

ONE-PIECE HAIRSPRING AND METHOD OF MANUFACTURING THE SAME

FIELD OF THE INVENTION

The invention concerns a hairspring and the method of manufacturing the same and, more specifically, a hairspring with a raised terminal curve formed in a single piece.

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BACKGROUND OF THE INVENTION

The regulating member of a timepiece generally includes an inertia wheel, called a balance, and a resonator called a hairspring. These parts have a determining role as regards the working quality of the timepiece. Indeed, they regulate the movement, i.e. they control the frequency of the movement.

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In the case of a hairspring with a raised terminal curve, many materials and methods have been tested, but without resolving difficulties as regards resonant assembly

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SUMMARY OF THE INVENTION

It is an object of the present invention to overcome all or part of the aforecited drawbacks, by providing a one-piece hairspring with a raised terminal curve, whose thermo-elastic coefficient can be adjusted and which is obtained using a manufacturing method that minimises assembly difficulties.

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The invention therefore concerns a one-piece hairspring that includes a balance spring coaxially mounted on a collet, made in the same layer of silicon-based material, characterized in that it includes a device that elevates or raises the outer coil of said balance spring above said layer of
5 silicon-based material in order to improve the concentric development of said hairspring.

According to other advantageous features of the invention:

- the elevation device includes elevation means for connecting the outer coil of the balance spring, which are made in a second layer of silicon-based material;
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- the elevation device has an end curve connected to said elevation means and formed in a third layer of silicon-based material, which forms a Breguet® coil;
- the end coil is a Phillips curve;
- 15 - the collet includes an extended part that projects from said balance spring so as to improve the guiding of said hairspring;
- the elevation device includes a second balance spring coaxially mounted on a second collet, connected to said elevation means, and formed in a third layer of silicon-based material to form a double balance
20 spring in series;
- the hairspring has at least one part made of silicon dioxide to make it more mechanically resistant and to adjust its thermo-elastic coefficient,
- at least one collet has a metal part into which an arbour is driven which avoids damaging the inner diameters made of silicon-based materials;
- 25 - at least one inner balance spring coil has a Grossmann curve so as to improve the concentric development of said hairspring.

More generally, the invention relates to a timepiece, characterized in that it includes a one-piece hairspring in accordance with any of the preceding variants.

Finally, the invention relates to a method of manufacturing a hairspring that includes the following steps:

- a) providing a substrate that includes a top layer and a bottom layer made of silicon-based material,
- 5 b) selectively etching at least one cavity in the top layer to define the elevation means, made of silicon-based material, of said hairspring,
- c) joining an additional layer of silicon-based material to the etched top layer of the substrate,
- 10 d) selectively etching at least one cavity in the additional layer to continue the pattern of the elevation means and to define the pattern of a balance spring and a collet, made of silicon-based material, of said hairspring,

characterized in that it further includes the following steps:

- 15 e) selectively etching at least one cavity in the bottom layer to continue the pattern of the elevation means and to define the pattern of an end coil;
- f) releasing the hairspring from the substrate.

According to other advantageous features of the invention:

- 20 - the etch of the balance spring and the collet in step d), is reversed with the etch of the end curve in step e),
- the pattern of an extended part of the collet is etched in at least one of the other layers of silicon-based material;
- the pattern of the end curve etched during step e) is replaced by the patterns of a second balance spring and a second collet so as to
- 25 form a double balance spring in series;
- after the step of etching a balance spring, the method includes step g): oxidising the balance spring made of silicon-based material so as

to make it more mechanically resistant and to adjust its thermo-elastic coefficient,

- 5 - prior to step e), the method includes step h): selectively depositing at least one metal layer on the bottom layer to define the pattern of a metal part on the collet,
- step h) includes step i): growing said deposition by successive metal layers at least partially over the surface of the bottom layer, so as to form the metal part for receiving an arbour, which is driven therein,
- 10 - step h) includes step j): selectively etching at least one cavity in the bottom layer for receiving the metal part and step k): growing said deposition by successive metal layers at least partially in said at least one cavity so as to form the metal part into which an arbour will be driven,
- step h) includes a last step l): polishing the metal deposition,
- 15 - several hairsprings are made on the same substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

