

PZT Thin Film Piezoelectric Traveling Wave Motor

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Shen Dexin, Zhang Baoan, Yang Genqing*, Jiao Jiwei, Lu Jianguo, Wang Weiyuan
State Key Laboratories of Transducer Technology,
*Ion Beam Laboratory
Shanghai Institute of Metallurgy, Chinese Academy of Sciences
865 Changning Road, Shanghai 200050, P.R. China

Abstract

With the development of MEMS, its applications in many fields attract more and more attention in the world. Among kinds of MEMS, micro motors which include electrostatic, electromagnetic type are the typical and important ones. As an alternative approach, the piezoelectric traveling wave micro motor, based on thin film material technology and IC technologies, circumvents many of the drawbacks of the above two type of micro motors. It displays its distinct advantages. In this paper, we report a PZT piezoelectric thin film traveling wave motor. The PZT film with thickness of $150\mu\text{m}$ and diameter of 8mm was first deposited onto a metal substrate as the stator material. Then, eight sections were patterned to form the stator electrodes. The rotor was 8kHz frequency power supply. The rotation speed of the motor is 100rpm . Besides, the influences of the friction between stator and rotor and the structure of rotor on the rotation have been studied.

Introduction

With the development of microelectromechanical systems(MEMS), the application attracts the attention of the world. Among kinds of MEMS, micro motors that include electrostatic, electromagnetic type are the typical and important ones. As an alternative approach, the piezoelectric traveling wave micro motor, based on thin film material technology and IC technologies, circumvents many of the drawbacks of the above two type of micro motors, and can be possibly applied in the research of piezoelectric vibratory gyroscope.

In this paper, we report a new structure for PZT thin film piezoelectric traveling wave motor, and discuss the relationship between rotation speed of rotor and friction, and that between excitation frequency and rotation speed.

Design and fabrication process of the piezoelectric motor

1. Traditional design of the piezoelectric motor structure

The structure of the traditional piezoelectric mini-motor[1] or micro motor[2] is shown in Fig. 1. In this structure, the public electrode is fabricated on the substrate. Then, the piezoelectric thin film is deposited, sputtered or coated on the substrate. The piezoelectric thin film is patterned to form fans, which support the rotor. The piezoelectric thin film is excited by AC source to produce acoustic vibration that leads to the rotation of the rotor. The design principle for the piezoelectric motor is that the mechanical deformation of the piezoelectric material electrically excited produces the traveling wave that drives the rotor. In the traditional structure, a short possible happens between the metal rotor and the fans. Therefore, another insulator layer on the fans is necessary. However, this extra layer causes a series of disadvantages and increases the complexity of process, even though suitable material has been selected to improve the rotation condition by increasing the friction between the rotor and the stator.

