also rely on adding energy (e.g., using elevated temperatures) to drive the sensing reactions within the sensor and improve the sensitivity. The equipment required for conventional gas sensors is also not readily miniaturized, which limits their use in mobile applications.

SUMMARY

[005a] In accordance with an aspect of the present application, there is provided a sensor configured to detect an analyte. The sensor comprises an antenna disposed on a substrate; a sensing material disposed on the substrate and electrically coupled to the antenna, the sensing material comprising: a particulate carbon structure including a multi-modal distribution of pore sizes that define a surface area including bonding sites configured to interact with one or more additives and the analyte, the particulate carbon structure configured to generate a resonant signal indicative of one or more characteristics of the analyte in response to an electromagnetic signal, the particulate carbon structure comprising: a plurality of distinctly sized interconnected channels defined by the surface area and configured to be infiltrated by the analyte; and a plurality of exposed surfaces configured to adsorb the analyte.

[005b] In accordance with another aspect of the present application, there is provided a sensor system configured to detect an analyte. The sensor system comprises a substrate; and a resonant circuit configured to be removed without requiring replacement of the substrate, the resonant circuit disposed on the substrate and comprising: an antenna disposed on the substrate; a sensing material disposed on the substrate and electrically coupled to the antenna, the sensing material comprising: a particulate carbon structure including a multi-modal distribution of pore sizes that define a surface area including bonding sites configured to interact with one or more additives and the analyte, the particulate carbon structure configured to generate a resonant signal indicative of one or more characteristics of the analyte in response to an electromagnetic signal, the particulate carbon structure comprising: a plurality of distinctly sized interconnected channels defined by the surface area and configured to be infiltrated by the analyte; and a plurality of exposed surfaces configured to adsorb the analyte.

[006] In some embodiments, a method for detecting an analyte comprises providing a first carbon-based material comprising reactive chemistry additives, providing conductive electrodes connected to the first carbon-based material, exposing the first carbon-based material to an analyte material, applying a plurality of

alternating currents having a range of frequencies across the conductive electrodes, and measuring the complex impedance of the first carbon-based material using the plurality of alternating currents. In some embodiments of the above method, the providing the first carbon-based material comprises using a microwave plasma to produce carbon particles, and printing the carbon particles to form the first carbon-based material. In some cases, the reactive chemistry additives are tuned to the analyte materials.

[007] In some embodiments, a sensor for detecting an analyte comprises a flexible substrate, a resonant gas sensor circuit, and a microprocessor arranged on the flexible substrate and electrically coupled to a second terminal of the transducer and to the ground electrode. The resonant gas sensor circuit can comprise a transducer arranged on the flexible substrate, a sensing material arranged on the flexible substrate, wherein the sensing material is coupled to the transducer, and comprises a first particulate carbon and a reactive chemistry additive, and a ground electrode electrically coupled to a first terminal of the transducer. The microprocessor can comprise an alternating current (AC) source configured to supply a plurality of AC signals to the transducer, the plurality of AC signals comprising a range of frequencies, and a detection circuit that measures a plurality of AC signals reflected from the transducer. The sensing material can comprise a plurality of carbon aggregates each comprising a plurality of carbon nanoparticles. Each carbon nanoparticle can comprise graphene, the graphene in the plurality of carbon nanoparticles comprises up to 15 layers, a percentage of carbon to other elements, except hydrogen, in the carbon aggregates is greater than 99%, a median size of the carbon aggregates comprising the carbon nanoparticles is from 0.1 microns to 50 microns, a surface area of the carbon aggregates is from 10 m^2/g to 300 m^2/g, when

What is claimed is:

1. A sensor configured to detect an analyte, comprising:

an antenna disposed on a substrate;

a sensing material disposed on the substrate and electrically coupled to the antenna, the sensing material comprising:

a particulate carbon structure including a multi-modal distribution of pore sizes that define a surface area including bonding sites configured to interact with one or more additives and the analyte, the particulate carbon structure configured to generate a resonant signal indicative of one or more characteristics of the analyte in response to an electromagnetic signal, the particulate carbon structure comprising:

a plurality of distinctly sized interconnected channels defined by the surface area and configured to be infiltrated by the analyte; and

a plurality of exposed surfaces configured to adsorb the analyte.

2. The sensor of claim 1, wherein each of the one or more distinctly sized interconnected channels includes at least one of microporous pathways or mesoporous pathways.

3. The sensor of claim 2, wherein each of the microporous pathways or mesoporous pathways is configured to increase a responsiveness of the sensing material proportionate to an amount of the analyte within the carbon structure.

4. The sensor of claim 1, wherein the sensing material is integrated into the antenna or positioned within a vicinity of the antenna.

5. The sensor of claim 1, wherein one or more characteristics of the resonant signal are indicative of a presence of one or more known harmful substances in the sensing material.

6. The sensor of claim 5, wherein the indication is based on a comparison of the one or more characteristics of the resonant signal with one or more characteristics of the known harmful substances.

7. The sensor of claim 1, wherein the sensing material is configured to oscillate at:

a first amplitude at one or more resonant frequencies of the sensing material; and

a second amplitude at one or more non-resonant frequencies of the sensing material, wherein the first amplitude is greater in magnitude than the second amplitude.

8. The sensor of claim 1, further comprising a pair of electrodes electrically coupled to a dielectric and the sensing material.

9. The sensor of claim 8, wherein the sensing material and the dielectric are positioned between the pair of electrodes and comprise a tank circuit.

10. The sensor of claim 1, wherein the particulate carbon structure is at least partially bound by a polymer.

11. The sensor of claim 10, wherein the polymer comprises one or more polymer additives configured to alter electrical properties of the sensing material by interacting with the analyte.

12. The sensor of claim 1, wherein the particulate carbon structure includes one or more tuned materials configured to increase a resonance sensitivity of the sensing material across one or more frequency ranges.

13. The sensor of claim 1, wherein the particulate carbon structure further comprises a plurality of three-dimensionally (3D) structured aggregates, each aggregate of the plurality of 3D structured aggregates including a plurality of nanoparticles.

14. The sensor of claim 13, wherein the 3D structured agglomerates are configured to generate an impedance response indicative of one or more characteristics of the sensing material based on an excitation signal.

15. The sensor of claim 1, wherein the sensing material is configured to generate one or more resonant signals indicative of a type of the analyte based on an electromagnetic signal.

16. A sensor system configured to detect an analyte, comprising:

a substrate; and

a resonant circuit configured to be removed without requiring replacement of the substrate, the resonant circuit disposed on the substrate and comprising:

an antenna disposed on the substrate;

a sensing material disposed on the substrate and electrically coupled to the antenna, the sensing material comprising:

a particulate carbon structure including a multi-modal distribution of pore sizes that define a surface area including bonding sites configured to interact with one or more additives and the analyte, the particulate carbon structure configured to generate a resonant signal indicative of one or more characteristics of the analyte in response to an electromagnetic signal, the particulate carbon structure comprising:

a plurality of distinctly sized interconnected channels defined by the surface area and configured to be infiltrated by the analyte; and

a plurality of exposed surfaces configured to adsorb the analyte.

17. The sensor system of claim 16, wherein the analyte is configured to be at least partially contained within a package.

18. The sensor system of claim 16, wherein the resonant circuit is attached to the antenna by compression.

19. The sensor system of claim 16, wherein degradation of a removable top layer of the sensing material is indicative of a need for replacement of the removable top layer.

20. The sensor system of claim 16, wherein the analyte comprises a volatile gas or vapor.