

DESCRIPTION

The present invention is concerned with miniature stepping motors comprising a stator, a magnetized rotor, and at least one coil that is magnetically coupled to the rotor and which is connected to a control circuit that supplies the coil with the current pulses needed to move the rotor, the motor that is associated with the control circuit forming a motor arrangement.

The invention relates to such arrangements, particularly those used in timepieces and more particularly watches.

The motor most used nowadays in watches is a Lavet type stepping motor. In this motor, a magnetized rotor of cylindrical shape sets up a radial magnetic field in the air gap of a magnetic circuit on which is wound a coil whose terminals are connected to a control circuit, usually an integrated circuit, that supplies current pulses, each pulse causing the rotor to move forward one step. The coil is formed by a very fine wire wound on a hollow insulating tube containing inside it a portion of the magnetic circuit. The cost of the wire and the difficulty of winding it on the tube and of producing reliable connections cause the coil to be the most expensive component of the motor.

Another type of motor is sometimes used in watches. In that case the rotor is shaped as a thin, magnetized disc that sets up in the air gap of the magnetic circuit axial fields that extend through flat, i.e. substantially plane and thin, coils arranged parallel with the rotor. As this type of motor uses six to eight coils of thin copper wire that are difficult to produce and to connect to each other and to the control circuit, it is even more expensive to manufacture than the Lavet motor. That is why this motor, which lends itself well to a compact construction, is hardly used in the watchmaking field. It has been possible to achieve a substantial price reduction for the coils by producing them simultaneously on a printed circuit, as described in detail in patent US-A-4 340 833. This technique, albeit of interest to industrial motors, even motors of small size, is however inapplicable to the watchmaking field as it is not suited to

the production of coils having sufficiently fine turns to achieve an efficient motor.

The above examples show that the stepping motors at present being used in watches are expensive and unreliable because, respectively, of the cost of the coils and of the difficulty of connecting them to the control circuit.

An object of the invention is to mitigate these drawbacks by providing a motor arrangement comprising :

- a stator;
- a rotor having a flat magnetized disk-like portion rotatably mounted in the stator and including at least one pair of magnetic poles to produce a field that is substantially parallel to the axis of rotation of the rotor in an air gap defined by the stator and the rotor; and
- at least one substantially flat coil, said coil being placed in the air gap at right angles to said axis of rotation, such as to intercept the flux created by the field;

which is particularly characterized in that said coil is arranged on one side of a semi-conductor chip in which is implanted a control circuit, said circuit being directly connected to said coil to supply it with drive pulses.

The arrangement according to the invention is an improvement of the arrangement formed by the motor using flat coils and by the control circuit associated with the motor.

One advantage of the invention stems from the fact that the coils and the control circuit form a single module, of small size, that can be mass produced cheaply.

Another advantage stems from the fact that the module both simplifies the assembly of the arrangement and improves its reliability. A further advantage is that the module enables the size of the motor arrangement to be reduced.

Other characteristics and advantages of the motor arrangement according to the invention will become apparent from the following description, made with reference to the accompanying drawings and

given by way of a non-limitating explanation, of an embodiment of such an arrangement wherein the same references designate like elements :

Figure 1a is a cross-sectional view of a prior art motor comprising a thin, disc-shaped, magnetized rotor and flat coils;

Figure 1b represents a plan view of the Figure 1a motor's rotor showing the lay-out of the magnetic poles;

Figure 1c represents a plan view of the Figure 1a motor's coil and of the coils' connections to a control circuit;

Figure 2 is a plan view of a module according to the invention consisting of a silicon chip formed with coils on one side thereof and in which is implanted an integrated control circuit whose output is connected to the coils' terminals;

Figure 3 is an enlarged plan view of a portion of the chip shown in Figure 2 showing one coil and its connection to the control circuit; and

Figure 4 shows a plan view of a preferred form of embodiment of the motor arrangement according to the invention, said arrangement consisting of a motor and of a control circuit.

A motor, known from the prior art and comprising flat coils, comprises a rotor 1, a stator 2 and a shaft 3 solid with the rotor and rotatably mounted in the stator. The stator is preferably made up, in the case of a watch motor, of parts of the movement's bottom plate. The rotor consists of a magnetized circular disc 4, near one end of shaft 3, and of a first circular plate 5 of soft magnetic material, this plate being secured to the side of disc 4 closest to stator 2. The motor further comprises, on stator 2, a second circular plate 6 having the same shape as plate 5, an insulating sheet 7 and eight flat coils 8a, 8b, ..., 8h. Plate 6 is secured to the portion of stator 2 facing the free side of disc 4 made of ferrite, the space between plate 6 and rotor 1 defining an air gap. Coils 8a, 8b, ..., 8h lie in the air gap on plate 6, sheet 7 being sandwiched between plate 6 and the coils to insulate the plate from the coils.