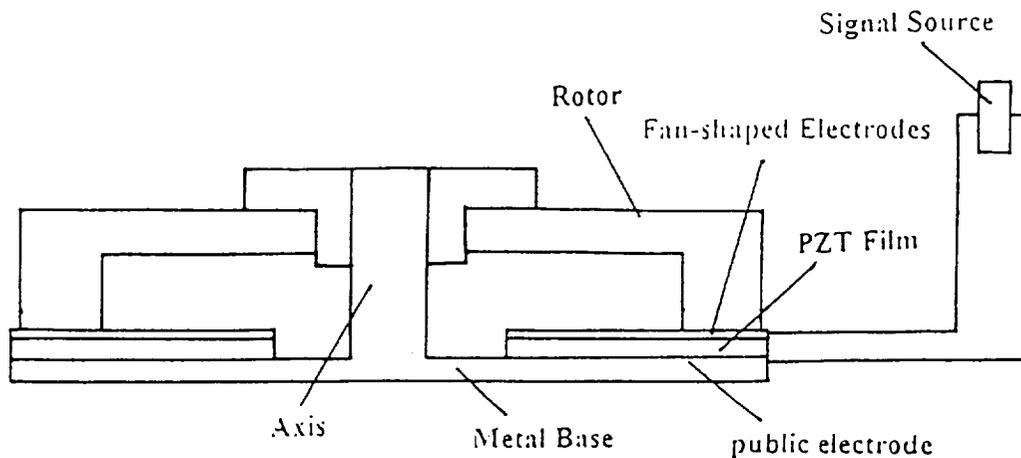


Figure 1 . Schematic diagram of the traditional motors

2. New design of the piezoelectric motor structure

After analyzing the vibration mode of PZT material for the rotor of the piezoelectric motor, the mechanical deformation of PZT thin film under AC excitation is determined to be an entirety deformation of the material. Meanwhile, the piezoelectric motor with new structure has some advantages compared with other motors fabricated with IC processes. The new designed structure is shown in Fig.2. In this structure, the public electrode, or the stator, of the piezoelectric motor faces upwards to support the rotor as shown in Fig.3, while the fans face downwards for linking leads easily as shown in Fig.4.

3. Fabrication processes for the piezoelectric motor

The stator material is commercially available. The substrate is copper with a thickness of less than $200\mu\text{m}$, which supports the PZT thin film with a thickness of less than $150\mu\text{m}$. Both faces of the PZT thin film are fused with silver layers as the electrodes. The outer silver face is also patterned to form eight fans for the connection with AC source. The inner silver face is a ring-shaped public electrode and adhered to the copper substrate. This stator is then assembled on an axle with the public electrode upwards and fans downwards. When AC source is applied, the stator with above new structure can drive the rotor of the piezoelectric motor on the public electrode. In our experiment, the piezoelectric motor with a 8mm diameter rotates in a rotation speed of above 100rpm under 10V AC excitation.

There is another fabrication process for the rotor of the thin film piezoelectric motor. The copper sheet with a thickness of less than $200\mu\text{m}$ is the substrate, on which SiO_2 layer is deposited. The PZT thin film with etched fans and leads is adhered to the substrate with epoxy. The public stator faces upwards to support the rotor. The final structure of the piezoelectric motor is shown in Fig.5.

