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A Micro Actuator using Meissner Effect of High Tc Superconducting Film (Meissnac)

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Abstract

A problem of the surface friction is inevitable in the micro machines. However, the levitation by Meissner effect of high Tc superconductor gives a complete solution to the problem. The repulsive force between permanent magnets and superconductors is utilized to levitate and actuate micro structures without the surface friction. In this paper, a micro actuator using Meissner effect of high Tc superconducting film (Meissnac) is proposed; Meissnac is drived by the control of (Superconducting/ Normal) states of superconductor. The levitating force and the driving force are analyzed by the numerical method.

1. Introduction

In the recent years, the micro mechanics in which a size of elements is 10(μm) order has been studied(1)(2). The micro machines are fabricated by micro machining techiniques compatible with VLSI process. Merits of micro mechanics are as follows;

1)Micro machines are fabricated by photo lithography and etching like VLSI device. Mass production of micro machines is possible with batch process. Assembly and adjustment process are not required.

2)It is possible to integrate micro machines and logic circuits or sensors on the same silicon substrate.

3)Micro machines are available in very small space where the conventional machines, especially robots are not available.

4)The high speed operation is possible because of its light weight.

5)The distortion by the thermal expansion is small.

6)Micro machines are secure for their small force and stored energy.

Applications of micro mechanics are expected in the control of the micro optics, the μm order postioning in the LSI fabrication process, the micro valve controlling fluids minutely, and biomedical technology. In applications of the micro optics, for example, SCOFSS(Small Cnatilevered Optical Fiber Servo System) was fabricated in Univ. of Utah(3) as Fig. 1. It controls the position of a laser beam. The optical fiber covered with the charged plastic pipe is actuated by the electrostatic force with electrodes. The diameter of the optical fiber is 140(μm).

Since elements of micro machines are 10(μm) order, the surface of elements is relatively rough. Furthermore, the moving element has very small mass. By these reasons, the surface friction between moving elements and fixed elements becomes large and the moving elements tend to move discretely. The levitation between permanent magnets and superconductors by Meissner effect removes the surface friction of micro mechanics(4).

In this paper, a micro actuator using Meissner effect of High Tc superconducting film (Meissnac) is proposed. A driving method of the actuator is also proposed; the driving force can be obtained by the difference of a pitch of stator and that of slider and the control of (S/N) states of superconductors applying current over Jc. The levitating force and the driving force of Meissnac are analyzed by the numerical method, discrete surface current method.

In comparison with conventional magnetic levitated machines, merits of Meissnac are as follows;

1)Smooth positioning in μm order is available.
2)Levitaion without energy dissipation and control.
3)Novel actuating principle based on control of (S/N) states of superconductors.

2. Structure of Meissnac

Meissnac is composed of a slider and a stator shown in Fig. 2. On the slider, permanent magnets magnetized vertically are attached in stripes. In the stator, stripes of YBCO superconductors of which thickness is μm order are patterned by photo lithography and etching. The width of permanent magnets and superconductors is in the order of 100[μm] and the length is 10[mm].

When the stator is cooled by liquid nitrogen, the levitating force is produced by Meissner effect between permanent magnets of the slider and superconductors of the stator. Since there are seven magnets of the slider and six superconducting poles on the stator in a particular distance, the difference between a pitch of the slider and that of the stator produces a horizontal force. However, the horizontal force is balanced when all of superconducting poles remain superconductive. The driving force is produced by turning superconducting state of certain superconducting poles into normal state. The transition from superconducting state to normal state is obtained by applying current over Jc to superconducting poles.

3. Levitating force and Drivding force

Since the length of magnets and superconducting ploes is sufficiently long compared to the width, the magnetic field including permanent magnets and superconductors is approximated by two dimensional field. The levitating force, Fy and the driving force, Fx are analyzed numerically by the discrete surface current method(5).

In the discrete surface current method, surface currents is repalced by certain numbers of discretely distributed surface line currents. Values of these discrete surface line currents are determined to satisfy boundary conditions at contour points. Boundary conditions are that the normal component of magnetic field on superconductors is zero and total amounts of surface currents in each superconductor are zero.

Discrete surface line currents and contour points are located on the surface of superconductors. Each superconducting pole is divided into 49 sectors and 50 discrete surface line currents are placed in each superconducting pole. A permanent magnet is repalced by equivalent magnetizing currents(6). The levitating force and the driving force are computed in follwing conditions

1)The distance between the slider and the stator is 50[μm].
2)The equivalent magnetizing current is 1[A].
3)The second and the fifth superconducting poles are normal state.

The computed levitating and driving force of each superconducting pole are shown in Fig. 3.

Maximum values of the levitaing force and the driving force are 1.7 and $0.26[N/m^2A^2]$. The unit is normalized by the area of a slider and the square of a magnetizing current. These values are sufficient to levitate and drive the slider in micro mechanics.

For example, the floppy diskette of which weight is about $10[mg/cm^2]$ order can be levitated and drived by these values. At that time, the applied magnetic field on superconductors must be below a lower critical magnetic field (Hc1). The distribution of magnetic flux between the slider and the stator is shown in Fig. 4

The (S/N) state of superconducting poles is controlled by applying current over Jc. The current is applied in the sequence shown in Fig. 5 to drive the slider in a particular direction.