Other peculiarities and features will appear more clearly from the following description, which is given by way of non-limiting illustration, with
20 reference to the annexed drawings, in which:

- Figures 1 to 5 show successive views of the manufacturing method according to the invention,
- Figures 6 to 8 show views of the successive steps of alternative embodiments,
- 25 - Figure 9 shows a flow chart of the method according to the invention,
- Figures 10 and 11 are perspective diagrams of a one- piece hairspring according to the invention

- Figure 12 is a perspective diagram of a hairspring according to a variant of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

- 5 The invention relates to a method, generally designated 1, for manufacturing a one-piece hairspring 21, 21' with an elevated or raised terminal curve for a timepiece movement. As illustrated in Figures 1 to 9, method 1 includes successive steps for forming at least one type hairspring, which can be entirely formed of silicon-based materials.
- 10 With reference to Figures 1 and 9, the first step 100 consists in taking a silicon-on-insulator (SOI) substrate 3. Substrate 3 includes a top layer 5 and a bottom layer 7 each formed of silicon-based material.
- Preferably, in this step 100, substrate 3 is selected such that the height of bottom layer 7 matches the height of one part of the final
- 15 hairspring 21.
- Preferably, top layer 5 is used as spacing means relative to bottom layer 7. Consequently, the height of top layer 5 will be adapted in accordance with the configuration of the hairspring with a raised terminal coil 21, 21'.
- 20 In a second step 101, seen in Figure 2, a cavity 8 is selectively etched, for example by a DRIE (deep reactive ionic etch) process, in top layer 5 of silicon-based material. Cavity 8 preferably forms a pattern 6 that defines the inner and outer contours of a silicon part belonging to elevation device 2 of hairspring 21, 21'.
- 25 In a first variant illustrated in Figures 10 and 11, pattern 6 forms the median part of elevation means 4 of elevation device 2 of hairspring 21. As Figure 2 illustrates, pattern 6 takes the approximate form of a curved, rectangular plate. However, advantageously according to method 1, the etch on the top layer 5 leaves complete freedom as regards the geometry of

pattern 6. Thus, it might not necessarily be rectangular, but, for example, trapezoidal.

In a second variant, illustrated in Figure 12, pattern 6 forms the intermediate part of elevation means 4' of elevation device 2' of hairspring 21'. As illustrated in Figure 2, pattern 6 takes the approximate form of a curved, rectangular plate. However, advantageously according to method 1, the etch on top layer 5 leaves complete freedom as regards the geometry of pattern 6. Thus, in particular, it might not necessarily be rectangular, but, for example, could form a complete ring.

10 Preferably, for the first variant of Figures 10 and 11, another cavity 10 may be etched during step 101 so as to form a pattern 9 distinct from pattern 6, which defines the inner and outer contours of a silicon part respectively belonging to a collet 27 of hairspring 21.

In the example illustrated in Figures 10 and 11, pattern 9 thus forms the median part of collet 27 of hairspring 21 with a raised terminal curve. As illustrated in Figure 2, pattern 9 is approximately cylinder-shaped with a circular section. However, advantageously according to method 1, the etch on top layer 5 leaves complete freedom as regards the geometry of pattern 9. Thus, in particular, it might not necessarily be circular but, may be, for example, elliptical and/or have a non-circular inner diameter.

20 Preferably, during step 101, at least one bridge of material 16 is made in order to hold the hairspring 21, 21' with a raised terminal curve on substrate 3 during manufacture. In the example illustrated in Figure 2, it can be seen that a bridge of material 16 is left between one of the main surfaces of pattern 6 and the rest of the non-etched layer 5.