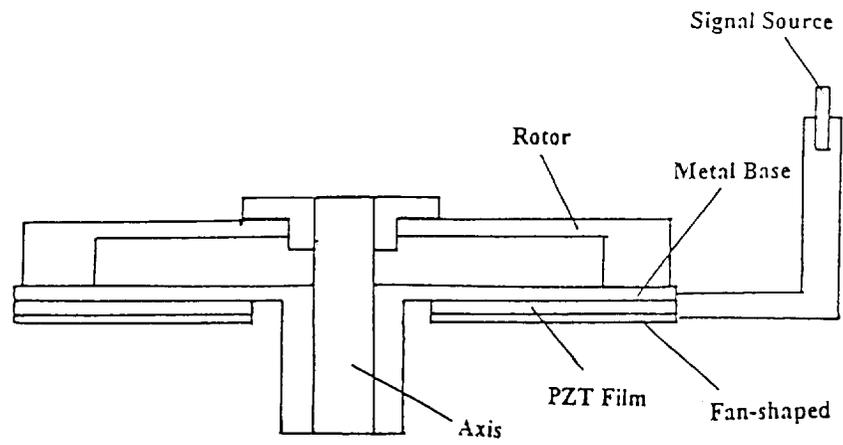


Figure 2. Schematic diagram of the motor

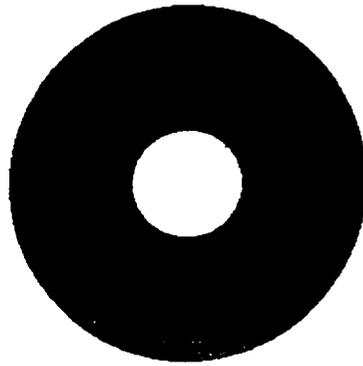


Figure 3. Schematic diagram of the public electrode

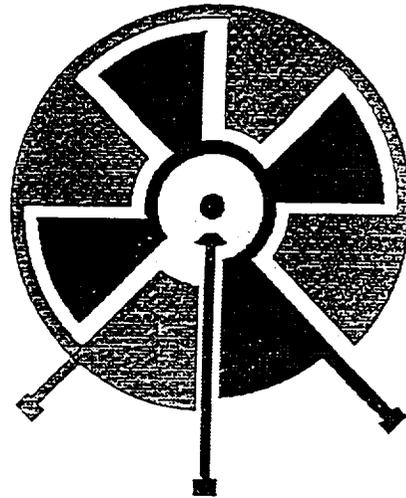


Figure 4. Schematic diagram of the fan-shaped electrode

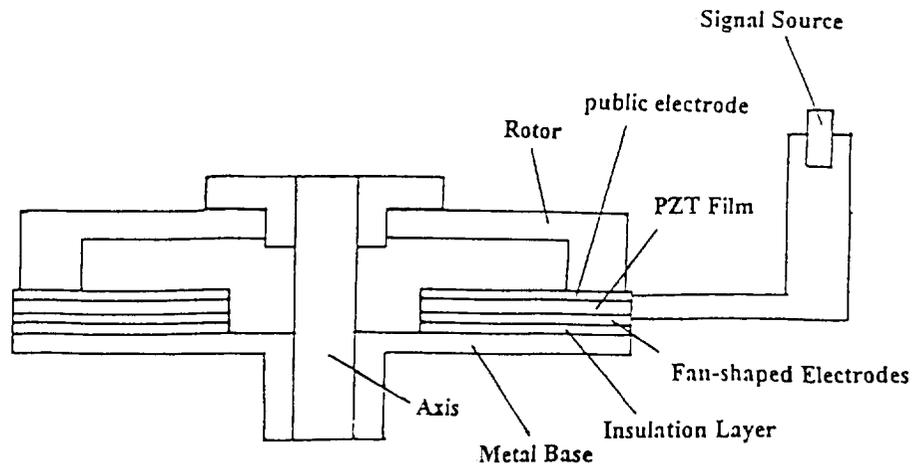


Figure 5. Detailed diagram of the motor

Results

1. Weight of rotor and rotation speed

The rotor on the public stator is even supported by the public stator. It is important to determine the weight of the rotor. The relationship of the weight of the rotor and the rotation speed is shown in Fig.6. When the rotor is very light, the friction force between the rotor and the stator is too small to drive the rotor. On the other hand, when the rotor is very heavy, the friction force hinders the rotation on the contrary. Only in the case of the rotor with a proper weight, it can rotate stably and continuously. In addition, the structure of the rotor is another important factor that influences the rotation mode. Therefore, the piezoelectric motor with a proper rotor, i.e., that is of proper weight and well-designed structure, can be in the best rotation state.

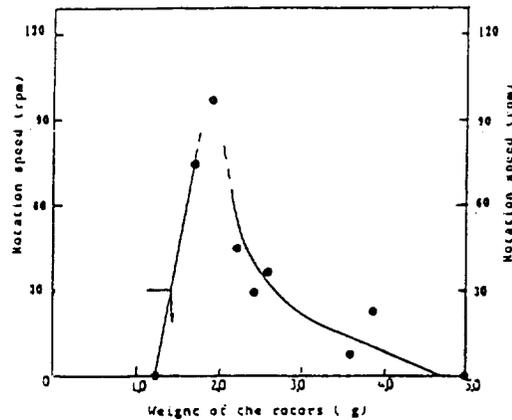


Figure 6. Relationship between the rotation speed and the weight of the rotors

2. Comparison of the rotation speed for the rotor with the two structures

There is no sensible difference of the rotation speed wherever the rotor is supported, by the public electrode or the fans as shown in Fig.7 and Fig.8.

