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A MOTOR AND A METHOD OF MANUFACTURING A MOTOR

Field

The present invention relates to a motor and a method of manufacturing a motor, particularly though not solely to an axial electromagnetic micromotor, a method of fabricating a winding for a motor and/or a method of fabricating a fluid dynamic thrust bearing for a motor.

Background

As electronic devices become smaller, there is increasing demand for smaller actuators. For example micro machines are increasing being used in electronic devices, such as micro fans in mobile telephones, or micro pumps in medical applications. Typically such micro-motors include a stator having windings, a rotor with magnets and a shaft / bearing arrangement to couple the rotor to the stator.

In some portable applications the motor will be subjected to vibration, shock loads and different orientations. Consequently it may be desirable that the bearing prevents the rotor from impacting the stator, which would otherwise reduce the life of the motor and cause undesirable speed variations.

Commonly the windings in a micromotor are provided in the form of a copper track on a PCB. However the technology used in making the tracks eg: photolithography followed by etching, limits the minimum width and/or the separation between the tracks. For example a typical prior art winding might have a track width of 45μm and a separation of 5μm.

Summary

In general terms in a first exemplary aspect the invention proposes a motor with printed windings. This may have the advantage of reducing the minimum

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width and/or the minimum separation and/or allow more reliable manufacturing of the windings. Reducing the width/separation may allow a higher number of turns per winding and/or may reduce the overall size of the motor.

In another exemplary independent aspect, the invention proposes that a motor has a printed fluid dynamic thrust bearing. This may have the advantage of reducing the overall size of the motor and/or allowing more reliable manufacturing.

In a first specific expression of the invention there is provided an electromagnetic motor comprising:

a stator including a plurality of printed electromagnetic windings to induce a rotating magnetic field in an airgap, and

a rotor having a plurality of magnetic poles to interact with the magnetic field in the airgap to cause the rotor to rotate about the stator.

In a second specific expression of the invention there is provided an electromagnetic motor comprising

a stator including a plurality of electromagnetic windings to induce a rotating magnetic field in an airgap,

a rotor having one or more magnet poles to interact with the magnetic field in the airgap to cause the rotor to rotate about the stator, and

a fluid dynamic thrust bearing in the airgap, including a printed formation to provide a lubricating fluid layer between the stator and rotor when rotating.

In a third specific expression of the invention there is provided a method of fabricating a winding for a motor comprising

printing a first conductor layer of conductive ink in a planar spiral on a stator.

In a forth specific expression of the invention there is provided a method of fabricating a fluid dynamic thrust bearing for a motor comprising

printing radially spaced spiral ridges of metallic or polymeric ink on a stator.

Brief description of the drawings

In order that the present invention may be more readily understood and put into practical effect, there shall now be described, by way of non-limitative example only, one or more embodiments of the inventions, with reference to and as illustrated by the accompanying drawings; in which:

Figure 1 is a perspective view of a motor according to an exemplary embodiment,

Figure 2 is a perspective view of the rotor in Figure 1,

Figure 3 is a perspective view of the stator in Figure 1,

Figure 4 is an exploded view of the winding in Figure 3,

Figures 5a and 5b are plan and perspective views of the bearing in Figure 3, and

Figure 6 is a flow diagram of a method of manufacturing according to an exemplary embodiment.

Detailed description

Referring to Figure 1 an axial type electromagnetic micro motor 100 is shown according to an exemplary embodiment, having a rotor 102 and a stator 104. The stator includes a plurality of windings or coils 106 and the rotor includes a plurality of magnets or poles 108. When current is flowing through the windings 106 in a specific sequence, a rotating magnetic field is induced in the air-gap 110 between the rotor 102 and the stator 104. The magnets 108 rotate in synchronism with the rotating magnetic field. Thus the speed of rotation can be controlled by the frequency of the current in the windings 106.

Figure 2 shows the rotor 102 in more detail. The rotor 102 is generally supported by a rotor body 200. The rotor body 200 includes a thin flat disk 202 and a central, cylindrical axial bushing 204 extending from the disk 202. A plurality of radially spaced permanent magnets or magnetic poles 108, are

attached on an annular locus to the disc 202, oriented with alternating polarities and each magnetic axis in parallel with the shaft and directed towards the stator 104. The delineation between each pole is shown by radially spaces lines 210 in Figure 2. The rotor bottom surface 212 is a substantially flat, smooth surface. A magnetically permeable yoke plate or back iron 206 may lie between the magnets 108 and the disk 202 to concentrate the magnetic field, reduce any leakage flux and/or improve the operating characteristics.