In a third step 102, shown in Figure 3, an additional layer 11 of silicon-based material is added to substrate 3. Preferably, additional layer 11 is secured to top layer 5 by means of silicon fusion bonding (SFB). Thus, step 102 advantageously covers top layer 5 by binding the top faces of

pattern 6 and possible 9, with a very high level of adherence, to the bottom face of additional layer 11.

In a fourth step 103, shown in Figure 4, cavities 18 and 20 are selectively etched, for example, by a DRIE process similar to that of step 5 101, in additional silicon layer 11. These cavities 18 and 20 form three patterns 17, 19 and 24, which define the inner and outer contours of the silicon parts of hairspring 21, 21' with a raised terminal curve.

In the example illustrated in Figure 4, pattern 17 is approximately cylindrical with a circular section, and pattern 19, is approximately spiral-shaped. However, advantageously according to method 1, the etch on additional layer 11 allows complete freedom as regards the geometry of patterns 17 and 19. Thus, in particular, pattern 19 may, for example, have more coils or an inner coil including a Grossmann curve that improves its concentric development, as explained in EP Patent No. 1 612 627, which is 15 incorporated herein by reference.

Preferably, for the first variant of Figures 10 and 11, pattern 17 made in additional layer 11 is of similar shape to and plumb with pattern 9 made in top layer 5. This means that cavities 18 and 10, respectively forming the inner diameter of patterns 17 and 9, communicate with each other and are 20 approximately one on top of the other. In the example illustrated in Figures 10 and 11, patterns 9 and 17 respectively form the upper and median parts of collet 27 of hairspring 21.

Advantageously, as patterns 17 and 19 are etched at the same time, they form a one-piece part in additional layer 11. In the first variant 25 illustrated in Figures 10 and 11, patterns 17 and 19 form respectively the lower portion of collet 27 and the balance spring 25 of hairspring 21 with a raised terminal curve. In the second variant illustrated in Figure 12, pattern 17 and 19 respectively form first collet 27' and first balance-spring 25' of hairspring 21' with a raised terminal wave.

Preferably, pattern 24 made in additional layer 11 is of similar shape to and approximately plumb with pattern 6 made in top layer 5. In the first variant illustrated in Figures 10 and 11, patterns 6 and 24 respectively form the upper and intermediate parts of elevations means 4 of elevation device 5 2 of hairspring 21.

In the second variant illustrated in Figure 12, patterns 6 and 24 respectively form the upper and intermediate parts of elevation means 4' of elevation device 2' of hairspring 21'. Of course, similarly, the pattern of bridge of material 16 can be extended into additional layer 11 during step 10 103.

After this fourth step 103, it is clear that patterns 17, 19 and 24 etched in additional layer 11 are connected by the bottom of pattern 24, with a high level of adherence, above pattern 6, which is etched in top layer 5.

15 Preferably, as shown in dotted lines in Figure 9, method 1 can include a fifth step 104 that consists in oxidising at least pattern 19, i.e. the balance spring 25, 25' of hairspring 21, 21' so as to make said first balance spring more mechanically resistant and to adjust its thermo-elastic coefficient. This oxidising step is explained in EP Patent No. 1 422 436, 20 which is incorporated herein by reference.

Advantageously, according to the invention, after fourth step 103, or preferably, after fifth step 104, method 1 may include three embodiments A, B and C, as illustrated in Figure 9. However, each of the three embodiments A, B and C ends in the same final step 106, which consists in 25 releasing the manufactured hairspring 21, 21' with a raised terminal curve from substrate 3.

Advantageously, release step 106 can be achieved simply by applying sufficient forces to hairspring 21, 21' to break bridge of material 16. This forces may, for example, be generated manually by an operator or by 30 machining.

According to a first embodiment A, in a sixth step 105, cavities 12 and 14 are selectively etched, for example by a similar DRIE process to that of steps 101 and 103, in bottom layer 7 of silicon-based material. These cavities 12 and 14 form three patterns 13, 15 and 22, which define the inner and outer contours of silicon parts of hairspring 21, 21' with a raised terminal curve.

