HIGH TEMPERATURE BIMORPH ACTUATOR

FIELD OF THE INVENTION

[0001] This invention relates to bimorph actuators that have the ability to bend and that also have large displacement capabilities. In particular, this application relates to bimorph actuators comprising piezoelectric materials and which are operational over large changes in temperature.

BACKROUND OF THE INVENTION

[0002] Actuators are devices which transform an input signal (mainly an electrical signal) into motion. Many types of acutators are known and available, but none of them meet the characteristics desired, such as a small space requirment, the ability to operate at elevated temperatures and no requirement of additional pumps and resevoirs. Bimorph actuators are bender actuators and are generally comprised of two elongated strips or layers of active material which are glued together, usually with an additional passive material or substrate in the middle. The top material is actuated out of phase with the bottom material to produce a net bending motion and transverse deflection of the beam like structure. This motion is typically used to make or break an electrical circuit by causing one contact on the bimorph to touch or move away from a second contact.

[0003] It is known in the art for the active materials of bimorph actuators to be piezoelectric materials. Piezoelectric materials are those that change shape or deform as a result of being subjected to an electric field. This phenomenam is known as the piezoelectric effect. Both the direction and the magnitude of the piezoelectric material deformation depends on the direction and the magnitude of the applied electric field. That is, a positive or negative voltage causes the material to expand or contract. The deformation due to the application of voltage is highly directionally dependent and relative to the applied electric field and direction of polarization used to induce the piezoelectric properties in the materials. If an actuator has only one piezoelectric element, the actuator will exhibit substantial deflection due to temperature change. This is because of an unbalanced design, i.e. one that is not symetric. One side expands more than the other and results in unwanted displacement from the temperature change.

[0004] Piezoelectric materials exist in both naturally occurring and man-made form. Examples of naturally occurring piezoelectric materials are quartz, topaz and Rochelle salt (sodium potassium tartrate tetrahydrate). Naturally occurring materials exhibit relatively low piezoelectric effect, as compared to man-made or industrial pieolectric materials. One example of a common industrial pieolectric material is PZT (lead zirconate titinate). U.S. Pat. No. 6,629,341 discloses a method of fabricating a piezoelectric macro-fiber composite actuator, wherein the piezoelectric material is sliced to provide a pluarlity of piezoelectric fibers in juxtaposition.

[0005] The polarization of the active material can be lost as a result of a combination of time, temperature and applied electric field opposite of the direction of polarization. For example, it has been found that a common piezoelectric material, PZT 5A, loses its piezoelectric properties (i.e. it depolarizes) above about 150° C. if the electric field is applied along the direction of polarization. However, this temperature is reduced to only about 50° C. if the electric field is applied opposite the direction of polarization. Since both positive and negative fields are required to operate a conventional bimorph actuator, the temperature limit is much lower than otherwise possible due to depolarization at elevated temperature and negative electric field. For instance, as shown in the accompanying FIG. **1**A, if both the negative voltage and positive voltage are applied to the top **100** active material parallel to the direction of the force **120**, with polarization **140** in the plane of the material, in this case horizontal, such that the electric field in the positive charged field **130** is in the same direction as the polarization **140**, then the positive voltage will cause the active material **100** to expand. On the bottom active material **110**, the negative charge results in an electric field **150** which is parallel to the direction of force **170**, but is in the opposite direction of the polarization **160** causing that active material **110** to contract.

[0006] A similar result is exhibited in FIG. **1**B, wherein the electric field is applied perpendicular to the direction of force. In this case, the top active material **200** is subjected to a negative voltage, and the electric field **220** and the polarization **230** are in opposite but parallel directions to each other while being perpendicular to the beam **201**, and cause the active material **200** to contract. For the bottom active material **210**, a positive electric field **240** is perpendicular to the beam **201**, but is parallel and in the same direction as the polarization **250**, resulting in a contracting force **270**.

[0007] The results in both the illustrations of FIGS. **1**A and **1**B is the depolarization at relatively low temperatures, about 50° C. for PZT 5A active material.

[0008] Therefore, it is desirable for a bimorph actuator comprising piezoelectric material that does not exhibit the problem of depolarization due to electric fields at an extended temperature range.

[0009] It is also desirable for such a bimorph actuator to be of a size that it functions in small spaces, and not require additional resources such as pumps.

SUMMARY OF THE INVENTION

[0010] A bimorph actuator has been found that uses commonly available piezoelectric material and is operational up to about 150° C. or one half of Curie temperature, in that it does not exhibit depolarization due to negative electric fields and/or elevated temperature. This result is accomplished by driving both piezoelectric materials with a positive electric field along the direction of polarization.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Refer now to the figures, which are meant to be exemplary and not limiting, and wherein like elements are numbered alike, and not all numbers are repeated in every figure for clarity of the illustration.

[0012] FIG. **1**A is an example of a known bimorph actuator that exhibits depolarization at high temperature.

[0013] FIG. **1**B is an example of a known bimorph actuator that exhibits depolarization at high temperature.

[0014] FIG. **2** is an illustrative embodiment of a bimorph actuator that does not exhibit depolarization at high temperature.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The present invention is a novel bimorph actuator that avoids the problem of depolarization due to negative electric fields. In one embodiment of the bimorph actuator it uses piezoelectric materials as the reactive materials.