[0003a] According to an aspect of the present disclosure, there is provided a container configured to store an item. The container comprises: a surface defining a volume of the container; and an electromagnetic state sensing device including one or more resonance portions printed on the surface of the container, each resonance portion including an assembly of three-dimensional (3D) carbon-containing structures configured to: detect an electromagnetic radiation ping emitted from a user device; and generate an electromagnetic radiation return signal in response to the electromagnetic radiation ping, the electromagnetic radiation return signal indicating a state of the item in a corresponding portion of the container proximate to the printed resonance portion.

[0003b] According to another aspect of the present disclosure, there is provided a container configured to store an item. The container comprises: a surface defining a volume of the container; and an electromagnetic state sensing device including an assembly of three-dimensional (3D) carbon-containing structures printed on the surface of the container, the electromagnetic state sensing device comprising: a first resonance portion printed on a first surface area of the container and configured to generate a first electromagnetic radiation return signal in response to an electromagnetic radiation ping emitted from a user device, the first electromagnetic radiation return signal indicating a presence of the item in a first portion of the container proximate to the first surface area; and a second resonance portion printed on a second surface area of the container and configured to generate a second electromagnetic radiation return signal in response to the electromagnetic radiation ping emitted from the user device, the second electromagnetic radiation return signal indicating a presence of the item in a second portion of the container proximate to the second surface area.

[0004] Further details of aspects, objectives, and advantages of the technological embodiments are described herein, and in the drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The drawings described below are for illustration purposes only. The drawings are not intended to limit the scope of the present disclosure.

[0006] **FIG. 1** depicts an environment in which electromagnetic state sensing devices can be deployed, according to an embodiment.

[0007] **FIG. 2** presents a flow chart depicting a processing flow by which electromagnetic state sensing devices can be deployed, according to an embodiment.

[0008] **FIG. 3A** is a schematic of an electromagnetic state sensing device, according to an embodiment.

[0009] **FIG. 3B1** illustrates a deployment scenario in which a first state of liquid contents is measured, according to an embodiment.

[0010] **FIG. 3B2** illustrates a deployment scenario in which a second state of liquid contents is measured, according to an embodiment.

[0011] **FIG. 3B3** illustrates a deployment scenario in which a state of liquid contents is measured and displayed, according to an embodiment.

[0012] **FIG. 3B4** illustrates a cross-sectional view of a printed display for indicating the state of contents of a product, according to an embodiment.

[0013] **FIG. 3C** is a selection chart for determining a dynamic range of an electromagnetic state sensing device, according to an embodiment.

[0014] **FIG. 4A1** and **FIG. 4A2** are equivalent circuit models of an electromagnetic state sensing device in a first environment and a second environment, respectively, according to an embodiment.

[0015] **FIG. 4B** depicts an empirical data capture technique as used for calibrating electromagnetic state sensing devices in different environments, according to an embodiment.

[0016] **FIG. 5A** depicts a signature capture technique as used for electromagnetic state sensing, according to an embodiment.

[0017] **FIG. 5B** depicts a signature analysis technique as used for electromagnetic state sensing, according to an embodiment.

[0018] **FIG. 6** depicts a virtual assistant as used as a hub in a replenishment system, according to an embodiment.

CLAIMS

What is claimed is:

1. A container configured to store an item, comprising:

a surface defining a volume of the container; and

an electromagnetic state sensing device including one or more resonance portions printed on the surface of the container, each resonance portion including an assembly of three-dimensional (3D) carbon-containing structures configured to:

detect an electromagnetic radiation ping emitted from a user device; and

generate an electromagnetic radiation return signal in response to the electromagnetic radiation ping, the electromagnetic radiation return signal indicating a state of the item in a corresponding portion of the container proximate to the printed resonance portion.

2. The container of claim 1, wherein the resonance portion is configured to resonate at a first frequency in response to the electromagnetic radiation ping when the item is in a first state, and is configured to resonate at a second frequency in response to the electromagnetic radiation ping when the item is in a second state.

3. The container of claim 1, wherein a resonant frequency of the assembly of 3D carbon-containing structures is based at least in part on one or more physical characteristics of the item.

