mer sensor is configured such that a portion of the electroactive polymer deflects in response to the change in a parameter being sensed. The electrical energy state and deflection state of the polymer are related. The change in electrical energy or a change in the electrical impedance of an active area resulting from the deflection may then be detected by sensing electronics in electrical communication with the active area electrodes. This change may comprise a capacitance change of the polymer, a resistance change of the polymer, and/or resistance change of the electrodes, or a combination thereof. Electronic circuits in electrical communication with electrodes detect the electrical property change. If a change in capacitance or resistance of the transducer is being measured for example, one applies electrical energy to electrodes included in the transducer and observes a change in the electrical parameters.

For ease of understanding, the present invention is mainly described and shown by focusing on a single direction of energy conversion. More specifically, the present invention focuses on converting electrical energy to mechanical energy. However, in all the figures and discussions for the present invention, it is important to note that the polymers and devices may convert between electrical energy and mechanical energy bi-directionally. Thus, any of the exemplary transducers described herein may be used with a generator or sensor. Typically, a generator of the present invention comprises a polymer arranged in a manner that causes a change in electric field in response to deflection of a portion of the polymer. The change in electric field, along with changes in the polymer dimension in the direction of the field, produces a change in voltage, and hence a change in electrical energy.

As the terms are used herein, a transducer refers to an electroactive polymer with at least two electrodes; an electroactive polymer device refers to a transducer with at least one additional mechanical coupling or component; an electroactive polymer actuator refers to a transducer or device configured to produce mechanical output of some form; an electroactive polymer generator refers to a transducer or device configured to produce electrical energy; and an electroactive polymer sensor refers to a transducer or device configured to sense a property or event.

Thus, polymers and transducers of the present invention may be used as an actuator to convert from electrical to mechanical energy, a generator to convert from mechanical to electrical energy, a sensor to detect changes in the mechanical or electrical state of the polymer, or combinations thereof. Mechanical energy may be applied to a transducer in a manner that allows electrical energy to be removed or electrical changes to be sensed. Many methods for applying mechanical energy, removing electrical energy and sensing electrical changes from the transducer are possible. Actuation, generation and sensing devices may require conditioning electronics of some type. For instance, at the very least, a minimum amount of circuitry is needed to apply or remove electrical energy from the transducer. Further, as another example, circuitry of varying degrees of complexity may be used to sense electrical states of a sensing transducer.

In one embodiment, an electroactive polymer transducer active area may be electrically controlled via suitable electronic control (e.g., a processor configured to control an active area) to provide a variable surface feature height and displacement depth in a passive layer that varies with time. For instance, a microprocessor that controls the actuation of electroactive polymer transducer may be connected to a sensor. The displacement depth may be varied in time by the microprocessor according to measurements taken by the sensor.

6. Methods of Use

The present invention also incorporates methods of using an electroactive polymer transducer. FIG. **4** illustrates a process flow **300** for using an electroactive polymer transducer in accordance with one embodiment of the present invention. While electroactive polymer transducers will now be described as a method, those skilled in the area will recognize that the present invention encompasses a transducers and devices capable of performing the actions as described below.

Process flow **300** begins by actuating a first portion of the electroactive polymer (**302**). The first portion includes an undeflected thickness for a first surface region on a first surface of the polymer before actuation of the first portion. Actuation creates a first surface feature on the first surface. The surface feature may comprise a polymer surface feature that elevates above the undeflected thickness after the actuation or an electrode portion below the undeflected thickness for the first surface region after the deflection. Exemplary feature shapes and arrangements are described above.

Process flow **300** proceeds by actuating a second portion of the electroactive polymer (**304**). The second portion includes an undeflected thickness for a second surface region on the first surface of the polymer. The second actuation creates a second surface feature on the first surface. In one embodiment, the first and second portions are actuated simultaneously. In another embodiment, the second portion actuates after the first portion.

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. An object **322** is shown sliding over a surface **324**. A surface deforming electroactive polymer transducer **326** attaches to the bottom of object **322**. Actuation of an active area **328** on transducer **326** pushes object **322** from surface **324** and tilts object **322**. Sequentially actuating active areas **328***a*, **328***b*, and **328***c* pushes object **322** forward along surface **324** in direction **329**. Thus, transducer **326** is used to drive traveling waves across the interface that push object **322** across surface **324**. In another embodiment, the surface deforming transducer **326** attaches to surface **324** and acts as a conveyor on surface **324** to move objects on the surface.

7. Applications

A few additional exemplary applications will now be described. These applications are provided for illustrative purposes and are not meant to the limit the application of transducers and devices described herein in any way. Electroactive polymer transducers and devices described herein are very scalable. Thus, transducers and devices of the present invention may be used in both macroscopic applications, such as speakers, or in microscopic applications, such as an actuator fabricated on a semi-conductor device.

Creation of letters as described above is well suited for used in reconfigurable displays. For example, a dashboard in a car may include a surface deforming electroactive polymer transducer that includes multiple states. One state might be clean in which little or no surface features are visible. Upon initiation by a user, various menus and controls are then created on the dashboard. Combing the sensing ability of the polymers allows a driver or passenger to input commands and interface with a processor or affect one or more controlled systems in the car. The dashboard surface features may include letters, logos, symbols and other features related to control of systems in a car such as climate control, an audio system, a navigation system, etc. Other than dashboards, such reconfigurable actuators and sensors are useful to produce calculators, keyboards, handheld electronics devices, etc.