Figure 3 shows the stator 104 in more detail. The stator 104 includes a base 300 and a shaft 302 extending from the base. A plurality of radially spaced windings 106 are attached to the base 300 on an annular locus oriented with each magnetic axis parallel to the shaft 302 and directed towards the magnets 108.

Figure 4 shows one of the windings 106 in more detail. Each winding 106 has multiple layers, for example four printed planar spiral conductor layers 402 stacked on top of each other, with electrically isolation provided by five interleaved insulating layers 404. Each conductor 402 has contacts 406 at each end which are either connected to an adjacent conductor layer in series, or connected externally to the power supply.

A fluid dynamic thrust bearing 306 is provided between the rotor bottom surface 212 and the windings 106, to minimise friction and avoid any contact. Figure 5 shows the bearing 306 having a pattern on the rotor face or the stator face, which generates a separation layer or pressurised air film when the rotor 102 rotates relative to the stator 104. The pattern includes radially spaced expanding spiral ridges 500 on the top surface 502 of the stator 104, on top of the windings 106.

In use, with the rotor 102 in place on the stator 104, the bushing 204 has a tight clearance on the shaft 302 to allow smooth rotation. In most applications, the motor 100 will be oriented with the shaft 302 generally vertical. In this case when the rotor 102 is stationary, the magnets 108 will

rest on the ridges 500. When rotor 102 is rotating the bearing 306 creates a separation layer or air film, which reduces any wobble in the rotor 102 and ensures the air-gap 110 is consistent. If the shaft 302 is not vertical, then a further bearing (not shown) may be provided on the opposite side of the rotor 102, to further regulate rotation. Alternatively, in some applications a load connected to the rotor may also provide an axial thrust, which allows the bearing 306 to work effectively in non-vertical orientations.

A thin layer of conformal coating may be provided on the contact surfaces between the rotor and the stator, as a protective and/or lubricating layer. For example a Diamond Like Carbon (DLC) layer may be provided on the inner surface of the bushing 204, the outer surface of the shaft 302, and the top surface 502 of the stator 104 including the ridges 500. The DLC layer helps to protect the components from damage and to further reduce friction.

The motor 100 may be manufactured according to the method 600 shown in Figure 6. Manufacturing may be done in a batch process where multiple motors are formed simultaneously. The method generally comprises providing a stator 602 and providing a rotor 604. A set of windings may be printed 606 on the stator. Windings may be provided in multiple layers. A bearing pattern may be printed 608 on the windings. Once the components are manufactured they may be coupled together.

Providing the stator 602 includes forming the stator base 300, forming the shaft 302 and attaching the base 300 to the shaft 302. The stator base 300 may be a substrate for example a body of silicon or injection moulded plastic. The shaft 302 may be a steel rod machined to give a smooth finish and accurately controlled tolerance. The shaft 302 is aligned with the stator base 300 and attached using adhesive.

Providing the rotor 604 includes forming the rotor body 200, forming and attaching the yoke plate 206 and forming and attaching the magnets 108. The rotor body 200 is injection moulded plastic having a smooth finish and accurately controlled tolerance. The yoke plate 206 is a machined thin annular

iron plate which is attached to the disk 202 using instant adhesive. A ring is sintered using Samarium-Cobalt (Sm-Co) composite magnetic alloy. A number of alternating polarity magnetic poles are magnetised concurrently in the ring by applying very strong magnetic fields to each area designated as a pole. The magnets 108 are attached to the yoke plate 206 using adhesive.

Printing the windings 606 includes printing each conductor layer 402 and coating in between with the insulating layer 404. As shown in Figure 4 a first insulating layer 404 of polymeric material is non-conformally spin or dip coated onto the stator base 300. A first conductor layer 402 of metallic ink such as gold (Au), silver (Ag) or chromium (Cr) is precision inkjet printed in a spiral pattern on the first insulating layer 404. An outer contact 406 of the first conductor layer is provided for connection to another winding or the supply. A second insulting layer 408 is coated on the first conductor layer 402, with a mask covering an inner contact 410 of the first conductor layer 402, which is then removed to create a void 412. A second conductor layer 414 is printed on the second insulting layer 408, with an inner contact 416 connected to the inner contact 410 of the first conductor layer through the void 412.

