SURFACE DEFORMATION ELECTROACTIVE POLYMER TRANSDUCERS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a non-provisional of U.S. Provisional Application No. 61/111,648 filed Nov. 5, 2008, the entirety of which is incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention relates to dielectric elastomer or electroactive polymer film transducers. More particularly, the present invention is related to such transducers and their abilities and applications related to surface deformation.

BACKGROUND OF THE INVENTION

[0003] A tremendous variety of devices used today rely on actuators of one sort or another to convert electrical energy to mechanical energy. Conversely, many power generation applications operate by converting mechanical action into electrical energy. Employed to harvest mechanical energy in this fashion, the same type of actuator may be referred to as a generator. Likewise, when the structure is employed to convert physical stimulus such as vibration or pressure into an electrical signal for measurement purposes, it may be characterized as a sensor. Yet, the term “transducer” may be used to generically refer to any of the devices.

[0004] A number of design considerations favor the selection and use of advanced dielectric elastomer materials, also referred to as “electroactive polymers” (EAPs), for the fabrication of transducers. These considerations include potential force, power density, power conversion/consumption, size, weight, cost, response time, duty cycle, service requirements, environmental impact, etc. As such, in many applications, EAP technology offers an ideal replacement for piezoelectric, shape-memory alloy (SMA) and electromagnetic devices such as motors and solenoids.

[0005] Examples of EAP devices and their applications are described in U.S. Pat. Nos. 7,394,282; 7,378,783; 7,368,862; 7,362,032; 7,320,457; 7,259,503; 7,233,097; 7,224,106; 7,211,937; 7,199,501; 7,166,953; 7,064,472; 7,062,055; 7,052,594; 7,049,732; 7,034,432; 6,940,221; 6,911,764; 6,891,317; 6,882,086; 6,876,135; 6,812,624; 6,809,462; 6,806,621; 6,781,284; 6,768,246; 6,707,236; 6,664,718; 6,628,040; 6,586,859; 6,583,533; 6,545,384; 6,543,110; 6,376,971 and 6,343,129; and in U.S. Patent Application Publication Nos. 2008/0157631; 2008/0116764; 2008/0022517; 2007/0230222; 2007/0200468; 2007/0200467; 2007/0200466; 2007/0200457; 2007/0200454; 2007/0200453; 2007/0170822; 2006/0238079; 2006/0208610; 2006/0208609; and 2005/0157893, the entireties of which are incorporated herein by reference.

[0006] An EAP transducer comprises two electrodes having deformable characteristics and separated by a thin elastomeric dielectric material. When a voltage difference is applied to the electrodes, the oppositely-charged electrodes attract each other thereby compressing the polymer dielectric layer therebetween. As the electrodes are pulled closer together, the dielectric polymer film becomes thinner (the z-axis component contracts) as it expands in the planar directions (along the x- and y-axes), i.e., the displacement of the film is in-plane. The EAP film may also be configured to produce movement in a direction orthogonal to the film structure (along the z-axis), i.e., the displacement of the film is out-of-plane. U.S. Patent Application Serial No. 2005/0157893 discloses EAP film constructs which provide such out-of-plane displacement—also referred to as surface deformation or thickness mode deflection.

[0007] The material and physical properties of the EAP film may be varied and controlled to customize the surface deformation undergone by the transducer. More specifically, factors such as the relative elasticity between the polymer film and the electrode material, the relative thickness between the polymer film and electrode material and/or the varying thickness of the polymer film and/or electrode material, the physical pattern of the polymer film and/or electrode material (to provide localized active and inactive areas), and the tension or pre-strain placed on the EAP film as a whole, and the amount of voltage applied to or capacitance induced upon the film may be controlled and varied to customize the surface features of the film when in an active mode.

[0008] Numerous transducer-based applications exist which would benefit from the advantages provided by such surface deformation EAP films.

SUMMARY OF THE INVENTION

[0009] The present invention seeks to improve upon the structure and function of surface deformation EAP-based transducers. The present invention provides customized transducer constructs for use in various applications, including but not limited to haptic feedback for user interface devices (e.g., key buttons, key pads, touch pads, touch screens, touch plates, touch sensors, etc.), fluid movement and control mechanism such as pumps and valves, breaking and clutch mechanisms, power generation, sensing, etc.

[0010] The transducers comprise at least one electroactive polymer film layer comprising a thin dielectric elastomer layer, wherein a portion of the dielectric elastomer layer is sandwiched between first and second electrodes wherein the overlapping portions of the electrodes define one or more active film regions with the remaining portion of film defining one or more inactive film regions, wherein activation of the active region chances a thickness dimension of the film. The relative positioning of the active region(s) and inactive region(s) defines the thickness mode output profile or the inactive region(s) may be central to the active region(s). Multiple transducers may be provided in a stacked arrangement to provide a multi-phase functionality and/or to enhance output.

[0011] To enhance the output of the change in thickness dimension, at least one passive polymer layer, the polymer layer extending over at least a portion of one side of the electroactive polymer film wherein activation of the active region also changes a thickness dimension of the passive layer. One or more of the passive layers may be mechanically coupled to one or more rigid structures which may form part of an actuator, and in certain embodiments, functions as an output mechanism. A passive layer may extend over portions or all of the active and the inactive regions, or may extend over only the inactive region or portions thereof.

[0012] In certain embodiments, electrical buses are provided to couple the electrodes to a source of power and/or to each other to provide a common ground, etc. In particular, a first conductive layer is disposed on at least a portion of the inactive film region and electrically coupled to the first electrode, and a second conductive layer is disposed on at least a portion of the inactive film region and electrically coupled to