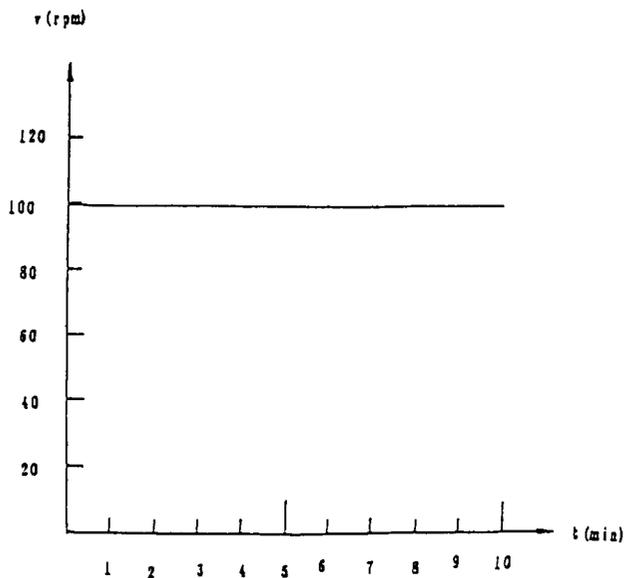


Figure 7. Rotation characteristics of the new motor

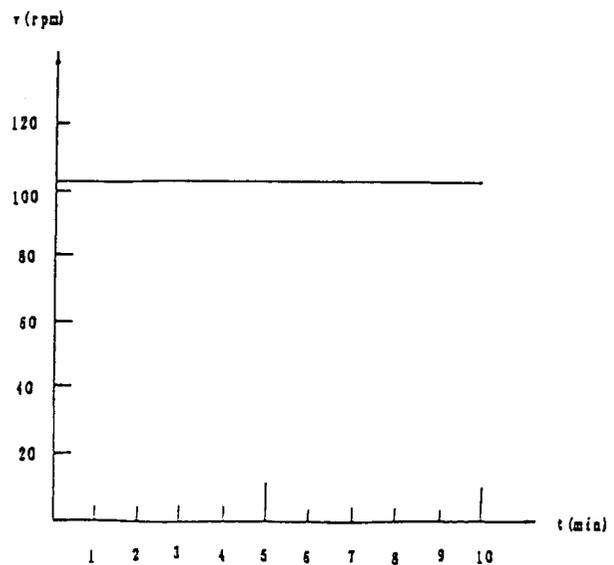


Figure 8. Rotation characteristics of the traditional motor

3. Relationship of the resonant frequency and rotation speed

The rotor of the piezoelectric motor is driven by the vibration of the piezoelectric thin film under AC excitation. The experiment showed that the rotation speed is sensitive to the excitation frequency, i.e., unless the piezoelectric thin film is resonantly excited, it produces large mechanical output to drive the rotor. The rotor of the new structure motor can rotate only near at the resonant and anti-resonant frequency, though with a great difference of mechanical output. With a small frequency shift from the resonant and anti-resonant value, the rotation speed decreases sharply and soon reaches zero. In Fig.9, the relationship of the excitation frequency and rotation speed for the rotor with proper weight is shown.

