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A SURVEY MEMS MICROMOTOR ASSEMBLIES & APPLICATIONS

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Abstract— The conception and fabrication of micromotors is comparatively new in the field of engineering and is gradually gaining more serious attention from scientists, engineers, researchers and manufactures. Their designs and prototypes are finding various applications in robotics, medical instruments and various other fields. This article tries to give a short description of the advance made in this field so far.

Keywords— MEMS, The Electric Induction Micromotor, Electroctatic Micmotors, Piezoelectric Micromotors, Microfabrication techniques,

INTRODUCTION

As technology and understanding have advanced in the area of micromachining more complex and novel devices are being conceptualized and fabricated all over the world. One area of micromachining technology that has seen considerable growth in the last decade has been in the realm of Micro Electro-Mechanical Systems (MEMS) which encompasses a wide variety of devices that combine microelectronic systems with mechanical structures to do work in a way that had never before been possible. Of particular interest in this report are the families of MEMS devices known as micromotors. MEMS micromotors are real rotational actuators characterized by their millimeter to submillimeter dimensions, fabrication compatibility with standard micro machining techniques, and their intended role in micro-scale devices. Three main design ideologies exist, and this work presents a concise survey of these designs. These three devices include electric induction micmotors, electrostatic micmotors, and piezoelectric micromotors.

TECHNOLOGY OVERVIEW AND COMPARISON

A. THE ELECTRIC INDUCTION MICROMOTOR

Within each of these three subsets of micromotors there are more sub categories even still. The electric induction micromotor is one of the first types of micromotor fabricated using micromachining techniques. This class of micromotor is characterized by the use of electromagnetic induction between two substances; the stator, to which the driving signal is applied, and the rotor, which is acted upon by the stator field to induce a rotational torque. In that sense, induction micromotors share a lot with their larger cousins that are found in every home and every industrial and business setting. In the most general sense the stator has a collection of conductors that when excited with pulse DC signals in a particular fashion produce an electromagnetic field rotating through the rotor struture. In some fashion (there are many ways to accomplish this), this rotating electromagnetic field interacts with the rotor to create torque to turn the motor output [1, 2, 3]. Figure 1 illustrates the structure and operation of a microfabricated electric induction micromotor.

Fig.1 Electromagnetic induction micromotors basic structure and operation [1, 2]

One of the most unique characteristics of the induction micromotor is its ability to function not only as a motor, but also as a generator, opening up possibilities for small scale mobile power generation [1, 2]. The lack of any active electrical components on the rotor eliminates the need for electrical brushes which in turn lowers the wear of the motor, giving induction micromotors one of the longest lifetimes of the technologies discussed here as well [2]. Some limitations on the operation of induction micromotors limit their uses. First of all, these devices are the largest of the three families of micromotors. The use of magnetic materials and windings decreases the power per unit volume of induction motors [3]. They also typically require a high driving voltage on the stator, in some cases as high as 300V and frequencies up to 2 MHz. This can make the motor controller more complicated to implement. The stator frequency also has to be high for the motor to work properly causing the motor to run at a fairly high RPM. This leads to the need for gearing in many designs, adding another layer of complexity to the fabrication process. These micromotors are compatible with micromachining techniques with a few exceptions for permanent magnet rotor types that usually require some mechanical assembly [2]. The remainder of the components can be fabricated using sacrificial layer surface micromachining.

B. THE ELECTROSTATIC MICROMOTOR

Electrostatic motors are charge coupled devices that rely on the attractive force of opposing electrical charges to induce a torque on the rotor, which is why this class of devices is also referred to as variable capacitance micromotors. They have a somewhat simpler layout when compared to induction micromotors, consisting of a series of electrodes that make up the stator, and a rotor that stays connected to ground through its bearing. A multiple phase square waves excite the stator poles, increasing or decreasing the local charge. This charge differential acts to either attract or repel the grounded rotor converting the electrical energy into mechanical motion [4]. These motors come in a variety of configurations the most common of which are the side-drive and the parallel-drive. With the side-drive configuration the stator poles are located to the side of the rotor, requiring that the rotor be a salient pole shape [3, 4]. The other drive configuration consists of two parallel circular plates [5]. One serves as the rotor and can rotate freely, and the other is made up of a circular array of electrodes that turn the rotor like a fan driving a pinwheel. Fig. 2 shows an axial field electrostatic micromotor.