4. Conclusion

·Meissnac is proposed. The levitating force and the driving force are analyzed by the numerical method. The forces of Meissnac are enough to actuate micro structures. The fabrication of Meissnac in micro size is now on the way.

References

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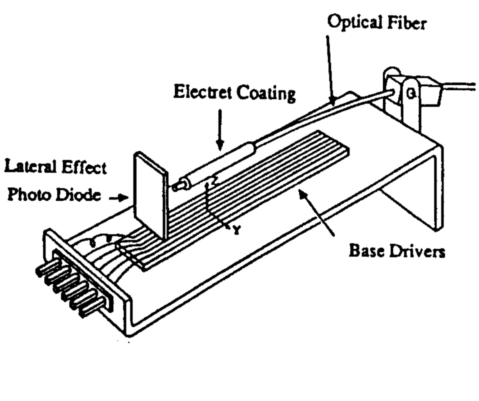


Fig. 1 Schematic drawing of SCOFSS

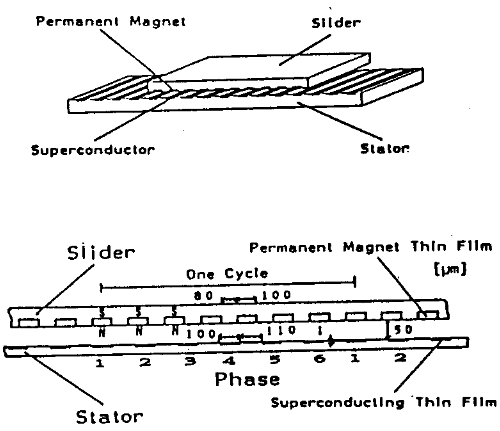


Fig. 2 Schematic drawing of Meissnac.

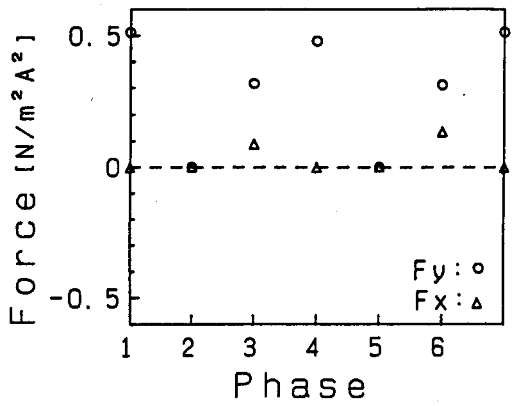


Fig. 3 Computed levitating and driving force of each phase of the stator.

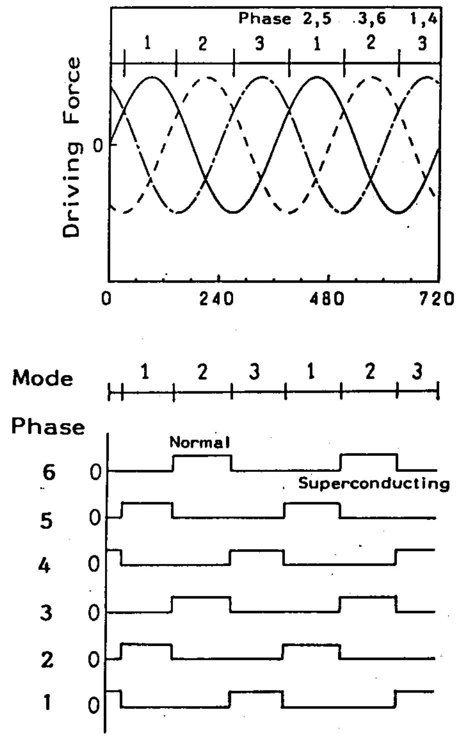
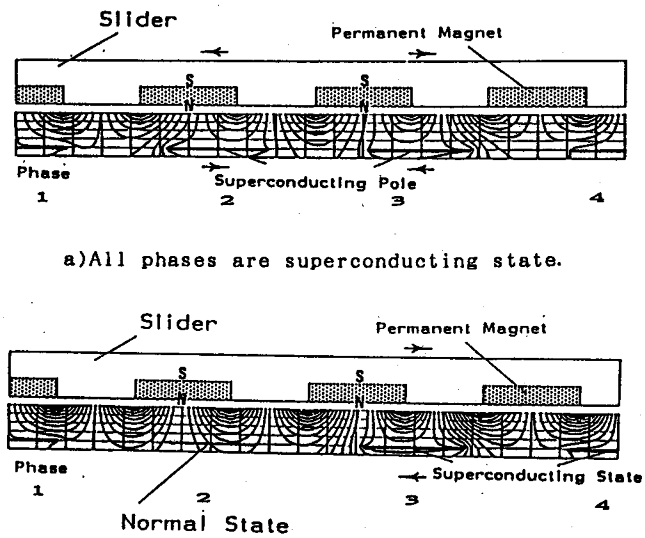


Fig. 5 Driving force and mode of actuation



a)All phases are superconducting state.

b)The second and the fifth phase are normal state.

Fig. 4 Distribution of magnetic flux between the slider and the stator;

a)All phases are superconducting state.

b)The second and the fifth phase are normal state.