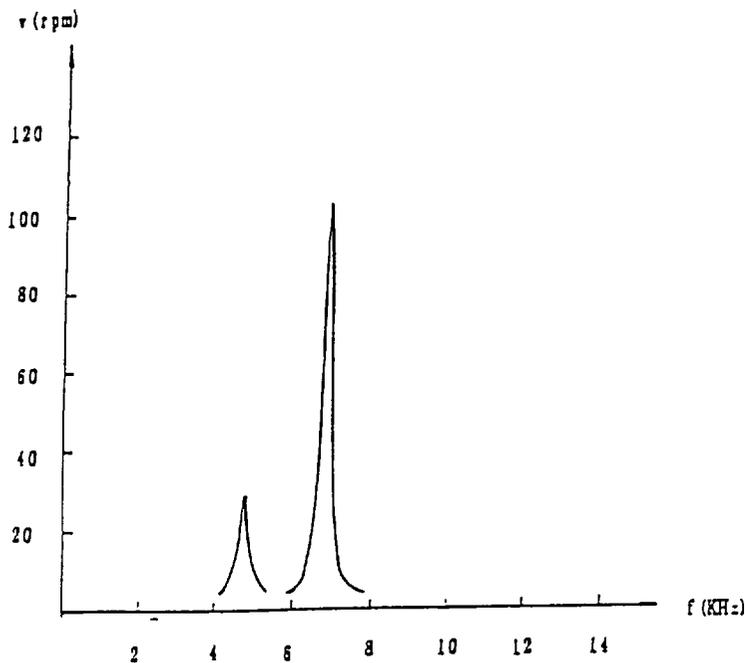


Figure 9. Relationship between the rotation speed and the resonance frequency

Discussion

In this piezoelectric motor with such a new and simple structure, its rotor of micro piezoelectric motor can be fabricated with IC process. Combined with electro-moulding process, it is feasible to fabricate piezoelectric micro motor. The problem of the short between fans can be solved in our new structure piezoelectric motor though the rotor is fabricate with metal materials. The new structure of the piezoelectric micro motor with 2mm diameter is shown in Fig. 10. In the structure, the transition layer of TiN, which is deposited on the silicon substrate and patterned, helps adhere the electrodes and leads on PZT thin film to the substrate. The fans and leads are all made of platinum. The other face of the PZT thin film is deposited with metal and patterned to form the public electrode. All above construct the stator of the new structure piezoelectric micro motor. Assembled with the axle and rotor fabricated with electro-moulding process, a piezoelectric micro motor can be developed completely.

References

- [1] Patent CH Appl. 2282/92 20 July 1992.
- [2] A.M. Flynn, L.S. Tavrow, S.F. Bart, R.A. Brooks, D.J. Ehrlich, K.R. Udayakumar and L.E. Cross, Journal of Microelectromechanical Systems, 1(1) (1992), 44.

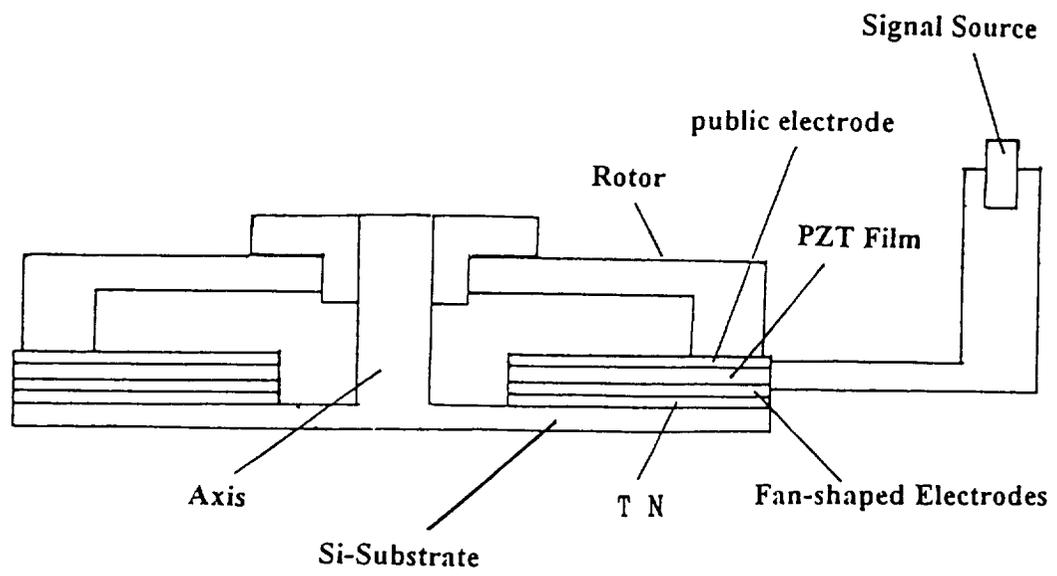


Figure 10. Schematic diagram of the Si-based micromotor