In the first variant illustrated in Figure 5, pattern 13 is approximately cylinder-shaped with a circular section and pattern 15 is approximately spiral-shaped. Moreover, pattern 22 takes the form of a curved rectangular plate. However, advantageously according to method 1, the etch in bottom layer 7 leaves complete freedom as regards the geometry of patterns 13, 15 and 22. Thus, in particular, pattern 15 may, for example, have more coils.

Preferably, for the first variant of Figures 10 and 11, pattern 13, made in bottom layer 7, is of similar shape to and substantially plumb with patterns 9 and 17 made in top layer 5 and additional layer 11. This means that cavities 12, 10 and 18 respectively forming the inner diameters of patterns 13, 9 and 17, communicate with each other and are approximately one on top of the other. In the first variant illustrated in Figures 10 and 11, patterns 17, 9 and 13 respectively form the high, median and low parts of collet 27 of hairspring 21.

Preferably for the second variant of Figure 12, pattern 13 made in bottom layer 7 is of similar shape to and approximately plumb with pattern 17 made in top layer 5. This means that cavities 12 and 18 respectively forming the inner diameter of patterns 13 and 17 are approximately one on top of the other, without being contiguous. In the second variant illustrated in Figure 12, patterns 17 and 13 respectively form the first collet 27' and the second collet 27'' of the double series hairspring 21'.

Preferably, pattern 22 made in bottom layer 7 is of similar shape to and approximately plumb with pattern 6 made in top layer 5. In the first variant illustrated in Figures 10 and 11, patterns 22, 6 and 24 respectively

form the low, intermediate and high parts of elevation means 4 of elevation device 2 of hairspring 21. In the second variant illustrated in Figure 12, patterns 22, 6 and 24 respectively form the low, intermediate and high parts of elevation means 4' of elevation device 2' of hairspring 21'. Of course, the
5 pattern of bridge of material 16 can be extended into bottom layer 7 during step 105.

Moreover, preferably for the first variant of Figures 10 and 11, pattern 15 is made to satisfy the criteria of a Phillips hairspring. Thus, advantageously, as patterns 22 and 15 are etched at the same time, they
10 therefore form a one-piece part in bottom layer 7. In the first variant illustrated in Figures 10 and 11, patterns 22 and 15 respectively form the low part of elevation means 4 and the terminal curve 23 of elevation device 2 of hairspring 21.

Finally, preferably for the second variant of Figure 12, pattern 15 is
15 made in a similar manner to pattern 19 made during step 103. Thus, advantageously, as patterns 13, 22 and 15 are etched at the same time, they therefore form a one-piece part in bottom layer 7. In the second variant illustrated in Figure 12, patterns 22, 15 and 13 respectively form the low part of elevations means 4' and the second balance spring 23' of elevation device 2', and the second collet 27'' of double balance spring 21' in series. Advantageously, according to method 1, the etch in bottom layer 7 allows complete freedom as regards the geometry of pattern 15. Thus, pattern 15 may, for example, have more coils or an inner coil that includes a Grossmann curve for improving its concentric development, as explained in
20 EP Patent No 1 612 627, which is incorporated herein by reference.
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After final step 106, explained above, first embodiment A thus produces a one-piece hairspring 21 or 21' with a raised terminal curve, formed entirely of silicon-based materials, as shown in Figures 10 and 11 or 12. It is thus clear that there are no longer any problems as regards forming
30 the parts, since they are directly formed on fixed elements during manufacture of hairspring 21 or 21'.

