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題目(和文)	交流圧力源を用いたフレキシブルERマイクロバルブ搭載多自由度ソフトマイクロアクチュエータに関する研究
Title(English)	A study on a multi-DOF soft microactuator with built-in flexible electro-rheological microvalves using an alternating pressure source
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Thesis outline

Thesis title: A study on a multi-DOF soft microactuator with built-in flexible electro-rheological microvalves using an alternating pressure source

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The outline of this thesis are shown as follows:

In chapter 1 “Introduction”, the research background and the research purpose are demonstrated. A microrobot such as an in-pipe microrobot that performs advanced tasks in narrow and complex space has been required and multi-DOF (degree of freedom) soft microactuators are needed to be developed. Among different types of microactuators, a soft fluidic microactuator is a promising candidate for the microrobot application due to the benefits of high energy density in microscale size and softness to safely interacting with the environment. For the control of the soft microactuator, a flexible electro-rheological microvalve (FERV) is effective, because the flexible microvalve that controls an electro-rheological fluid (ERF) flow by changing its apparent viscosity with an electric field applied by the fixed electrodes has no sliding parts causing friction and fatigue and can be integrated into the microactuator to reduce the overall size. In order to minimize the size of the multi-DOF actuator system, an alternating pressure system is useful, because its piping system is simple and small for multiple microactuators by rectifying alternating pressure supplied by only one pipe with synchronized switching of the FERVs. From the above, the research purpose is to construct elemental technologies for a multi-DOF soft microacuators using highly flexible FERVs and an alternating pressure source.

In chapter 2 “Development of hybrid structure FERV”, a novel hybrid structure FERV is proposed and developed. The purpose of developing this FERV is to increase the flexibility of the FERV for integration into a soft microactuator as a built-in control valve. The proposed hybrid structure FERV is made from low rigidity PDMS (polydimethylsiloxane) and high rigidity SU-8. The channel structure made from PDMS makes the FERV bendable, while the strengthen structures made from SU-8 maintain the flow channel height. All of the materials including the electrodes made from a conductive polymer PEDOT:PSS used in the fabrication process of the proposed FERV are UV-curable, which makes the fabrication process fast and simple. From the fabrication result using a newly developed MEMS (micro electro mechanical systems) fabrication process, the proposed FERV with 0.60 mm width, 0.19 mm height and 5.0 mm length is proved to have 7 or more times higher flexibility than that of the previous proposed FERVs. The experiments are conducted to demonstrate the static and dynamic characteristics of the FERV, which shows acceptable results for practical applications.

In chapter 3 “Optimal design and fabrication of one-DOF bending microactuator with built-in FERVs using alternating pressure source”, a one-DOF bending microactuator with built-in FERVs using an alternating pressure source is developed using the hybrid structure FERVs. The FERVs fabricated in chapter 2 are integrated into the microactuator to reduce the size of the microactuator. Among various types of soft microactuators, an antagonistic microactuator with two folded wall type soft microactuators is utilized, since it has a high bending angle while using a small volume of fluid. In order to optimize the dimensions of the microactuator, a lumped parameter model of the antagonistic microactuator with an alternating pressure source and FEM (finite element method) model of the soft microactuator are demonstrated and simple simulations are conducted. The designed 10 mm long microactuator is successfully fabricated and bonded to the hybrid structure FERVs. The successfully fabricated microactuator is connected to an alternating pressure source and the experiments are conducted. The experimental results show the maximum bending angle of ±11° by using the applied pressure with the peak to peak value of 100 kPa and the frequency of 5 Hz. Lastly, the results of the experiments and the simulations are compared, which verifies the validity of the proposed microactuator and its mathematical models.

In chapter 4 “Development of multi-DOF soft microactuator with built-in FERVs using alternating pressure source”, a multi-DOF microactuator with built-in FERVs using an alternating pressure source is proposed by connecting multiple one-DOF bending microactuators with built-in FERVs in series with rotation around the actuator axis and a two-DOF mictoactuator is investigated. The FEM simulations are conducted to investigate the length proportion of the first microactuator at the root to the second microactuator at the tip that yields similar tip displacements in horizontal and vertical directions. The first and the second microactuators designed from the simulation are successfully fabricated and integrated with the hybrid structure FERVs. A 20 mm long two-DOF microactuator is successfully fabricated by connecting the first and the second microactuators. Then, the bending characteristics of the fabricated microactuator are demonstrated using air pressure. Lastly, an experiment is conducted with the successfully fabricated two-DOF microactuator with an alternating pressure source and reveals the subjects to realize the desired motion.

In chapter 5 “Conclusions and future work”, the obtained results of the research are summarized and future work is described.