Similarly, a third insulating layer 418 is coated on second conductor layer 414, and a third conductor layer 420 is printed on the third insulating layer 418. An outer contact 422 of the second conductor layer is connected to an outer contact 424 of the third conductor layer 420. A forth insulating layer 426 is coated on the third conductor layer 420 with a mask covering an inner contact 428 of the third conductor layer 420, which is then removed to create a void 430. A forth conductor layer 432 is printed on the forth insulating layer 426 with an inner contact 434 connected to the inner contact 428 of the third conductor layer 420 through the void 430. A fifth insulating layer 436 is coated on the forth conductor layer 432. An outer contact 438 of the fourth conductor layer 432 is provided for connection to another winding or the supply.

The height of each conductor layer is relatively low, for example 10μm. Printing the conductor layers may for example allow easier fabrication and/or

lower width and/or lower separation of the conductors. The width of each conductor may be .8μm to 5μm, for example 1μm. The separation between adjacent conductors in the spiral may be .8μm to 2μm, for example 1μm. However depending on the application, the conductors may be configured differently. Providing lower width and/or separation allows a higher number of turns per winding for a given space and/or allows the overall size of the motor to be reduced for a given output.

In the configuration shown in Figure 4 the direction of the spiral of each conductor layer alternates, so that the current direction (i.e. clockwise of anticlockwise) in each layer of a given winding is always the same. In the configuration shown in Figure 1 with 6 windings, two diametrically opposite windings are connected in series, such that the 3 winding pairs are connected to a three phase AC supply. The supply may be variable frequency if control of the speed of rotation is required.

Printing the bearing 608 includes precision injet printing the ridges 500 on top of the fifth insulating layer 436 from metallic or polymeric ink. Both the conductor layers and the bearing are made in a single print setting on the same area on the stator base, thus ensuring accurate alignment. Printing the bearing may for example allow easier and/or more accurate fabrication of the ridges.

Contact surfaces between the rotor and the stator are deposited with DLC using filtered cathodic vacuum arc (FCVA) deposition to achieve a coating of for example 2μm to 3μm thickness.

In batch processing, the stator base 300 of a large number of motors may be a silicon substrate. In this case, the substrate may be diced to singulate each separate motor.

One application for an embodiment of the present invention is as a MEMS micro-cooler fan to dissipate heat in a portable device. For example an etched

silicon fin-like-disc ("propeller") may be attached by adhesive to the top surface of the rotor, such that it forms a propeller for air convection. Alternatively the fins could be moulded directly into the upper surface of disk. The propeller and rotor may rotate within a housing, which in turn draws in air towards the propeller, and projects the air out. For example, a 6 coil 8 pole configuration might be controlled to rotate at between 5000-8000RPM. The fan and the motor together might be 2mm thick and 12mm in diameter.

Whilst the preferred embodiments of the invention have been described in detail, many variations are possible within the scope of the invention as will be clear to a skilled reader.

Claims:

1. An electromagnetic motor comprising:

a stator including a plurality of printed electromagnetic windings to induce a rotating magnetic field in an airgap, and

a rotor having a plurality of magnets to interact with the magnetic field in the airgap to cause the rotor to rotate about the stator.

2. An electromagnetic motor comprising

a stator including a plurality of electromagnetic windings to induce a rotating magnetic field in an airgap,

a rotor having a plurality of magnets to interact with the magnetic field in the airgap to cause the rotor to rotate about the stator, and

a fluid dynamic thrust bearing in the airgap, including a printed formation to provide a lubricating fluid layer between the stator and rotor when rotating.

3. The motor as claimed in claim 1 or claim 2 wherein the motor is an axial type micromotor.

4. The motor as claimed in any proceeding claim wherein each winding comprises at least one planar spiral conductor.

5. The motor as claimed in claim 4 wherein the width of the conductor within the spiral is less than 5μm.

6. The motor as claimed in claim 4 or claim 5 wherein the seperation between adjacent conductors in the spiral is less than 2μm.

7. The motor as claimed in any of claims 4 to 6 wherein the width of each conductor is between 0.8μm and 5μm.

8. The motor as claimed in any of claims 4 to 7 wherein the separation between adjacent conductors in the spiral is between 0.8μm and 2μm.

9. The motor as claimed in any of claims 4 to 8 wherein the conductor is printed metallic ink selected from the group consisting of gold, silver, chromium or any combination thereof.