In the first variant illustrated in Figures 10 and 11, hairspring 21 includes a balance spring 25, coaxially connected to a collet 27, whose outer coil has an elevation device 2, mainly comprising a rectangular plate etched in three layers 11, 5, 7 which act as elevation means 4 and a terminal curve 23. As shown in Figures 10 and 11, the hairspring 21 with a raised terminal curve that is obtained therefore has a Breguet® configuration. Advantageously according to the invention, it will be noted that collet 27 is also etched in three layers 11, 5, 7, which improves the guiding of hairspring 21. Moreover, inner coil 26 of balance spring 25 has a Grossmann curve to improve its concentric development.

Further, the etches performed in steps 103 and 105 of method 1 leave complete freedom as to the geometry of terminal curve 23, balance springs 25, elevation means 4 and collet 27. Thus, in particular, the continuity between balance spring 25, elevation means 4 and terminal curve 23 may have a different geometry.

In accordance with the same reasoning, collet 27 can have uniformly peculiar or different dimensions and/or geometries at least over one of bottom, median and/or top parts 13, 9 and 17. Indeed, depending upon the arbour on which collet 27 will be mounted, the inner diameter can have a complementary shape over all or part of the height of collet 27. Likewise, the inner and/or outer diameters are not necessarily circular but may be, for example, elliptical and/or polygonal.

It should also be noted that the very high level of structural precision of deep reactive ionic etching decreases the start radius of balance spring 25, i.e. the outer diameter of collet 27, which means that the inner and outer diameters of collet 27 can be miniaturised. It is thus clear that hairspring 21 is able to receive, through cavities 18, 10 and 12, advantageously an arbour of smaller diameter than that which is currently usually manufactured.

Preferably, said arbour can be secured to the internal diameter 18 and/or 10 and/or 12 of one of collets 27. The lighting of collet can for example be made by resilient means etched in collet 27 made in a silicon

based material. The arbour can be tightened using resilient means etched in silicon collet 27' or 27''. Such resilient means may, for example, take the form of those disclosed in Figures 10A to 10E of EP Patent No. 1 655 642 or those disclosed in Figures 1, 3 and 5 of EP Patent No. 1 584 994, said
5 Patents being incorporated herein by reference.

In the second variant illustrated in Figures 12, hairspring 21' has a first balance spring 25' coaxially connected to a collet 27' and whose outer coil includes an elevation device 2' mainly comprising a rectangular plate etched in three layers 11, 5, 7 acting as elevation means 4', a second
10 balance spring 23', and a second collet 27''. As shown in Figure 12, the hairspring 21' thereby obtained has a double, series hairspring configuration.

Further, the etches performed in steps 103 and 105 of method 1 leave complete freedom as to the geometry of balance springs 25' and 23',
15 elevation means 4' and collets 27' and 27''. Thus, in particular, the continuity between balance springs 25', 23' and elevation means 4' may have a different geometry. It is also possible to envisage, as in the preceding variant, that the inner coils of each of balance springs 25' and 23' could have a Grossmann curve to improve the concentric development of
20 each coil.

In accordance with the same reasoning, collets 27' and 27'' can also have peculiar or different dimensions and/or geometries. Indeed, depending on which collet 27', 27'' the arbour will be mounted with, the inner diameter of said collet can then have a complementary shape. Likewise, the inner
25 and/or outer diameters of each collet 27', 27'' are not necessarily circular but may be, for example, elliptical and/or polygonal.

It should also be noted that the very high level of structural precision of deep reactive ionic etching decreases the start radius of each of balance springs 25' and 23', i.e. the outer diameter of collets 27' and 27'', which
30 means that the inner and outer diameters of collets 27' and 27'' can be miniaturised. It is thus clear that hairspring 21' is capable of receiving,

through cavities 18 or 12, advantageously an arbour of smaller diameter than that which is currently usually manufactured.

Preferably, said arbour can be secured to the internal diameter 18 and/or 12 of one of collets 27', 27". The other collet can then be mounted
5 either on the sprung balance bar or on the balance. The arbour can be tightened using resilient means etched in silicon collet 27' or 27". Such resilient means may, for example, take the form of those disclosed in Figures 10A to 10E of EP Patent No. 1 655 642 or those disclosed in Figures 1, 3 and 5 of EP Patent No. 1 584 994, said Patents being
10 incorporated herein by reference.