Figure 1b shows, in a plan view, disc 4 and the lay-out of the magnetic poles, the disc being preferably made of ferrite or samarium-cobalt. In the illustrated embodiment, disc 4 comprises four pairs of magnetic poles arranged in the vicinity of the rotor's periphery.

These poles set up magnetic fields H in the air gap between rotor 1 and stator 2 where coils 8a ... 8h are located. In the air gap, fields H all extend substantially parallel to the rotor's axis of rotation, but in alternate directions. Beyond the air gap, the fields are channelled from one magnetic pole to the adjacent pole by plates 5 and 6 having, for this purpose, high magnetic permeability. If the portion of stator 2 close to the coils were made of soft magnetic material, plate 6 would of course be otiose.

The shape and lay-out of coils 8a ... 8h are shown, in a plan view, in Figure 1c. These coils, which are similar, in the form of plane, circular discs having little thickness in relation to their outer diameter, are so arranged as to intercept as much as possible of the flux set up by magnetic fields H in the air gap. Each coil, made of very thin copper wire, has an input terminal and an output terminal, these terminals being respectively referenced 9a and 10a for coils 8a, 9b and 10b for coil 8b, etc. Further, in the illustrated embodiment, firstly, the turns of a coil are wound one way and the turns of an adjacent coil are wound the other way and, secondly, all of the coils' input terminals are connected to one another by a conductor 11 and all of the coils' output terminals are connected by a conductor 12. Thus, currents having the same direction flow in neighbouring portions of the turns of two adjacent coils in response to a voltage applied to conductors 11 and 12.

Figure 1c further illustrates a control circuit 15. This circuit, generally produced in the form of an integrated circuit implanted in a silicon wafer or chip, is intended to supply current drive pulses to the coils to drive the rotor. Circuit 15 includes a pair of inverters 16 and 17 and a logic circuit 18. The outputs of the inverters are respectively connected to conductors 11 and 12 by wires 19 and 20, whereas their inputs are directly connected to circuit 18.

If the motor arrangement is intended for a watch, logic circuit 18 essentially comprises a time base circuit that is frequency stabilized by a quartz resonator, a frequency divider, and a circuit for shaping the signals applied to inverters 16 and 17, these inverters then supplying polarized drive pulses to the motor's coils. Logic circuit 18 also comprises at least one input terminal for time

setting the watch by means of signals supplied by at least one outside control member. Control circuit 15 is moreover supplied with energy by a cell fitted inside the watch case. These circuit parts and these components, which are known per se, have not been shown in Figure 1c, nor will they be described.

The above described motor arrangement may be designed in slightly different, but known, ways. In particular, to increase the length of the active portions of the coils' turns and to improve the motor's efficiency, coils 8a,..., 8h are best given a triangular shape, similar to that illustrated in Figure 5 of the cited document. Also, the coils, instead of being connected in parallel, could be connected in series. Further, each coil could also be connected directly to a pair of inverters, circuit 15 then comprising as many pairs of inverters, similar to inverters 16 and 17, as there are coils.

The present invention proposes, when control circuit 15 is an integrated circuit, to simplify the above motor arrangement and to make it more reliable by gathering, into a single module, the circuit, the coils and the connections between the circuit and the coils.

Such a module, referenced 24, is shown in plan in Figure 2. It comprises a silicon chip 25 also called a semi-conductor substrate or wafer, an integrated control circuit not shown, produced in accordance with CMOS technology and implanted in the substrate, and eight coils 26a, 26b, ... 26g, 26h arranged on one side of chip 25 at the center of which is formed a hole 27 through which extends the rotor's shaft 3. Coils 26a ... 26h, which are directly connected to the control circuit, have the same function as coils 8a ... 8h described above.

In the case of a motor arrangement for a watch, chip 25 is square and typically has 4 mm sides and a thickness of 0.2 mm, whereas coils 26a ... 26h have an outer diameter of about 1 mm and negligible thickness. In these conditions, the diameter of rotor 1 is about 5 mm. Further, disc 4 and plates 5 and 6 respectively have a thickness of

about 0.4 mm and 0.3 mm. The overall thickness of the motor, arrangement assuming there is a space of 0.1 mm between disc 4 and coils 26a ... 26h, would then be 1.3 mm.

A part of chip 25 is shown in an enlarged plan view in Figure 3, showing coil 26g, the two inverters 16 and 17 of integrated control circuit 15 and the connections between the ends of the coil and the inverters' outputs.

Coil 26g has about 150 turns. It is formed by an aluminium conductor 30 spirally wound in a single layer, with adjacent coils being distant by about one micrometer. Conductor 30, which has an inner terminal 31 and an outer terminal 32, has a square cross-section of 2 by 2 micrometers and a resistance between the terminals, corresponding to the coil's resistance, of about 2000 ohms. Coil 26g, in the illustrated embodiment, is circular but could of course be triangular to improve the efficiency of the motor arrangement.