Fig. 2 Fabrication design of Electrostatic motor [9]

Because the force between the stator and the rotor is dependent only on the distance between them and the gap potential is not size factors like the length of a conductor coil, the electrostatic micromotor is capable of achieving higher power densities then the induction micromotor [3]. This allows electrostatic micromotors to be manufactured much smaller than other varieties. The manufacture of these micromotors is also simplified by eliminating the need for special films, and magnetic materials. Only commonly used micromachining techniques are required to fabricate one of these motors, including sacrificial layer surface micro machining and photolithography, with only common materials such as basic silicon and polysilicon [5]. Like the induction motors, however, the electrostatic micromotors usually require a high driving voltage to achieve practical speeds and torques.

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C. THE PIEZOELECTRIC MICROMOTOR

The piezoelectric micromotor operates using a phenomenon exclusively accessible to the microscale world; where upon the rotor rides flexural waves on the stator created using the piezoelectric effect. These motors typically consist of a rotor plate on a bearing of some sort that comes into physical contact with the stator plate parallel to the rotor. The stator is either manufactured from, or attached to a material that exhibits strong reactions to the piezoelectric effect, where by the crystalline structure of the substance deforms in an electric field. Many cutting edge devices use a compound called leadzirconate-titanate (or PZT for short) as the elastic piezoelectric membrane layer [4, 5]. The surface deformations are controlled in such a way that the waves propagate around the surface of the stator while in contact with the rotor. The friction between the rotor and the flexural waves is translated into torque that spins the rotor in the opposite direction of wave propagation [5, 6]. The unique mechanical element of the piezoelectric micromotor is how the rotor is actuated through the friction between the stator surface waves and the rotor itself. This implies that the rotor need not have any electrical characteristics at all, unlike with the other two technologies, which in turn simplifies the fabrication process. Another unique characteristic of the friction driven rotor is that the rotational losses due to friction are very low. With both induction and electrostatic micromotors any friction on the bearing has a direct and detrimental effect on the output power of the motor; something that does not occur at all with the piezoelectric motor. The high torque to speed ratio of the friction driven rotor eliminates the need for gear reduction for most applications as well, in effect simplifying the fabrication of the motor [14]. Standard surface micromachining techniques can be used to fabricate piezoelectric motors, just as with the electrostatic motors. Even more freedom in materials choice is available because there are no electrical requirements for the rotor or stator [6], but the entire structure is usually fabricated from silicon and polysilicon (for the bearings) and whatever piezoelectric material is being used for the actuator. The one significant limitation with piezoelectric micromotors is mechanical wear on the friction bearing between the stator and the rotor. Some mechanical fatigue will occur whenever deice is used, giving it a short lifespan. To combat this, more durable materials such as copper and nickel are used in fabricating the stators and rotors to slow down wear and fatigue. [6]

Fig. 3 Piezoelectric micromotors model

DISCUSSION OF APPLICATIONS

As the science and technology involved with micromotors matures and is refined, scientists and engineers are focusing more and more on not just how to make these devices, but also on what to do with them. Finding viable applications for micromotors doesn't require a giant leap in imagination, as things like miniaturized robotics and other machines like pumps immediately come to mind. One application in telecommunications utilizes an electrostatic micromotor with a polished mirror mounted perpendicular to the plain of the rotor in an optical switch. The electrostatic motor allows for the position of the rotor to be controlled precisely letting the mirror to be positioned to reflect an optical beam from one port to another [7]. Another application involving optics is in a novel type of microscale diffraction grating scanner. The major appeal for optical applications is in the quantity of devices that can be manufactured at the same time [7]. Micromotor optical devices may become ubiquitous to the communications field and in computing as well as fiber optical data transmission moves further into the mainstream. Regardless of where these devices first make their appearance in the consumer market, seeking out new applications will always be vital to the continuation of research in micromotors and MEMS devices in general.

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CONCLUSION

The construction of miniaturized rotating electric machines through microfabrication techniques is becoming a reality. This paper explores the design of three motor types and discussed here are the primary branches in micromotor fabrication. We provide a comparison of these machines, with a few other devices in existence that differ, but are usually some sort of hybrid device, combining the principles of one technology with another. The manufacturing technology is bringing the techniques needed to fabricate these devices into the mainstream, where they will soon find rolls to fill in the world of consumer goods, from wrist watch motors, to microscale robotic devices for medical applications and beyond.

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