CLAIMS

1. A device comprising:

a substrate, the substrate being formed of an elastomer, the substrate being elastically stretchable along at least a first axis;

an oxidized portion of the substrate, the oxidized portion having an interface interrupted by micro-cracks; and

an electrically conductive element disposed on the interface,

wherein the electrically conductive element extends contiguously into and across each of a plurality of the micro-cracks, the plurality of the micro-cracks being anisotropically oriented.

2. The device as recited in claim 1, wherein the electrically conductive element is bonded to the substrate by the oxidized portion.

3. The device as recited in claim 1 or claim 2, wherein the interface further comprises a network of continuous cracks.

4. The device as recited in claim 3, wherein the micro-cracks are characterized by a micro-crack length, and wherein the continuous cracks are characterized by a crack length at least one order of magnitude longer than the micro-crack length, wherein the micro-cracks are formed with the oxidized portion in a pre-strained state.

5. The device as recited in any one of claims 1 to 4, wherein the micro-cracks are formed by applying stretching forces along the first axis to a workpiece, the workpiece comprising the substrate and the oxidized portion disposed on the substrate wherein the micro-cracks are aligned to extend transversely to the first axis.

6. The device as recited in any one of claims 1 to 5 , wherein the substrate comprises:

a narrower end;

a wider end, the wider end being spaced apart from the narrower end along a normal axis; and

an inclined surface extending between the narrower end and the wider end, the inclined surface being inclined relative to the normal axis,

and wherein the oxidized portion is disposed on the inclined surface, the oxidized portion being deformable responsive to a displacement of the inclined surface relative to the wider end.

7. The device as recited in claim 6, wherein the inclined surface defines a recess in the substrate, and wherein the electrically conductive element and the oxidized portion are disposed in the recess.

8. The device as recited in claim 6 , wherein the substrate comprises a frustum-shaped portion between the narrower end and the wider end, and wherein the inclined surface forms an inner part of the frustum-shaped portion.

9. The device as recited in any one of claims 6 to 8, wherein the electrically conductive element is operably connected to a first sensing circuit, the first sensing circuit being configured to sense a strain force along a strain direction orthogonal to the normal axis.

10. The device as recited in claim 9 , further comprising a pair of interdigital electrodes disposed across the wider end, the interdigital electrodes being operably connected to a second sensing circuit, the second sensing circuit being configured to sense a normal force along a normal direction parallel to the normal axis.

11. The device as recited in claim 10 , further comprising an array of microstructures having an electrically conductive coating, wherein the array of microstructures is

compressible in response to the normal force to provide a variable area of contact between the electrically conductive coating and the pair of interdigital electrodes.

12. The device as recited in claim 11 , wherein the substrate, the pair of interdigital electrodes, and the array of microstructures, are aligned along the normal axis, and wherein the pair of interdigital electrodes are disposed between the substrate and the array of microstructures.

13. A system comprising:

the device as recited in any one of claims 9 to 12;

a processor operably connected to the first sensing circuit, and the second sensing circuit, the processor being configured to execute computer-readable instructions stored in a memory to perform a method of determining a friction factor based on the strain force obtained from the first sensing circuit and the normal force obtained from the second sensing circuit, wherein the friction factor corresponds to a tactile sense; and

a wearable housing, the wearable housing being coupled to the substrate at least at the wider end, and wherein the narrower end extends to a contact portion facing out of the wearable housing.

14. A method of making a device, comprising:

providing oxygen plasma to a substrate to form an oxidized portion, the substrate being formed of an elastomer, the substrate being elastically stretchable along at least a first axis;

stretching the oxidized portion along at least a first axis parallel to a lateral plane of the substrate to form a plurality of anisotropically oriented micro-cracks in an interface of the oxidized portion; and

concurrently with the stretching, forming an electrically conductive element on the interface, the electrically conductive element being formed to extend contiguously into and across each of a plurality of the micro-cracks, wherein the stretching comprises:

securing the substrate to a pair of clamps, the pair of clamps being spaced apart and parallel relative to one another; and

increasing a clamp spacing between the pair of clamps by an increment spacing in a range from 10% to 40%, inclusive, wherein the increment spacing is along the first axis.

15. The method as recited in claim 14 , wherein the substrate is formed of an elastomer, the elastomer comprising any one or more selected from the group consisting of a polysiloxane, a polyurethane, a rubber, and a polyvinylpyrrolidone, and wherein a pre-strain applied during the stretching is in a range of 10% to 40% strain, inclusive, and wherein the oxidized portion comprises an oxide of silicon, and wherein the electrically conductive element is formed of a material selected from the group consisting of: gold, platinum, copper, silver, and an alloy thereof.