators.

Oscillators guided by flexures are characterized by the absence of friction; to protect them from shocks, a classical anti-shock implementation is not appropriate due to the constant friction exhibited by classical anti-shocks and the absence of physical pivot axis in flexure based oscillators. Therefore, CSEM imagined a novel anti-shock concept targeted for flexure based watch oscillators [5] which consists in assembling a top and a bottom axes to the oscillator at the location of the virtual pivot (Figure 3). These axes only come into contact with the fixed parts of the anti-shock when subjected to shocks above a given amplitude (typically > 60-100G). Two stages of protection are activated depending on the amplitude of the shock. For casual shocks on the wrist, the anti-shock axes will come into contact with viscoelastic springs that will dissipate the energy of the shock by shearing of a viscoelastic material so as to avoid consecutive rebounds that would cause unwanted energy losses; for accidental shocks the larger diameters of the anti-shock axes can also come in contact with rigid end stops.

[1] A. Perret, "Le silicium comme matériau dans la fabrication de pièces mécaniques", SSC, 2001.

[2] F. Barrot, *et al.*, "Hybridization of Silicon Micro-components", CSEM Scientific and Technical Report (2014) 13.

[3] F. Barrot, *et al.*, “Un nouveau régulateur mécanique pour une réserve de marche exceptionnelle”, SSC, 2014.

[4] S. Jeanneret, *et al.*, “Procédés de micro-fabrication avec application horlogère, développements récents”, SSC, 2008.

[5] S. Droz, *et al.*, "shock-absorber device, in particular for a micromechanical clockwork component", US 2016/0291548 A1.