According to a second embodiment B, after step 103 or 104, method 1 includes a sixth step 107, shown in Figure 6, consisting in implementing a LIGA process (from the German "röntgenLithographie, Galvanoformung & Abformung"). This process includes a series of steps for electroplating a
15 metal on the bottom layer 7 of substrate 3 in a particular shape, using a photostructured resin. As this LIGA process is well known, it will not be described in more detail here. Preferably, the metal deposited may be, for example, gold or nickel or an alloy of these metals.

In the example illustrated in Figure 6, step 107 may consist in
20 depositing a cylinder 29. In the example illustrated in Figure 6, the cylinder 29 is for receiving an arbour, which is advantageously driven therein. Indeed, one drawback of silicon is that it has very few elastic and plastic zones, making it very brittle. The invention thus proposes to tighten an arbour, for example a balance staff, not against the silicon of collet 27, 27'
25 or 27", but on the inner diameter 28 of metal cylinder 29, which is electroplated during step 107.

Advantageously, according to method 1, the cylinder 29 obtained by electroplating allows complete freedom as regards its geometry. Thus, in particular, the inner diameter 28 is not necessarily circular, but for example
30 polygonal, which could improve the transmission of stress in rotation with an arbour of matching shape.

In a seventh step 108, similar to step 105 shown in Figure 5, cavities are selectively etched, for example by a DRIE method, in bottom layer 7 of silicon-based material. These cavities allow patterns to be formed similar to patterns 13, 15 and 22 of the first embodiment A according to one of the two variants.

After final step 106, explained above, the second embodiment B thus produces a one-piece, hairspring with a raised terminal curve, formed of silicon-based materials with the same advantages as embodiment A, with the addition of a metal part 29. It is thus clear that there is no longer any problem as regards forming parts, since they are formed directly on fixed elements during manufacture of the hairspring 21 or 21'. Finally, advantageously, an arbour can be driven against the inner diameter 28 of metal part 29. One could therefore preferably envisage cavities 12 and/or 10 and/or 18 according to the variant including sections of larger dimensions than that of inner diameter 28 of metal part 29, so as to prevent the arbour being in push fit contact with collet 27, 27' or 27''.

According to a third embodiment C, after step 103 or 104, method 1 includes a sixth step 109 shown in Figure 7, consisting in selectively etching a cavity 30, for example, by a DRIE process, to a limited depth in bottom layer 7 of silicon-based material. Cavity 30 forms a recess to be used as a container for a metal part. As in the example illustrated in Figure 7, the cavity 30 obtained can take the form of a disc. However, advantageously according to method 1, the etch of bottom layer 7 allows complete freedom as regards the geometry of cavity 30.

In a seventh step 110, as illustrated in Figure 7, method 1 includes implementation of a galvanic growth or LIGA process for filling cavity 30 in accordance with a particular metal shape. Preferably, the deposited metal may be, for example, gold or nickel or an alloy of these metals.

In the example illustrated in Figure 8, step 110 may consist in depositing a cylinder 31 in cavity 30. Cylinder 31 is for receiving an arbour, which is advantageously driven therein. Indeed, as explained above, one

advantageous feature of the invention consists in tightening the arbour, for example the balance staff, not against the silicon-based material of collet 27, 27' or 27'' but on the inner diameter 32 of metal cylinder 31, which is electroplated during step 110.

5 Advantageously according to method 1, cylinder 31 obtained by electroplating allows complete freedom as regards its geometry. Thus, in particular, the inner diameter 32 is not necessarily circular but, for example, polygonal, which could improve the transmission of stress in rotation with an arbour of matching shape.

10 Preferably, method 1 includes an eighth step 111, consisting in polishing the metal deposition 31 made during step 110, in order to make said deposition flat.