4. The container of claim 1, wherein a resonant frequency of the assembly of 3D carbon-containing structures is based at least in part on a permeability of the container.

5. The container of claim 1, wherein the state of the item comprises a presence of the item in the corresponding portion of the container.

6. The container of claim 5, wherein the resonance portion is configured to indicate the presence of the item in the corresponding portion of the container by generating a first electromagnetic radiation return signal in response to the electromagnetic radiation ping, and is configured to indicate an absence of the item in the corresponding portion of the container by generating a second electromagnetic radiation return signal in response to the electromagnetic radiation ping.

7. The container of claim 6, wherein the first electromagnetic radiation return signal has a first frequency, and the second electromagnetic radiation return signal has a second frequency different than the first frequency.

8. The container of claim 1, wherein the state of the item comprises a deformation of the item in the corresponding portion of the container.

9. The container of claim 8, wherein the resonance portion is configured to indicate the deformation of the item in the corresponding portion of the container by generating a first electromagnetic radiation return signal in response to the electromagnetic radiation ping, and is configured to indicate a lack of deformation of the item in the corresponding portion of the container by generating a second electromagnetic radiation return signal in response to the electromagnetic radiation ping.

10. The container of claim 9, wherein the first electromagnetic radiation return signal has a first frequency, and the second electromagnetic radiation return signal has a second frequency different than the first frequency.

11. The container of claim 1, wherein the item comprises a liquid, and the assembly of 3D carbon-containing structures is printed on an area of the surface of the container associated with a threshold fill level of the liquid in the container.

12. The container of claim 11, wherein the electromagnetic radiation return signal indicates whether an amount of the liquid in the container exceeds the threshold fill level.

13. The container of claim 11, wherein the resonance portion is configured to generate the electromagnetic radiation return signal at a first resonant frequency based on the amount of the liquid in the container exceeding the threshold fill level, and is configured to generate the electromagnetic radiation return signal at a second resonant frequency, different than the first resonant frequency, based on the amount of the liquid in the container not exceeding the threshold fill level.

14. The container of claim 1, wherein the user device is a smartphone, a radio frequency identification (RFID) reader, or a near-field communication (NFC) device.

15. The container of claim 1, further comprising an electrophoretic ink display configured to display the state of the item.

16. A container configured to store an item, comprising:

a surface defining a volume of the container; and

an electromagnetic state sensing device including an assembly of three-dimensional (3D) carbon-containing structures printed on the surface of the container, the electromagnetic state

sensing device comprising:

a first resonance portion printed on a first surface area of the container and configured to generate a first electromagnetic radiation return signal in response to an electromagnetic radiation ping emitted from a user device, the first electromagnetic radiation return signal indicating a presence of the item in a first portion of the container proximate to the first surface area; and

a second resonance portion printed on a second surface area of the container and configured to generate a second electromagnetic radiation return signal in response to the electromagnetic radiation ping emitted from the user device, the second electromagnetic radiation return signal indicating a presence of the item in a second portion of the container proximate to the second surface area.

17. The container of claim 16, wherein the item comprises a liquid, and the first and second resonance portions are configured to indicate an amount of the liquid in the container in response to the electromagnetic radiation ping.

18. The container of claim 17, wherein:

the first resonance portion is configured to resonate at a first frequency in response to the electromagnetic radiation ping when a fill level of the liquid in the container is above the first portion of the container, and is configured to resonate at a second frequency in response to the electromagnetic radiation ping when the fill level of the liquid in the container is below the first portion of the container; and

the second resonance portion is configured to resonate at the first frequency in response to the electromagnetic radiation ping when the fill level of the liquid in the container is above the second portion of the container, and is configured to resonate at the second frequency in response to the electromagnetic radiation ping when the fill level of the liquid in the container is below the second portion of the container.

19. The container of claim 16, wherein a resonant frequency of the assembly of 3D carbon-containing structures is based at least in part on one or more physical characteristics of the item.

20. The container of claim 16, wherein a resonant frequency of the assembly of 3D carbon-containing structures is based at least in part on a permeability of the container.