VARIABLE CAPACITANCE SENSORS AND METHODS OF MAKING THE SAME

TECHNICAL FIELD

This present disclosure relates to organic vapor detection using capacitance-based sensors and processes for their fabrication.

BACKGROUND

Variable capacitance sensors are typically constructed using dielectric materials by parallel plate-type electrodes. Typically, one electrode is conductive and at the same time sufficiently porous so the organic vapors can reach the microporous dielectric material. However, in order to achieve an adequate detection signal it is typically necessary to use sensors with a relatively large areal footprint that must be accommodated; for example, on a printed circuit board.

SUMMARY

In one aspect, the present disclosure provides a method of making a variable capacitance sensor, the method comprising steps:

a) providing a ceramic capacitor comprising:
   - a first conductive electrode comprising electrically interconnected first conductive sheets;
   - a second conductive electrode comprising electrically interconnected second conductive sheets, wherein the first conductive sheets are at least partially interleaved with the second conductive sheets, and wherein the second conductive electrode is electrically insulated from the first conductive electrode; and
   - ceramic material at least partially disposed between and contacting the first conductive sheets and the second conductive sheets; and

b) replacing at least a portion of the ceramic material with an microporous dielectric material, wherein the microporous dielectric material is at least partially disposed between and contacts the first conductive sheets and the second conductive sheets.

In some embodiments, step b) comprises: etching away at least a portion of the ceramic material; and applying the microporous dielectric material to replace at least a portion of the ceramic material removed by etching.

In some embodiments, substantially all of the ceramic material is replaced with the microporous dielectric material. Accordingly, in some embodiments, step b) comprises: etching away substantially all of the ceramic material; and applying the microporous dielectric material to replace of the ceramic material removed by etching.

In some embodiments, the microporous dielectric material comprises a polymer of intrinsic microporosity (PIM).

In another aspect, the present disclosure provides a variable capacitance sensor comprising:

a first conductive electrode comprising electrically interconnected first conductive sheets;

a second conductive electrode comprising electrically interconnected second conductive sheets, wherein the first conductive sheets are at least partially interleaved with the second conductive sheets, and wherein the second conductive electrode is electrically insulated from the first conductive electrode; and

microporous dielectric material at least partially disposed between and contacting the first conductive sheets and the second conductive sheets.

In some embodiments, the microporous dielectric material comprises a polymer of intrinsic microporosity. In some embodiments, the variable capacitance sensor further comprises a ceramic material at least partially disposed between and contacting the first conductive sheets and the second conductive sheets. In some embodiments, the variable capacitance sensor further comprises an encapsulant layer covering a portion of the first and second conductive electrodes.

Advantageously, variable capacitance sensors according to the present disclosure may combine high sensitivity with a low areal footprint; for example, making them suitable for incorporation in miniature sensing devices. In addition, methods according to the present disclosure make it possible to make variable capacitance sensors of high sensitivity at a relatively low price without need of specialized equipment.

As used herein,

the term "microporous" means that the material has a significant amount of internal, interconnected pore volume, with the mean pore size (as characterized, for example, by sorption isotherm procedures) being less than about 100 nm; and

the term "conductive" means electrically conductive.

The foregoing embodiments may be implemented in any combination thereof, unless such combination is clearly erroneous in view of the teachings of the present disclosure. The features and advantages of the present disclosure will be further understood upon consideration of the detailed description as well as the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a process flow diagram of an exemplary process for making a variable capacitance sensor according to the present disclosure;

FIG. **2** is a schematic perspective view of an exemplary variable capacitance sensor according to the present disclosure; and

FIG. **3** is a schematic perspective view of an exemplary variable capacitance sensor according to the present disclosure.

While the above-identified drawing figures, which may not be drawn to scale, set forth several embodiments of the present disclosure, other embodiments are also contemplated, as noted in the discussion. Like reference numbers have been used throughout the figures to denote like parts.

DETAILED DESCRIPTION

Referring now to FIG. **1**, in an exemplary process according to the present disclosure a ceramic capacitor **100** is etched to remove at least a portion of the ceramic material **102** separating first and second conductive electrodes **104**,**106**, respectively, thereby providing etched ceramic capacitor **120**. First and second conductive electrodes **104**,**106** include first and second conductive sheets **108**, **110**, respectively. Microporous dielectric material **112** is used to fill in at least a portion of the space originally occupied by etched ceramic material thereby forming variable capacitance sensor **130**.

High-quality, low-cost ceramic capacitors are produced by large number of manufacturers. They offer their products in many shapes and sizes, and when purchased in bulk, the price is often pennies per capacitor. Exemplary commercial suppliers include Kemet Corp. of Simpsonville, S.C.; AVX Corporation of Fountain Inn, S.C.; EPCOS Inc. of Munich, Germany; Panasonic Industrial Company of Secaucus, N.J.; and ITW Paktron of Lynchburg, Va. The ceramic capacitor may be obtained with or without an outer protective covering such, for example, as an encapsulant layer.