 In a ninth step 112, similar to step 105 shown in Figure 5, cavities are selectively etched, for example, by a DRIE process, in bottom layer 7 of
15 silicon-based material. These cavities form patterns similar to patterns 13, 15 and 22 of the first embodiment A according to one of the two variants.

 After final step 106 explained above, third embodiment C produces a one-piece, hairspring formed of silicon-based materials with the same advantages as embodiment A, with the addition of a metal part 31. It is thus
20 clear that there are no longer any manufacturing problems, since the parts are directly formed on fixed elements during manufacture of hairspring 21 or 21'. Finally, advantageously, an arbour can be driven against inner diameter 32 of the metal part. One could therefore preferably envisage cavities 12 and/or 10 and/or 18 according to the variant having sections of
25 larger dimensions than that of the inner diameter 32 of metal part 31, to prevent the arbour being in push fit contact with collet 27, 27', 27''.

 According to the three embodiments A, B and C, it should be understood that the final hairspring 21 or 21' is thus assembled prior to being structured, i.e. prior to being etched and/or altered by electroplating.
30 This advantageously minimises the dispersions generated by current

manufacturing methods and, consequently, improves the precision of a regulator member on which it will depend.

Advantageously, according to the invention, it is also clear that it is possible for several hairsprings 21 or 21' with a raised terminal curve to be
5 made on the same substrate 3, which allows batch production.

Moreover, it is possible to make a driving insert of the same type as metal depositions 29 and/or 31 also, or solely from additional layer 11 and/or top layer 5.

Method 1 may include after step 105, 108 or 112, a step of the same
10 type as step 104 which would consist in oxidising pattern 15, i.e. terminal curve 23 or balance spring 23' of hairspring 21 or 21' so as to make it more mechanically resistant and to adjust its thermo-elastic coefficient. A polishing step of the type of step 111 may also be performed between step 107 and step 108.

15 Advantageously according to the invention, whichever embodiment A, B or C is used, method 1 allows step 103, which consists in etching balance spring 25, 25' and collet 27, 27' in additional layer 11 to be reversed with step 105, 108 or 112, which consists in etching terminal curve 23 or balance spring 23' and collet 27'' in bottom layer 7. This means that
20 terminal curve 23 or balance spring 23' and collet 27'' can be etched first on additional layer 11, then balance spring 25, 25' and collet 27, 27' can be etched in bottom layer 7. In such case, terminal curve 23 could be oxidised, in step 104, for example, before balance spring 25 is oxidised.

A conductive layer could also be deposited over at least a part of
25 hairspring 21 or 21' so as to prevent isochronism problems. This layer may be of the type disclosed in EP Patent No. 1 837 722, which is incorporated herein by reference.

The height of collet 27 may be more limited than in Figures 10 and 11 of the first variant illustrated, i.e. for example, it may be limited to layers

5 and 11. The elevation means 4 could also take a different form from a curved rectangular plate.

Finally, at least a second bridge of material could be provided, so as to hold hairspring 21 to substrate 3 during manufacture, which could be
5 performed between the outer curve of pattern 19 and the rest of the non-etched layer 11.

CLAIMS

1. One-piece hairspring (21, 21'), which comprises a balance spring (25, 25') coaxially mounted on a collet (27, 27'), made in the same layer of silicon-based material, characterized in that it includes an elevation device (2, 2') for the outer coil of said balance spring, above said layer of silicon-based material so as to improve the concentric development of said hairspring.

2. Hairspring according to claim 1, characterized in that the elevation device (2, 2') includes elevation means (4, 4') connecting the outer coil of the balance spring (25, 25'), which are made in a second layer of silicon based material.

3. Hairspring according to claim 2, characterized in that the elevation device (2) includes a terminal curve (23) connected to said elevation means (4) and formed in a third layer of silicon based material.

