SURFACE DEFORMATION ELECTROACTIVE POLYMER TRANSDUCERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. §119(e) from co-pending U.S. Provisional Patent Application No. 60/500,148 filed Sep. 3, 2003, naming R. Pelrine et al. as inventors, and titled "Shear Mode EPAM", which is incorporated by reference herein for all purposes.

U.S. GOVERNMENT RIGHTS

[0002] This application was made in part with government support under contract number MDA972-02-C-0001 awarded by the United States Defense Advanced Research Project Agency. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

[0003] The present invention relates generally to electroactive polymers that convert between electrical energy and mechanical energy. More particularly, the present invention relates to electroactive polymers and their abilities and applications related to surface deformation, surface texturing and surface geometry control.

[0004] In many applications, it is desirable to convert between electrical energy and mechanical energy. Common technologies that convert electrical energy to mechanical work include motors and piezoelectric ceramics for example. Most conventional electrical to mechanical technologies provide limited mechanical output abilities. Motors provide continuous rotary output—and generally require additional and bulky coupling to provide discontinuous output or low-frequency motion. Piezoelectric ceramics are typically limited to in-plane strains between the rigid electrodes below about 1.6 percent and are not suitable for applications requiring greater strains or out-of plane deformations.

[0005] New high-performance polymers capable of converting electrical energy to mechanical energy, and vice versa, are now available for a wide range of energy conversion applications. One class of these polymers, electroactive elastomers (also called dielectric elastomers, electroelastomers, or EPAM (Electroactive Polymer Artificial Muscle)), is gaining wider attention. Electroactive elastomers may exhibit high energy density, stress, and electromechanical coupling efficiency. To date, electroactive polymer transducers and devices have been directed towards in-plane strains for conversion between electrical and mechanical energy.

[0006] Many applications demand a light-weight, scaleable device that converts between electrical and mechanical energy in out-of plane directions.

SUMMARY OF THE INVENTION

[0007] The present invention provides electroactive polymer transducers that produce out-of-plane deflections. The transducers form a set of surface features based on deflection of an electroactive polymer. The set of surface features may include elevated polymer surface features and/or depressed electrode surface features. Actuation of an active area may produce the polymer deflection that creates one or more surface features. In one embodiment, a passive layer operably connects to a polymer and augments out-of-plane deflections. The passive layer may comprise a thicker and softer material to amplify thickness changes and increase surface feature visibility.

[0008] In one aspect, the present invention relates to an electroactive polymer transducer. The transducer comprises an electroactive polymer including an undeflected thickness for a surface region on a first surface of the polymer. The transducer also comprises a first electrode disposed on a portion of the first surface of the electroactive polymer. The transducer further comprises a second electrode disposed on a portion of a second surface of the electroactive polymer. The electroactive polymer is configured to include a polymer surface feature above the undeflected thickness after deflection of an active area. The first electrode is configured to include an electrode surface feature below the undeflected thickness after deflection of the active area

[0009] In another aspect, the present invention relates to an electroactive polymer transducer. The transducer comprises an electroactive polymer including an undeflected thickness for a surface region on a first surface of the polymer. The transducer also comprises a first electrode disposed on the first surface of the electroactive polymer and a second electrode disposed on a second surface of the electroactive polymer. The electroactive polymer and first electrode are configured to produce a set of surface features on the first surface after deflection of an active area. The set of features includes a) a polymer surface feature that is elevated above the undeflected thickness and outside the first electrode on the first surface or b) an electrode surface feature that is depressed below the undeflected thickness.

[0010] In yet another aspect, the present invention relates to an electroactive polymer transducer. The transducer comprises an electroactive polymer including an undeflected thickness for a surface region on a first surface of the polymer. The transducer also comprises a first electrode disposed on a portion of the first surface of the electroactive polymer. The transducer further comprises a second electrode disposed on a portion of a second surface of the electroactive polymer. The electroactive polymer and first electrode are configured to produce a set of surface features on the first surface after deflection of an active area. The set of surface features includes a polymer surface feature above the undeflected thickness on the first surface or an electrode surface feature below the undeflected thickness. The transducer additionally comprises a passive layer that neighbors the first surface and is configured to deflect with the deflection of the electroactive polymer such that a surface of the passive layer opposite to the electroactive polymer forms a set of passive layer surface features that resembles the set of surface features on the first surface

[0011] In still another aspect, the present invention relates to a method of actuating an electroactive polymer transducer. The method comprises actuating a first portion of the electroactive polymer including an undeflected thickness for a first surface region on a first surface of the polymer before actuation of the first portion to create a first surface feature on the first surface. The method also comprises actuating a second portion of the electroactive polymer including an undeflected thickness for a second surface region on the first