[0036] 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.

[0037] Application of a relatively large voltage difference between electrodes **14** and **16** on the transducer portion **10** shown in **FIG. 1A** thus causes transducer portion **10** to change to a thinner, larger area shape as shown in **FIG. 1B**. In this manner, the transducer portion **10** converts electrical energy to mechanical energy.

[0038] As shown in **FIGS. 1A and 1B**, 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**. Electrodes may also be patterned with special shapes to achieve customized surface deflections, as will be described in further detail below.

[0039] As the term is used herein, an active area refers to a portion of a transducer comprising polymer material **12** and at least two electrodes. When the active area is used to convert electrical energy to mechanical energy, the active area includes a portion of polymer **12** having sufficient electrostatic force to enable deflection of the portion. When the active area is used to convert mechanical energy to electrical energy, the active area includes a portion of polymer **12** having sufficient deflection to enable a change in electrostatic energy. As will be described below, a polymer of the present invention may have multiple active areas.

[0040] **FIG. 1C** illustrates an extended side view of a transducer **10** outside the portion shown in **FIG. 1A** and including a surface region **21** before actuation in accordance with one embodiment of the present invention. As the term is used herein, a surface region **21** generally refers to a surface portion of interest for an electroactive polymer transducer that includes at least a part of the polymer surface covered by an electrode (or electrode portion) and polymer surface outside the electrode (or portion) that is affected by deflection of an active area including the electrode (or portion). For the planar polymer **12** and rectangular electrode **14** of **FIG. 1C**, surface region **21** comprises the surface area of polymer **12** covered by electrode **14** and neighboring surface portions **23** of polymer **12** perimetrically surrounding electrode **14** on the top surface of polymer **12**. In one embodiment, surface region **21** comprises all surface portions of an electroactive polymer transducer affected by elastic and electrostatic forces resulting from actuation of an active area of polymer **12**, including polymer and electrode material surface portions of a driven active area and polymer and electrode material surface portions proximate to the driven active area.

[0041] Before actuation, transducer **10** can be described by an undeflected thickness **22** over surface region **21**. The undeflected thickness **22** refers to the approximate thickness of polymer **12** before deflection to produce a surface feature. Thickness **22** may be measured from one surface of polymer **12** to the other surface of polymer **12** over the surface region **21**. Typically, polymer **12** is relatively flat on both its top and bottom surfaces and has a relatively constant thickness **22** across the polymer surface and surface region **21**. Electrodes **14** and **16** often include a minimal or negligible depth and add little to thickness **22** and in these cases undeflected thickness **22** may include electrodes **14** and **16**. The undeflected thickness **22** thus corresponds to the thickness of the polymer in cross section. For commercially available polymers, the undeflected thickness **22** may roughly correspond to the thickness of the polymer as manufactured and received. In one embodiment, polymer **12** is pre-strained, as will be described in further detail below, and thickness **22** refers to the undeflected thickness in surface region **21** after pre-straining. It is understood that the thickness of polymer **12** and electrodes **14** and **16** between top and bottom surfaces over the surface region **21** may vary slightly, say by **1-20** percent in some cases. Here, undeflected thickness **22** may refer to an average or arithmetic representation of the varying thicknesses across surface region **21**. It is understood that some polymers may not include perfectly consistent thicknesses and that an undeflected thickness for a surface region **21** may better describe the thickness of surface region **21** before actuation. In one embodiment, transducer **10** is substantially flat before deflection. In another embodiment, transducer **10** is configured on a curved surface and with a generally consistent thickness for the polymer on the curved surface. While deflection as described herein will mainly be described via an actuation using electrodes **14** and **16**, it is understood that generation and sensing functions as described below may also lead to deflections and surface features.

[0042] **FIG. 1D** illustrates a side view of transducer **10** including surface region **21**, after deflection of an active area, in accordance with one embodiment of the present invention. Polymer **12** material outside an active area typically resists active area deflection. While the amount of resistance may vary based on how the entire polymer is held or configured by a frame for example, polymer **12** material outside an active area commonly acts as a spring force, based on elasticity of the material. Since the polymer **12** material is compliant, the material may deform and bulges out-of-plane in the thickness direction (orthogonal to the plane) in response to deflection or actuation of an active area.

[0043] The polymer **12** and one or both electrodes **14** and **16** of transducer **10** are configured to produce polymer surface features **17***a-b* form on the top surface of polymer **12** above the undeflected thickness **22** after deformation of the active area. The polymer surface features **17** refer to portions of an electroactive polymer elevated above the undeflected thickness **22** as a result of deflection, electrostatic forces and/or elastic response in the polymer. In this case, elevated surface features **17***a-b* are created around the edges of an active area corresponding to the surface shape of electrode **14** (and to a lesser extent, electrode **16** on the opposite surface). The surface features **17***a-b* may be distinct bulges as shown in **FIG. 1D**, or they may be more distributed increases in thickness outside the electrode region **14**, depending on the films tension and elasticity. Similarly, bottom polymer surface features **17***c-d* are formed on the