4. Hairspring according to claim 3, characterized in that the terminal curve (23) is a Phillips curve.

5. Hairspring according to any of the preceding claims, characterized in that the collet (27) includes one extended part (9, 13) that projects from said balance spring so as to improve the guiding of said hairspring.

6. Hairspring according to claim 2, characterized in that the elevation device (2') includes a second balance spring (23') coaxially mounted on a second collet (27'') connected to said elevation means (4') and formed in a third layer of silicon based material for forming a double series hairspring.

7. Hairspring according to any of the preceding claims, characterized in that it includes at least one silicon dioxide part to make said

hairspring more mechanically resistant and to adjust the thermo-elastic coefficient thereof.

8. Hairspring according to any of the preceding claims, characterized in that at least one collet (27, 27', 27'') has one metal part
5 (29, 31) for receiving an arbour that is driven therein.

9. Hairspring according to any of the preceding claims, characterized in that at least one balance spring (25, 25', 23') inner coil (26) has a Grossmann curve so as to improve the concentric development of said hairspring.

10 10. Timepiece characterized in that it includes a one-piece hairspring (21, 21') according to any of the preceding claims.

11. Method (1) of manufacturing a one-piece hairspring including the following steps:

- a) providing (100) a substrate (3) including a top layer (5) and a bottom layer (11) of silicon-based materials,
- b) selectively etching (101) at least one cavity (8, 10) in the top layer (5) to define elevation means (4) made of silicon-based material, of said hairspring,
- c) joining (102) an additional layer (7) of silicon-based material to the etched top layer (5) of the substrate (3),
- d) selectively etching (103) at least one cavity (18, 20) in the additional layer (7) to continue the pattern of the elevation means (4) and to define the patterns of a balance spring (25) and a collet (27), made of silicon-based material, of said hairspring;

characterized in that it further includes the following steps:

- e) selectively etching (105, 108, 112) at least one cavity (12, 14) in the bottom layer (11) to continue the pattern of the elevation means (4) and to define the pattern of a terminal curve (23), made of silicon-based material, and

f) releasing (106) the one-piece hairspring (21) from the substrate.

12. Method according to claim 11, characterized in that the etch of the balance spring (23) and collet (27) in step d) is reversed with that of the terminal curve (23) in step e).

13. Method according to claim 11 or 12, characterized in that, a pattern (9, 13) of an extended part of the collet (27) is etched in at least one of the other layers of silicon-based material.

14. Method according to claim 11, characterized in that the pattern of the terminal curve (23) etched during step e) is replaced by the patterns of a second balance spring (23') and a second collet (27'') in order to form a double hairspring (21') in series.

15. Method according to any of claims 11 to 14, characterized in that, after a step of etching a balance spring (25, 25', 23'), it further includes the following step:

g) oxidising the balance spring (25, 25', 23'), made of silicon-based material, so as to make said balance spring more mechanically resistant and to adjust the thermo-elastic coefficient thereof.

16. Method according to any of claims 11 to 15, characterized in that, prior to step e), it further includes the following step:

h) selectively depositing (107, 110) at least one metal layer on the bottom layer to define the pattern of a metal part (29, 31) of said hairspring.

17. Method according to claim 16, characterized in that step h) includes the following step:

i) growing (107) said deposition by successive metal layers at least partially over the surface of the bottom layer so as to form the metal part (29) for receiving an arbour that is driven therein.

18. Method according to claim 16, characterized in that step h) includes the following phases:

j) selectively etching (109) at least one cavity (30) in the bottom layer for receiving the metal part (31);

k) growing (110) said deposition by successive metal layers at least partially in said at least one cavity so as to form the metal part (31) for receiving an arbour, which is driven therein.

19. Method according to any of claims 16 to 18, characterized in that step h) includes the following last phase:

l)polishing (111) the metal deposition.

20. Method according to any of claims 11 to 19, characterized in that several one-piece hairsprings (21, 21') are made on the same substrate (3).