Laminated Piezoelectric Actuator for Low-Voltage Drive

Yoichi MAMIYA, Hideo KOMAMURA, Takayuki INOUE

Abstract

The laminated piezoelectric actuator is a device featuring high displacement accuracy, fast response and high generated force and its applications have been advancing for positional control of precision machinery such as in chip fabrication systems. Expectations for these actuators are increasing because of the recent rise in the requirements for size/voltage reductions that are aimed at application in consumer equipment such as digital cameras and cellular phones. Additionally the increase in the precision requirements of general precision machinery has been influential. This paper introduces the laminated piezoelectric actuators of NEC TOKIN and focuses specifically on the new laminated piezoelectric actuator for low voltage drive that can effectively meet recent market requirements.

Keywords

piezoelectric actuator, precision positioning, chip fabrication system

1. Introduction

Actuator is the generic name for devices that convert the input energy into mechanical energy. The piezoelectric actuator is an electrical actuator that inputs electric power and outputs displacement or a force.

Compared to other actuators such as electromagnetic, pneumatic and hydraulic ones, the piezoelectric actuator features higher displacement accuracy, larger generated force and faster response rate. These features have advanced applications of piezoelectric actuators in the industrial equipment field that need precision positioning control in the order of a few nanometers to hundreds of micrometers. Such applications include the precision positioning stage and probes of chip fabrication systems, precision flow control (mass-flow controller) of gases used with CVD systems, probe drives of scanning tunneling microscopes (STMs) and atomic force microscopes (ATMs), as well as for vibration isolators used with the above systems.

Piezoelectric actuators have recently been required to apply low-voltage drives with the aim of reducing the size, energy consumption and costs of the fabrication and analysis systems that apply them. In this paper, we will introduce NEC TOKIN's laminated piezoelectric actuators by focusing on the model has been developed to meet these market requirements. This innovative design is driven by a lower voltage than has been used hitherto.

2. Construction of the Laminated Piezoelectric Actuator

The laminated piezoelectric actuator is fabricated by forming a piezoelectric ceramic material into a sheet of about 100μm thickness in a similar manner to the fabrication of laminated ceramic capacitors. Fabrication includes printing the internal electrodes made of Ag-Pd alloys as the main constituent on the sheet, laminating the required number of such sheets and providing sintering process to them. Since the piezoelectric ceramic displaces according to the applied voltage, lamination makes it possible to obtain a large displacement with a low voltage (100 to 150 V) and therefore enables the formation of a compact actuator. **Fig. 1** and **Photo** show the construction

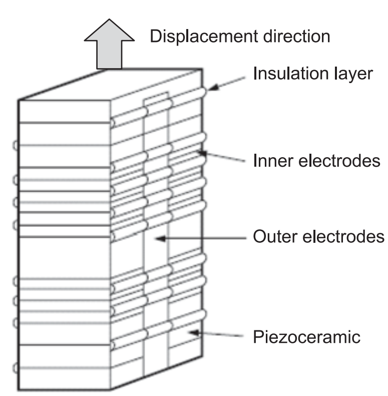

Fig. 1 Construction of the laminated piezoelectric actuator.

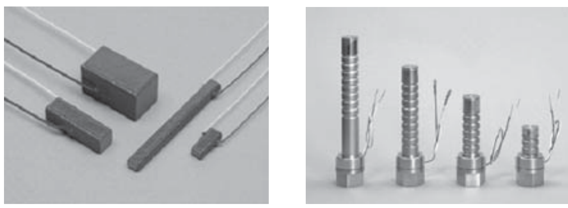

Photo External views of laminated piezoelectric actuators.

and external views of our laminated piezoelectric actuators. These devices use the NEPEC material originally developed by us as a piezoelectric ceramic material that was based on a device with a unique full-face electrode structure in which concentrations of electric fields and stresses are very rare. The product line includes two types of actuator, the "resin-coated actuators" for which the device side is coated with epoxy resin and the "metallic case-sealed actuators" for which the resin-coated actuators are sealed inside metallic cases.

3. Development of New Laminated Piezoelectric Actuator

One of the key characteristics of the laminated piezoelectric actuator, namely the displacement amount, is determined by the number of laminated ceramic sheets (i.e. the height of the laminate when the lamination intervals are constant) and the applied voltage as shown in **Fig. 2** . Provided that the ceramic material thickness is identical, a low laminate height means fewer laminated sheets and consequently a smaller displacement. On the other hand, another key characteristic of the laminated piezoelectric actuator, the generated force, is almost proportional to the cross-sectional area of the plane where the displacement is produced as shown in **Fig. 3** .

Since the displacement amount of the laminated piezoelectric actuator is proportional to the number of laminated sheets as well as the voltage, it is essential to increase the number of laminated sheets in order to make the actuator capable of working at a low voltage. In addition, there have been the following issues in making the low-voltage drive possible.

(1) Increase of the number of laminated sheets.
(2) Reduction of the coating resin thickness.
(3) Increase of the pre-compression pressure inside the metallic case.

We dealt with these issues by improving the design and the fabrication process. The main improvements are as described in the following.

