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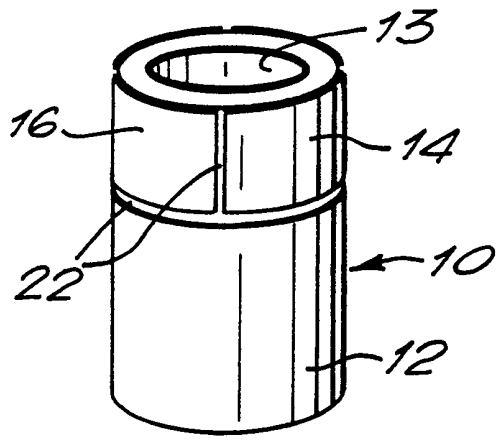
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(58) Field of search
UK CL (Edition K) H1E EAGD EAGE ED
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(54) Precision position actuator

(57) A voltage responsive actuator (10) comprising a body of material dimensionally variable under the influence of an applied voltage and having a reference surface, at least one first electrode (12) attached to the body and arranged to move the reference surface along one direction in response to a first electrical input, and at least one separate electrode (14, 16) attached to the body for the fine adjustment of the reference surface position. The actuator may consist of piezo-electric material and may be used in an interferometer.

FIG. 1.



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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

FIG.1.

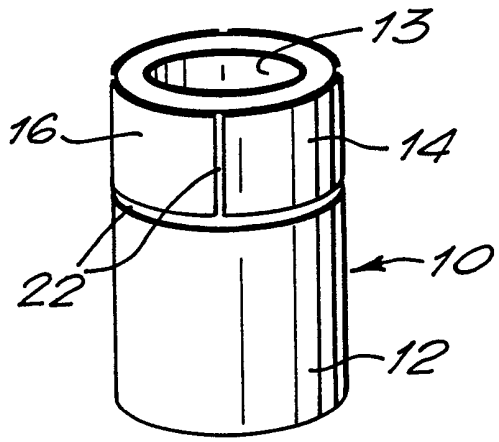


FIG.2.

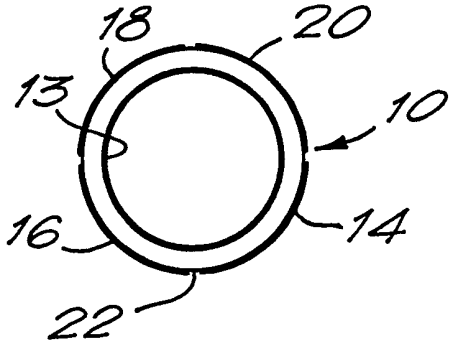
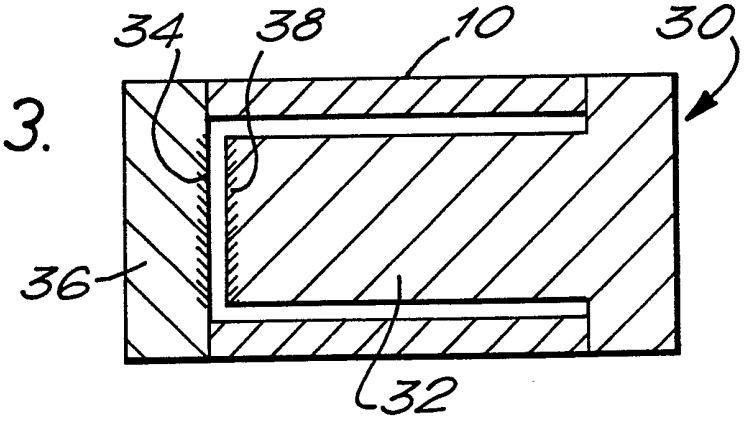


FIG.3.



PIEZO-ELECTRIC ACTUATORS

This invention relates to piezo-electric actuators.

Piezo-electric actuators are used, for example, in situations in which extremely fine and accurate movement is required. Piezo-electric materials undergo dimensional changes in an applied electric field. A wide variety of materials exhibit the piezo-electric effect, such as quartz, barium titanate, lithium niobate and Rochelle salt.

The dimensional change, i.e. expansion or contraction, of the piezo-electric material is a smooth function of the applied electric field. Because the effect is essentially a bulk distortion of the material, piezo-electric actuators can be very stiff and capable of submicrosecond response times. Typical movements would be in the order of micrometres, nanometres or even picometres. Under an applied electric field a piezo-electric crystal deforms along all its axes. It expands in some directions and contracts in others.