Inverter 16, shown in Figure 3, is made up of a pair of complementary CMOS transistors, each comprising a source, a gate and a drain, respectively referenced S_1 , G_1 and D_1 for the first transistor and S_2 , G_2 and D_2 for the second. Drains D_1 and D_2 are connected to one another and form the output of inverter 16. This output is connected to terminal 31 by an electric conductor 33. Inverter 17 has a structure identical to that of inverter 16 and its output is connected to terminal 32 by an electrical conductor 34. The other coils may be connected in parallel with coil 26g.

However, to reduce the length of the connecting conductors, it is best to connect each coil directly to a pair of inverters identical to inverters 16 and 17. The remainder of the control circuit and of the connections has not been shown. Since these elements take up relatively little space they can for instance be implanted in one of the corners of chip 25.

Coils 26a, ..., 26h are preferably produced on silicon chip 25 by the same process, and at the same time, as that used to produce in this chip the integrated control circuit, without any additional production step.

In order to understand how the coils are made, it should first

be recalled that the manufacture of an integrated MOS circuit involves several steps, the main ones being :

- diffusing into the silicon substrate through a succession of masks impurities in well-defined locations to form the various active and passive components of the circuit;
- covering the surface of the circuit with an insulating layer of silicon oxide;
- forming openings in the oxide layer where the circuit provides connection terminals; and
- depositing through a metallizing mask, by a metallization process in vacuo, conductive tracks of aluminium selectively connecting to one another the connection terminals.

If the metallizing mask also outlines the coils' turns and their connections with the circuit, the coils and the connections between the coils and the circuit will of course be produced at the same time and by the same process as the other metallizations. The fineness of definition that can be achieved for the conductors with the metallization process is moreover compatible with the small dimensions, given above, that are needed for the coils and the conductors forming the turns, to achieve good efficiency for the motor.

MOS integrated circuit technology thus makes it possible to produce, without any additional manufacturing step, module 24 in which the control circuit, the coils and the coils' electric connections with the circuit are gathered on one and the same silicon substrate. These connections may be achieved either by metallization, when there is no crossing with another metallization, as for instance with conductor 34, or by means of a diffused conduction channel, of p type when the substrate is of n type, when there is a crossing, as is the case with conductor 33 which must pass under coil 26g.

This module simplifies the construction of the motor arrangement by reducing the number of components. A preferred form of construction is shown in Figure 4 in which references 1, 2, 4, 5 and 6 designate the same elements as in Figure 1a, i.e. the rotor, the stator, the disc made of ferrite and the two plates of soft magnetic material, respectively. Module 24 is secured directly to plate 6, instead of coils 8a ... 8h in Figure 1a, so that the side thereof

bearing coils 26a ... 26h should face the rotor. At its center, the module carries a round stud 40, which, by engaging in a bearing 41 fixedly mounted in the center of rotor 1, acts as a shaft about which rotor 1 may rotate. With this structure, module 24 need not be formed with a hole at its center, this being a delicate operation made necessary in the construction shown in Figure 1a to let shaft 3 through.

CLAIMS

1. Motor arrangement comprising :

- a stator (2);
- a rotor (1) having a substantially flat magnetized disk-like portion rotatably mounted in the stator and including at least one pair of magnetic poles to produce a field (H) that is substantially parallel to the axis of rotation of the rotor in an air gap defined by the stator and the rotor; and

- at least one substantially flat coil (26a), said coil being placed in the air gap at right angles to said axis of rotation, such as to intercept the flux created by the field;

characterized in that said coil (26a) is arranged on one side of a semi-conductor chip (25) in which is implanted an integrated control circuit, said circuit being directly connected to said coil to supply it with drive pulses.

2. Motor arrangement according to claim 1, characterized in that said coil (26a) is formed by a single layer of turns.

3. Motor arrangement according to claim 1 or 2, characterized in that said chip (25) has a central opening (27) through which extends a shaft (3) intended to support said rotor (1) and bearing on said stator (2).

4. Motor arrangement according to claim 1, 2 or 3, characterized in that said chip (25) further carries a stud (40) acting as a shaft about which said rotor (1) may rotate.

5. Method of making a coil for a motor arrangement according to claim 1, characterized in that it comprises depositing, by a metallization process, on one side of said semi-conductor chip (25) a conductor (30, 34) to form said coil (26a) and its electrical connection to said circuit.

6. Method according to claim 5, characterized in that it comprises depositing said conductor (30, 34) at the same time and by the same metallization process as the one which serves to interconnect the components of the circuit implanted in said chip (25).