10. The motor as claimed in any proceeding claim wherein each winding comprises a plurality of planar spiral conductor layers stacked on top of each other, isolated with a plurality of interleaving coated insulating layers.

11. The motor as claimed in claim 10 wherein the direction of the spiral in each layer is opposite to the directly adjacent layers.

12. The motor as claimed in claim 11 wherein each spiral has a contact at each end, and the inner and outer contacts are alternately connected to directly adjacent conductor layers, to connect the conductor layers of each winding in series, such that in use the current in all conductor layers of a given winding is in the same direction.

13. The motor as claimed in claim 2 wherein the printed formation is a pattern of radially spaced spiral ridges on the stator.

14. The motor as claimed in claim 13 wherein the ridges are printed metallic or polymeric ink.

15. The motor as claimed in any proceeding claim wherein the motor is less than 2mm in height.

16. The motor as claimed in any proceeding claim wherein the motor is less than 12mm in diameter.

17. The motor as claimed in any of the preceding claims further comprising a protective and/or lubricating layer on at least one of the contact surfaces between the stator and the rotor.

18. The motor as claimed in claim 17 wherein the protective and/or lubricating layer comprises a layer of Diamond Like Carbon (DLC).

19. The motor as claimed in any one of claims 2, 13 or 14 further comprising a layer of Diamond Like Carbon (DLC) on the printed formation.

20. The motor as claimed in any of the preceding claims further comprising a shaft attached to the stator, about which the rotor rotates.

21. The motor as claimed in any of the preceding claims further comprising a magnetically permeable yoke plate on the side of the magnets opposite to the stator.

22. A method of fabricating a winding for a motor comprising

printing a first conductor layer of conductive ink in a planar spiral on a stator.

23. The method as claimed in claim 22 further comprising

coating a first insulating layer on a substrate, the first conductor layer printed onto the first insulating layer,

coating a second insulating layer on the first conductor layer, with a first mask covering an inner contact of the first conductor layer,

removing the first mask to provide a first void,

printing a second conductor layer on the second insulting layer,

connecting an inner contact of the second conductor layer to the inner contact of the first conductor layer through the first void, and

coating a third insulating layer on the second conductor layer,

24. The method as claimed in claim 23 further comprising

printing a third conductor layer on the third insulating layer,

connecting an outer contact of the second conductor layer to an outer contact of the third conductor layer,

coating a forth insulating layer on the third conductor layer, with a second mask covering an inner contact of the third conductor layer,

removing the second mask to provide a second void,

printing a forth conductor layer on the forth insulating layer,

connecting an inner contact of the forth conductor layer to the inner contact of the third conductor layer through the second void, and

coating a fifth insulating layer on the forth conductor layer.

25. The method as claimed in any one of claims 22 to 24 further comprising

providing a fluid dynamic thrust bearing on the stator.

26. The method as claimed in claim 25 wherein providing a fluid dynamic thrust bearing comprises

printing radially spaced spiral ridges of metallic or polymeric ink on the upper most layer of the windings.

27. The method as claimed in claim 25 or 26 further comprising coating a layer of Diamond Like Carbon (DLC) on the fluid dynamic thrust bearing.

28. The method as claimed in any one of claims 22 to 27 wherein a plurality of motors are manufactured together in batches, with the stator of each motor being part of a substrate, and wherein the radially spaced spiral ridges and the conductor layers are printed in a single print setting on the same area of the substrate.

29. The method as claimed in claim 28 further comprising singulating the substrate to separate each motor.

30. A method of fabricating a fluid dynamic thrust bearing for a motor comprising

printing radially spaced spiral ridges of metallic or polymeric ink on a stator.

31. The method as claimed in claims 30 further comprising coating a layer of Diamond Like Carbon (DLC) on the radially spaced spiral ridges.

32. The method as claimed in claim 30 or 31 further comprising providing a plurality of windings and wherein the radially spaced spiral ridges are printed on the windings.

33. The method as claimed in claim 32 wherein providing a plurality of windings comprises

printing a least one conductor layer of conductive ink in a planar spiral on a stator.

34. The method as claimed in claim 32 or 33 wherein a plurality of motors are manufactured together in batches, with the stator of each motor being part of a substrate, and wherein the radially spaced spiral ridges and the at least one conductor layer are printed in a single print setting on the same area of the substrate.

35. The method as claimed in claim 34 further comprising singulating the substrate to separate each motor.