Available online at www.sciencedirect.com

SCIENCE DIRECT®

Materials Chemistry and Physics 90 (2005) 391–395

MATERIALS CHEMISTRY AND PHYSICS

www.elsevier.com/locate/matchemphys

Review

Wear and dynamic properties of piezoelectric ultrasonic motor with frictional materials coated stator

Hyun-Phill Ko[a,b], Sangsig Kim[b], Jin-Sang Kim[a], Hyun-Jai Kim[a], Seok-Jin Yoon[a,*]

[a] Thin Film Materials Research Center, KIST, Seoul 130-650, South Korea
[b] Department of Electrical Engineering, Korea University, Seoul 136-701, South Korea

Received 31 March 2004; accepted 23 September 2004

Abstract

Piezoelectric ultrasonic motors have been studied, developed and utilized by researchers and companies all over the world. Ultrasonic motors (USM) produce rotational motion based on traveling waves made by the resonant vibrations of piezoceramic. These motors have been recently developed and utilized in practical applications. The dynamic properties and life of piezoelectric ultrasonic motors are strongly related to the frictional material Fused on the sliding surface. In this study, effects of frictional material properties on the performances of piezoelectric ultrasonic motors are investigated. It was possible to improve the torque of a traveling wave type ultrasonic motor by stator's coating.

Keywords: Stator; Coating; DLC; GET; TiAlN

Contents

1. Introduction

Ring type piezoelectric ultrasonic motors, which are different from the electromagnetically driven conventional motors, have applications in robotics, precise positioning *x*–*y* stage for semiconductor fabrication and optics and automation equipments.

The basic principle of an ultrasonic motor of rotary type uses mechanical bending vibration as driving source with a ring type stator (Fig. 1).

On one face of the stator, piezoelectric ceramics that generate a mechanical vibration in order to allow their progression in the form of a wave are attached and at the other face, protruding teeth that transmit an ellipsoidal-phase change to the driving rotor are formed.

More specifically, the present experiment relates to a ring type piezoelectric ultrasonic motor with a frictional

* Corresponding author.
E-mail addresses: ryanko@kist.re.kr (H.-P. Ko), sjyoon@kist.re.kr (S.-J. Yoon).

0254-0584/$ – see front matter © 2004 Published by Elsevier B.V.
doi:10.1016/j.matchemphys.2004.09.037

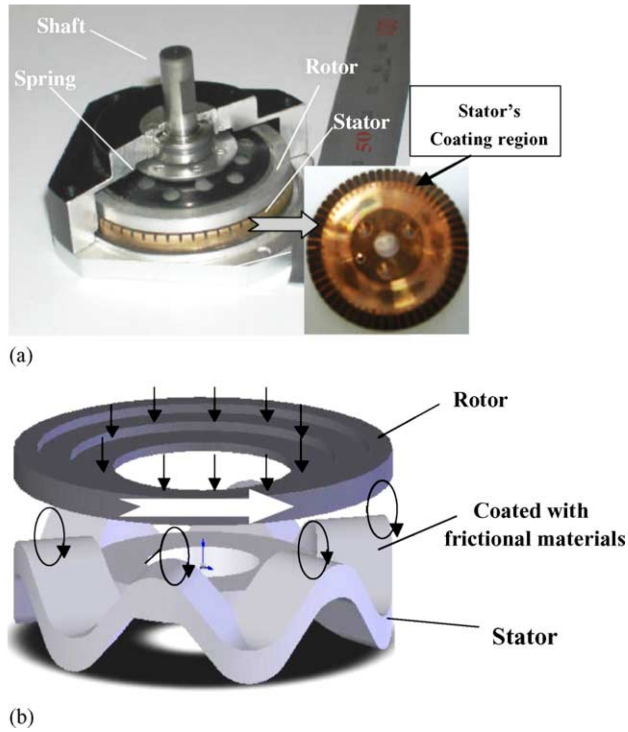

Fig. 1. (a) Components of reference piezoelectric ultrasonic motor; (b) principle of the piezoelectric ultrasonic motor.

force that drives the motor. The stator produces a mechanical displacement using a piezoelectric ceramic, which is driven by an alternate electric field at ultrasonic frequency.

Sliding loss and wear between the rotor and the stator are inevitable, because the rotational velocity of the rotor is almost constant and the vibration velocity of the stator is sinusoidal. Thus, the frictional material used on the sliding surface plays an important role in terms of the characteristics and lifetime of the motor. Since the life of the frictional material is one limitation of the ultrasonic motor life, it is necessary to establish the wear properties of the frictional material [1].

The dynamic properties and lifetime of piezoelectric ultrasonic motors are strongly related to the frictional material used on the sliding surface [2–8].

Surface treatments with various coatings can enhance the surface mechanical properties of stators and rotors, making it possible to control the wear and frictional behavior of the motors over a wide range of tribological conditions. The wear of the stator has direct influence on efficiency, reliability and quality of motors, their speed and torque. Therefore, stator's coating is very crucial in order to increase wear resistance of the stator or to modify its friction behavior. Table 1 shows some of the materials properties and dynamic properties of the reference motor, which are compared to the improving motors.

In this study, effects of frictional material properties on the performances of piezoelectric ultrasonic motors are investigated and it is shown that the coatings can improve the torque of a traveling wave type motor.

Table 1
Specification of reference motor

Parameters	Characteristics
Thickness of Piezo ceramic (mm)	0.5
Diameter of Piezo ceramic (Ø)	40
Thickness of stator (mm)	3.0
Diameter of stator (Ø)	40
Speed (rpm)	111
Torque (N m)	0.198

2. Experiments

2.1. Background

Frictional materials play a very important role in piezoelectric ultrasonic motors by their influence on their efficiency, speed, torque, etc.

Frictional materials of various kinds, such as Econol (Sumitomo Chemical), carbon fiber reinforced plastic (Japan Carbon), PPS (Sumitomo Bakelite), polyimide, etc. have been investigated [2].

In recent years, amorphous carbon films have attracted a great deal of attention because of their interesting diamond-like properties: high hardness, high wear resistance, low friction coefficient, high thermal conductivity and chemical inertness. These films are known as diamond-like carbon (DLC) films. Due to the above outstanding properties, DLC films have been considered for the applications such as protective, tribological coatings [3–5].

Titanium nitride and titanium aluminum nitride films have been widely applied to coatings of surface and high speed machining because of their high hardness and low coefficient of friction.

Glass Embedded Teflon (GET) is not a coating material but a kind of sheet, which is the adhesive tape sheet.

The GET contains Teflon and glass fiber, which are combined with each other as cruciform shape. Although the wear behavior of frictional material is a very complicated phenomenon, the object of the experiment is to provide a ring type piezoelectric ultrasonic motor that improves the dynamic properties by coating the stator with frictional materials.

In this study, we assume that the essential factors are reflected by five kinds of friction materials of glass embedded teflon (GET), titanium aluminum nitride (TiAlN), titanium nitride (TiN), diamond like carbon (DLC) and silicon-incorporated-diamond like carbon (Si-DLC).

2.2. Experimental details

The present experiment investigates the application of a coating of frictional material on the stator's surface.