MEMS are a watch´s best friend

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Besides the breakthrough of MEMS devices in automotive and consumer markets during the last decade (pressure sensors, accelerometers, gyroscopes,..), micro-machining allowed to develop innovative devices in niche markets like for example the watch industry. Swiss watch makers quickly understood the advantages like the manufacturing accuracy and design freedom offered by the combination of the micro-machining techniques and the mechanical properties of materials like for example silicon.

The mechanical properties of Si make it a material of choice to realize a spring. It has a high Young modulus, a low CTE and is a-magnetic. Deep reactive ion etching (DRIE) was the key enabling technology that allowed the realization of silicon watch parts.

One of the first components developed for watches is the silicon hairspring. This part can be considered as the hearth of the watch. Conventional hairsprings are fabricated from a roll-laminated wire wound in the form of a spiral. Only a few companies in the world master this technique. There are extremely stringent requirements on the alloy used to shape the spring in order to get a good thermal compensation. Proper oxidation of the silicon springs allows getting a fully thermally compensated spring with properties exceeding the performance of conventional hairsprings. This material is called the “Silinvar” (see Fig. 1). These devices are now manufactured in large volumes by Swiss watch makers. Since then many components like wheels and anchors have been realized in silicon.

The design freedom given by the use of photolithography allowed for the integration of complex mathematic considerations in order to improve the performance of the spiral hairsprings. Another example is the company Girard Perregaux who developed a totally new escapement mechanism based on a bi-stable spring element (figure x).

Silicon has outstanding mechanical properties. It is however brittle which makes it more challenging to integrate in conventional mechanisms in a watch. It is for example not possible to press-fit an axis in the center of silicon part. Recent advances allowed us realizing an hybridation of metallic parts on silicon either by bonding or direct electro-deposition (Figs 3 and 4). This marriage of booth the advanced mechanical properties of silicon with wafer level metallic parts (UV LIGA) allowed us to produce complex assemblies on wafer level. The obtained components can be worked like traditional parts by the watch makers, the interfacing with the other components of the watch being done on the metallic part.

Future trends in the MEMS developments for mechanical watches are the use of new materials like for example Silicon carbide, the development of innovative surface treatments reducing the friction (Fig. 5) as well as the fabrication of complex modules using wafer level assembly (WLA) techniques.

Figure 1. “Silinvar” hairspring. Lateral dimensions are controlled down to below +/- 200 nm.

Figure 2. Constant escapement spring structure by Girard Perregaux. The width of the bi-stable spring is 14 microns for a thickness of 120 microns and a length of 2 cm.

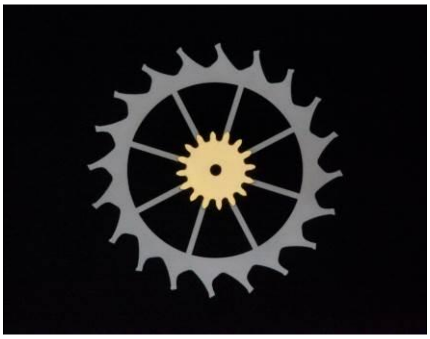

Figure 3. Hybride assembly of a metallic gear on a silicon wheel.

Figure 4. Electrodeposited gold in a Silicon balance wheel in order to get the required inertia. Courtesy of Patek Philippe SA.