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Article / Book Information

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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 機械	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（工学）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis, entitled "Development of Soft Electromagnetic Microactuators", has six chapters.

Chapter 1, "Introduction", reviews various driving methods of soft microactuators used in applications such as micropumps, microvalves, and microrobots and states that soft electromagnetic microactuators (SEMMAs) have advantages such as low voltage drive and high response. However, it is difficult to fabricate the SEMMA's moving part consisting of a magnetically responsive material and a structural polydimethylsiloxane (PDMS) material. Besides, when SEMMA is applied to micropumps for microfluidic diagnostic chips, the disposal cost of the moving part consisting of two materials that come in contact with biological samples is high. As a result, simplifying the structure and manufacturing of SEMMA's moving parts is necessary. Based on this background, this thesis aims to simplify the structure and manufacturing of the SEMMA's moving part using PDMS as the flexible structural part. Besides, this thesis also aims to simplify the moving part using one material that simultaneously satisfies the functions of flexibility and ferromagnetism.

Chapter 2, "A SEMMA utilizing an impact-driven membrane based on a cylindrical NdFeB magnet", proposes an actuator in which multiple PDMS membranes are driven by the impact of cylindrical magnets without integrating PDMS with the magnets or coils. The cylindrical magnets are driven up and down by the attractive and repulsive forces from a rotating multi-pole ring magnet. Multiple membrane vibrations are utilized to drive a pulsating micropump. The feasibility of the micropump with a simple structure, in which the disposable part is composed only of a PDMS membrane, is demonstrated through prototyping and experiments.

Chapter 3, "A SEMMA utilizing segmented NdFeB bonded magnets", proposes a SEMMA utilizing segmented NdFeB bonded magnets. Conventional magnetic membranes fabricated by uniformly mixing resin and powder magnets experience a strong self-demagnetization field, and the magnetic flux density, electromagnetic force, and displacement generated are weak or small. To this end, multiple grooves with a high aspect ratio are made in a PDMS mold, and the mixture of magnetic powders and wax powders is filled into the grooves to form the bonded magnet by heating and applying pressure, successfully generating a high surface magnetic flux density. The prototype SEMMA can generate a large force compared to the magnetic membrane fabricated by the conventional method without increasing the membrane's stiffness and finally result in a larger displacement.

Chapter 4, "A SEMMA utilizing a flexible coil", proposes a SEMMA with a flexible coil formed on a PDMS membrane using a conductive polymer composite (CPC). The wiring is formed by screen printing on the PDMS membrane that has been surface treated with oxygen plasma. We have confirmed that the wiring resistance increases due to the tensile or compression strain generated when the PDMS membrane is peeled off from the substrate or when printing multiple CPC layers. We then search for annealing temperatures to restore the resistance to that of samples without strains. We have confirmed that the wiring resistance can be recovered at 120 and 160℃. Finally, a prototype SEMMA, with a CPC-based spiral coil on a Φ30 mm circular PDMS membrane and a permanent magnet generating a static magnetic field, is fabricated. The membrane displacement when a step voltage is applied to the coil is measured. In addition to the step response with a time constant of several milliseconds due to electromagnetic force, we have confirmed the thermal deformation response with a time constant of several seconds due to the Joule heat of the coil. The displacement becomes larger due to the thermal expansion of the PDMS membrane.

Chapter 5, "A SEMMA utilizing a FePt film as a magnetically structural material", proposes a method to fabricate a moving part of a SEMMA using a single FePt film, a flexible structural and permanent magnetic material. First, FePt-based micro specimens are fabricated using electric discharge machining from FePt films with a thickness of several tens of millimeters by pulsed laser deposition (PLD), and their longitudinal elastic modulus and fracture strain are measured by tensile testing. The longitudinal elastic modulus of the PLD-made FePt film is less than one-sixth that of polysilicon and magnet materials,

and the fracture strain is seven times that of polysilicon and more than 100 times that of magnet materials, indicating that the PLD-made FePt is promising as a flexible structural material. Furthermore, the magnetic properties are comparable to those of isotropic SmCo magnets in terms of remanence, although the coercive is inferior. The FePt film is processed into stripes, locally magnetized by laser-assisted heating and a static external magnetic field. While one end of the stripe is fixed, the frequency response of displacement is measured by applying a variable magnetic field externally. By changing the magnetization location with laser-assisted local heating, the amplitude of each vibration mode can be varied even when an external magnetic field of the same amplitude and distribution is applied, demonstrating the feasibility of a SEMMA with a simple structure and manufacturing process.

Chapter 6, "Conclusions and outlook", summarizes the results achieved in this thesis and discusses future work.