Ceramic piezo-electric transducer (PZT) elements are usually made of lead zirconate titanate $Pb(Zr,Ti)O_3$ doped with La, Sr, Bi and Nb in various proportions to modify its properties. Because the crystallites of the polycrystalline ceramic material are randomly oriented, the piezo-electric effect is quite small until the material is poled. Poling involves aligning the crystallites by applying a large D.C. field across the PZT element. When an electric field is applied to a poled element the deformation in the direction of the

applied field (d_{33}) may be about 1 nm/volt at room temperature. The deformation transverse to the field (d_{31}) is usually about half of d_{33} and of opposite sign.

An example of an application for a PZT is as an actuator for a reflecting plate constituting one of a pair in a Fabry-Perot interferometer. The plates must be kept parallel and adjusted with respect to one another about a nominal gap of typically 2 um, but this could be as large as 1 mm or more.

To achieve optimum performance, the interferometer must be maintained parallel to an accuracy considerably better than that to which the plates are polished. Modern interferometer plates are polished such that deviations from the perfect plane surface are less than 2.5 nm (lambda/200 at lambda = 500 nm). To avoid significantly degrading the performance of the instrument, mechanical mounting errors should be less than lambda/500. In practice measuring small wavelength shifts often requires an instrumental stability of lambda/5000 or better over periods of days or weeks. This implies maintaining the parallelism and spacing of the Fabry-Perot plates to better than 0.1 nm (lambda =500 nm).

In one form of proposed interferometer the plates are spaced by means of a set of supporting piezo-electric stacks in the manner of a tripod. By applying an appropriate voltage to each of the stacks the gap between the plates can be adjusted while being kept substantially parallel. Such a construction is

described in the article "Tunable Fabry-Perot filters" published in Optical Engineering, November/December 1981, by P.D. Atherton, N.K. Reay and J. Ring.

Miniaturised interferometers have been developed in which one of the reflecting plates is mounted on one end of a piezo-electric tube which is itself mounted on a base. This plate will move in the axial direction of the tube when suitable voltages are applied to electrodes attached to the inner and outer surfaces of the tube. The other plate is fixed to a pillar mounted on the base inside the tube.

It has been found that such tubes may not expand uniformly, but tilt to render the plates out of parallel. One reason for this is that the PZT material is not homogeneous and will expand at different rates per unit voltage applied. Another reason for this is that the inner and outer walls of the tube may not be concentric, i.e. the thickness of the tube varies. This departure from parallelism between the plates compromises the overall transmission efficiency and the spectral resolution of the interferometer. It is an object of the invention to provide a voltage response actuator which expands/contracts in a uniform manner in a chosen direction.

According to the present invention there is provided a voltage response actuator comprising a body of material dimensionably varable under the influence of an applied voltage and having a reference surface, at least one first electrode attached to the body and arranged to

move the reference surface along one direction in response to a first electrical input, and at least one tilt electrode attached to the body to tilt the reference surface with respect to the one direction.

Alternatively the present invention could be considered to provide a voltage response actuator comprising: a body of material dimensionally variable under the influence of an applied voltage; a first electrode attached to a first area of the body and arranged to expand and/or contract a first portion of the body, corresponding to the first area, along one direction in response to a first electrical input; and at least one second electrode attached to a second area of the body and arranged to differentially expand and/or contract a second portion of the body corresponding to the second area in relation to a third adjacent portion of the body.

Preferably the material is in the form of a tubular member. In this case the first electrode embraces the rim or outer surface of a portion of the tube. The tiltor second electrode may be attached to an area of the remaining portion of the tube surface. Thus, any movement of the material which takes an end face of the tube out of parallel with a notional plane can be corrected by applying a suitable voltage to the tilt or second electrode. This will cause a compensating differential longitudinal expansion of one portion of the tube with respect to the other.

In a particular embodiment a set of second electrodes is located toward one end of the tube and a cylindrical

first electrode is located toward the other. However, this is not necessary, the set of electrodes could be positioned in between first electrodes on the same surface.

Generally, a set of second electrodes can be considered as defining a compensating tilt stage of the tube. By putting a differential voltage across each of the tilt electrodes as appropriate, the tube can be made to tilt in such a way as to maintain the orientation of an object mounted on the actuator that is to be moved.

Whereas a suitable material is the piezo-electric material described above it is also found that other materials dimensionally varrable under the influence of an applied voltage can be used. As an example electro-strictive materials such as PMN (lead magnesium niobate) can be used. PMN is particularly applicable in certain situations as it is found to expand more linearly, and can exhibit less hysteresis than piezo-electric materials.

A specific embodiment of the present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a piezo-electric tube according to the present invention;

Figure 2 is a plan view of the tube in Figure 1; and

Figure 3 is a section through a Fabry-Perot etalon incorporating the tube of Figure 1.

