BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A and **1**B illustrate a top perspective view of a transducer before and after application of a voltage in accordance with one embodiment of the present invention.

FIG. **1**C illustrates a side view of transducer including a surface region before actuation in accordance with one embodiment of the present invention.

FIG. **1**D illustrates a side view of transducer including surface region after actuation in accordance with one embodiment of the present invention.

FIG. **1**E illustrates a transducer comprising a rigid layer in accordance with one embodiment of the present invention.

FIG. **1**F illustrates a monolithic transducer comprising a plurality of active areas in accordance with one embodiment of the present invention.

FIG. **1**G illustrates an electroactive polymer transducer before deflection in accordance with a specific embodiment of the present invention.

FIG. **1**H illustrates the transducer of FIG. **1**G after deflection.

FIG. **2**A illustrates a transducer including a passive layer that enhances out-of-plane deflection in accordance with one embodiment of the present invention.

FIG. **2**B illustrates the transducer of FIG. **2**A in an actuated state.

FIG. **2**C illustrates a transducer comprising an electroactive polymer between two passive layers in accordance with a specific embodiment of the present invention.

FIG. **3**A shows a top elevated view of crossing common electrodes for a transducer in accordance with a specific embodiment of the present invention.

FIGS. **3**B-**3**C show top elevated photos for a transducer including a passive layer in accordance with another specific embodiment of the present invention.

FIG. **3**D illustrates a top elevated view of a transducer in accordance with a specific embodiment of the present invention.

FIG. **3**E illustrates a top elevated view of the transducer of FIG. **3**D with actuation of a letter.

FIG. **3**F illustrates a side view of grid surface features electrodes for a transducer in accordance with another specific embodiment of the present invention.

FIG. **4** illustrates a process flow for using an electroactive polymer transducer in accordance with one embodiment of the present invention.

FIG. **5**A illustrates a method for moving two objects relative to each other using stepwise deflection of multiple active areas in accordance with a specific embodiment.

FIG. **5**B illustrates surface deforming electroactive polymer transducers mounted to a surface of a wing and a flap in accordance with a specific embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is described in detail with reference to a few preferred embodiments as illustrated in the accompanying drawings. In the following description, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art, that the present invention may be practiced without some or all of these specific details. In other instances, well known process steps and/or structures have not been described in detail in order to not unnecessarily obscure the present invention.

1. General Structure of Electroactive Polymers

The transformation between electrical and mechanical energy in transducers and devices of the present invention is based on elasticity of an electroactive polymer and energy conversion of one or more portions of an electroactive polymer (EAP).

To help illustrate the performance of an electroactive polymer in converting electrical energy to mechanical energy, FIG. **1**A illustrates a top perspective view of a transducer portion **10** in accordance with one embodiment of the present invention. While electroactive polymer transducers will now be described as structures, those skilled in the area will recognize that the present invention encompasses a methods for performing the actions as described below.

The transducer portion **10** comprises an electroactive polymer **12** for converting between electrical energy and mechanical energy. In one embodiment, an electroactive polymer refers to a polymer that acts as an insulating dielectric between two electrodes and may deflect upon application of a voltage difference between the two electrodes. Top and bottom electrodes **14** and **16** attach to electroactive polymer **12** on its top and bottom surfaces, respectively, to provide a voltage difference across a portion of the polymer **12**. Polymer **12** deflects with a change in electric field provided by the top and bottom electrodes **14** and **16**. Deflection of the transducer portion **10** in response to a change in electric field provided by the electrodes **14** and **16** is referred to as actuation.

FIG. **1**B illustrates a top perspective view of the transducer portion **10** including deflection in response to a change in electric field. In general, deflection refers to any displacement, expansion, contraction, bulging, torsion, linear or area strain, or any other deformation of a portion of the polymer **12**. The change in electric field corresponding to the voltage difference applied to or by the electrodes **14** and **16** produces mechanical pressure within polymer **12**. In this case, the unlike electrical charges produced by electrodes **14** and **16** attract each other and provide a compressive force between electrodes **14** and **16** and an expansion force on polymer **12** in planar directions **18** and **20**, causing polymer **12** to compress between electrodes **14** and **16** and stretch in the planar directions **18** and **20**.

After application of the voltage between electrodes **14** and **16**, polymer **12** expands (stretches) in both planar directions **18** and **20**. In some cases, polymer **12** is incompressible, e.g. has a substantially constant volume under stress. For an incompressible polymer **12**, polymer **12** decreases in thickness as a result of the expansion in the planar directions **18** and **20**. It should be noted that the present invention is not limited to incompressible polymers and deflection of the polymer **12** may not conform to such a simple relationship.

Application of a relatively large voltage difference between electrodes **14** and **16** on the transducer portion **10** shown in FIG. **1**A thus causes transducer portion **10** to change to a thinner, larger area shape as shown in FIG. **1**B. In this manner, the transducer portion **10** converts electrical energy to mechanical energy.

As shown in FIGS. **1**A and **1**B, electrodes **14** and **16** cover the entire portion of polymer **12** as shown. More commonly, electrodes **14** and **16** cover a limited portion of polymer **12** relative to the total surface area of the polymer. For the present invention, this is done to utilize incompressibility of the polymer and produce surface features and deformations on one or more of the polymer surfaces. This may also be done to prevent electrical breakdown around the edge of polymer **12**.