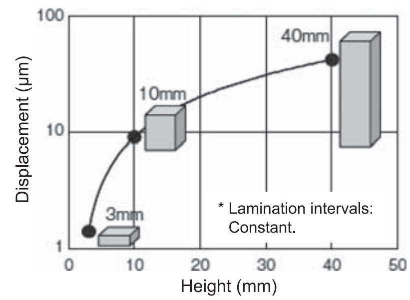

Fig. 2 Laminate height and displacement.

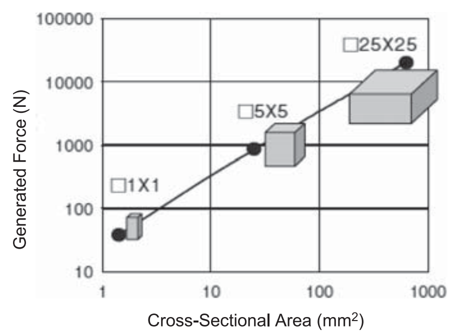

Fig. 3 Cross-sectional area and generated force.

(1) Increase of the number of laminated sheets

The thickness of each ceramic layer of the laminated piezoelectric actuator has previously been about 100 μm. We reduced the thickness by optimizing the sheet formation process and thereby made it possible to double the number of laminated layers.

(2) Reduction of the coating resin thickness

We changed the resin coating of the laminated piezoelectric actuator from an electrostatic powder coating of epoxy resin to an electro-deposition coating of acrylic epoxy resin. This has made it possible to make the coating resin denser and very thin as well as to reduce the binding force and thereby inhibit displacement.

(3) Increase of the pre-compression pressure inside the metallic case

Fig. 4 shows the load and displacement amount of a laminated piezoelectric actuator. It shows that the application of a load on the laminated piezoelectric actuator increases the displacement amount. At NEC TOKIN we optimized the compression load applied during the metallic case sealing process and succeeded in achieving an increase in the displacement amount without compromising the reliability-

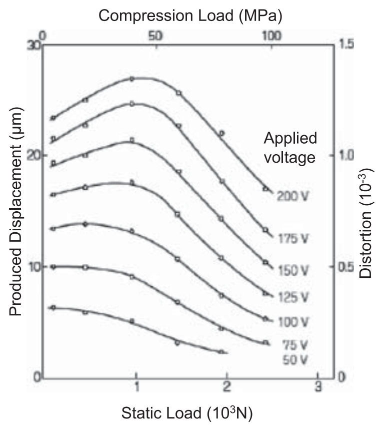

Fig. 4 Relationship between the load and the produced displacement.

related factors, such as the withstanding voltage, mechanical strength and repetition life.

4. Product Introduction

Table and **Fig. 5** show the characteristics and dimensions of the AUB400C801 laminated piezoelectric actuator for low-voltage drive (the new product). The AUB400C801 is optimized based on a reappraisal of the structural design and fabrication process. This strategy has increased the displacement by about 20% while using half of the voltage used to drive the previous same sized product. The new product has already been adopted and acclaimed well in a wide range of precision equipment fields.

5. Conclusion

In the above, we introduced the laminated piezoelectric actuator for low-voltage drives by focusing on its application in industrial fabrication equipment. It is expected that the applications of the laminated piezoelectric actuator will be expanded in various fields where precise, quick positioning control is required. In addition, thanks to other advantages including the high energy efficiency, easy device size reduction and ease of power consumption reduction, its application has also been expanded recently in the field of consumer equipment such as for digital cameras and cellular phone terminals.

The laminated piezoelectric actuator is a highly adaptable product in terms of its design, dimensions, operating

Table Characteristics of the laminated piezoelectric actuator for low voltage drives.

	Previous product ASB340C801	New product AUB400C801 (for low voltage drive)
Operating voltage	150 V	75 V
Displacement	36.7 μm	44.3 μm
Generated force	800 N	800 N
Dimensions	∅11.5 × 58.4L mm	∅11.5 × 58.4L mm

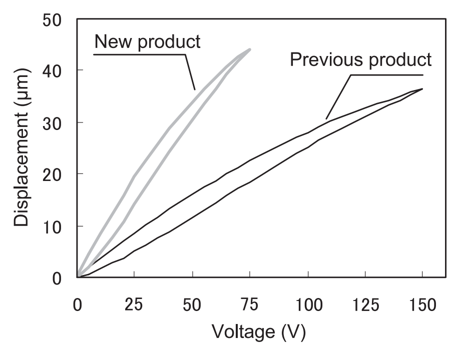

Fig. 5 Relationship between voltage and displacement of the laminated piezoelectric actuator.

characteristics, drive method, handling method and so on. At NEC TOKIN, we intend to enhance the technical support required for meeting diversifying needs and, at the same time, we will endeavor to reduce the size and improve the performance of our actuators in order to contribute to technical innovations in a wide range of fields. Such innovations are expected to range from consumer-oriented compact products to industry-oriented ultra-high precision products.

Authors' Profiles

Yoichi MAMIYA
Department Manager
1st Engineering Department
Piezoelectric Devices division
NEC TOKIN Corporation

Hideo KOMAMURA
Manager
1st Engineering Department
Piezoelectric Devices division
NEC TOKIN Corporation

Takayuki INOUE
1st Engineering Department
Piezoelectric Devices division
NEC TOKIN Corporation