Referring to Figures 1 and 2 of the drawing, a piezo-electric actuator comprises a radially outwardly polarised tube 10 of piezo-electric lead zirconate titanate ceramic material. The tube is 10 mm high, 15 mm outside diameter and has a wall thickness of 1 mm. The tube is made of PZT 5H material and is produced by Vernitron Limited.

An outer cylindrical silver electrode 12 is fired onto a lower 6mm portion of the outside surface of the tube. Similarly, an inner cylindrical silver electrode 13 is fired onto the inner surface of the tube. Tilt electrodes 14, 16, 18, 20 of equal area are formed on a remaining upper 3 mm portion of the outside of the tube. In this embodiment the tilt electrodes are four similar equally angularly spaced silver electrodes which are also fired onto the surface. Wires are attached to the electrodes by means of low temperature solder, electrically conductive epoxy or spring contacts. The electrodes are spaced by channels 22 which are about 1 mm wide.

Each of the electrodes is defined by firing the coating on the tube and either sand blasting, etching or engraving the channels 22 between them.

Referring to Figure 3, a piezo-electric tube 10 as shown in Figure 1 is mounted in a Fabry-Perot etalon. The tube is mounted on a fused silica base 30. The base extends inside the tube 10 in the form of a pillar 32.

A first movable reflecting plate 34 is mounted or connected on a plate 36 on the end 37 of the tube remote from the base 30. The end 37 represents a reference surface for the reflecting plate 36. A second static plate 38 is mounted or coated on the end of the pillar, facing the moving plate.. The Fabry-Perot cavity defined between the two plates is typically 2 um but could be any value up to about 1 mm or greater.

Ideally, the faces of the plates are parallel. Practically, the faces of the plates will not be parallel after manufacture and may change during use. The tilt electrodes on the tube are used to provide the initial alignment, to realign during use and to correct for misalignment introduced by the tube during scanning. As mentioned previously, the length of the tube will not always change evenly, causing a departure from parallelism. Compensating voltages are applied to the tilt electrodes to compensate for this as required.

Typical voltages of + and - 1 kilovolt are used to drive the lengthening electrode to cause movement between the plates.

The number of tilt electrode plates could be any odd or even number spaced about the outer, or indeed inner, surface of the tube. Also, the tilt electrodes may be located anywhere along the length of the tube, for example, between two separate outer lengthening electrodes.

The reference surface on the end 37 of the tube could serve as a mounting surface, as described, or any other

function requiring movement by the body.

Thus, the invention resides in separating the electrodes on a PZT into a main lengthening electrode and at least one compensating electrode which is actuated separately. Indeed, the overall concept of using such separate electrodes can be applied to other forms of PZT, such as solid bars and plates. In all cases the PZT may be actuated to change dimension along either the d_{33} direction or the d_{31} direction with respect to the direction of poling of the actuator.

CLAIMS

1. A voltage responsive actuator comprising a body of material dimensionally variable under the influence of an applied voltage and having a reference surface, at least one first electrode attached to the body and arranged to move the reference surface along one direction in response to a first electrical input, and at least one tilt electrode attached to the body to tilt the reference surface with respect to the one direction.

2. An actuator as claimed in claim 1 in which a plurality of tilt electrodes are attached to the body.

3. An actuator as claimed in claim 2, in which the shapes of the tilt electrodes are similar.

4. An actuator as claimed in claim 1, 2 or 3, in which each tilt electrode covers an equal area on the surface of the body.

5. An actuator as claimed in claim 1, 2, 3 or 4, in which the or each of the tilt electrodes are located adjacent the reference surface.

6. An actuator as claimed in any preceding claim, in which the body is constituted by a tube.

7. An actuator as claimed in claim 6, in which the first electrode is attached to the outer surface of the tube about the axis thereof.

8. An actuator as claimed in claim 6 or 7, in which the tilt electrodes are attached to the outer surface of the tube about the axis thereof.

9. An actuator as claimed in claim 7 or 8 in which an earth electrode is attached to the inner surface of the tube.

10. An actuator as claimed in any of claims 1 to 5 in which the body is a solid bar.

11. An actuator as claimed in any preceding claim in which in use an object to be moved by the actuator is mounted on the reference surface.

12. An actuator as claimed in any preceding claim in which the material is a piezo-electric or an electro-strictive material.

13. An actuator substantially as specifically described herein with reference to the accompanying drawings.

14. An interferometer comprising a pair of reflecting plates, at least one plate being mounted for relative movement with respect to the other plate on an actuator as claimed in any preceding claim.

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