SUMMARY

The subject matter of the present disclosure has been developed in response to the present state of the art, and in particular, in response to the limitations of conventional joint testing systems. Specifically, conventional joint testing methods and systems do not allow for joints to be tested and monitored in situ or while a structure is in use. Accordingly, the subject matter of the present disclosure has been developed to provide a system and method for monitoring structural health of bonded components in situ that overcome at least some of the above-discussed shortcomings of the prior art.

According to one embodiment, there is disclosed a system for monitoring structural health of bonded components, having at least two components. The system includes an energy-harvesting device configured to convert non-electrical energy into electrical energy. The system also includes a damage-detection module powered by electrical energy from the energy- harvesting device. Further, the system includes electrically-conductive ink applied onto the bonded components and across an interface between the at least two components of the bonded components. The electrically-conductive ink forms an electrical circuit with the damage-detection module. Additionally, the system includes a visual-indication device electrically coupled with the damage-detection module. The visual-indication device is configured to visually indicate damage to the bonded components in response to receipt of electrical energy. The damage-detection module is configured to detect a break in the electrically-conductive ink and to transmit electrical energy from the energy-harvesting device to the visual-indication device in response to detecting the break in the electrically-conductive ink. The visual-indication device is further configured to generate a permanent visual indication of damage to the bonded components.

In some implementations of the system, the energy-harvesting device, damage-detection module, and visual-indication device are affixed to at least one of the bonded components. The energy-harvesting device, damage-detection module, and visual-indication device can be integrated into at least one of the bonded components. The energy-harvesting device, damage-detection module, and visual-indication device can be permanently coupled to at least one of the bonded components.

and across the interface. The electrically-conductive ink forms an electrical circuit with the damage-detection module. Also, the structure includes a visual-indication device electrically coupled with the damage-detection module and spaced away from the electrically-conductive ink. The visual-indication device is configured to visually indicate damage to the interface in response to receipt of electrical energy. The damage-detection module is configured to detect a break in the electrically-conductive ink and to transmit electrical energy from the energy-harvesting device to the visual-indication device in response to detecting the break in the electrically-conductive ink.

In some implementations of the structure, the visual-indication device is affixed to the substrate. The structure includes or can be an aircraft. The substrate may form a portion of the aircraft.

According to yet another embodiment, a method of monitoring structural health of bonded components includes applying electrically-conductive ink onto bonded components and across an interface between the bonded components to form an electrical circuit. The method further includes converting non-electrical energy into electrical energy, and transmitting the electrical energy through the electrical circuit. Additionally, the method includes detecting a break in the electrically-conductive ink. The method also includes visually indicating a break in the electrically-conductive ink on a visual-indication device, powered by the electrical energy, in response to a break in the electrically-conductive ink being detected. The visual-indication device is configured to generate a permanent visual indication of damage to the bonded components.

In some implementations of the method, applying the electrically-conductive ink onto the bonded components and across the interface between the bonded components to form the electrical circuit includes applying multiple passes of electrically-conductive ink across the interface about a periphery of the interface. Applying multiple passes of electrically-conductive ink can include applying multiple passes each having at least one of a square, triangular, or sinusoidal shape. Moreover, converting non-electrical energy into electrical

What is claimed is:

1. A system for monitoring structural health of bonded components, having at least two components, the system comprising:

a damage-detection module powered by electrical energy from an energy-harvesting device;

electrically-conductive ink applied onto the bonded components and across an interface between the at least two components of the bonded components, the electrically-conductive ink forming an electrical circuit with the damage-detection module; and

a visual-indication device electrically coupled to the damage-detection module, the visual-indication device configured to visually indicate damage to the bonded components in response to receipt of electrical energy;

wherein the damage-detection module is configured to detect a break in the electrically-conductive ink and to transmit electrical energy from the energy-harvesting device to the visual-indication device in response to detecting the break in the electrically-conductive ink; and

wherein the visual-indication device is configured to generate a permanent visual indication of damage to the bonded components.

2. The system according to claim 1, wherein the energy-harvesting device, damage-detection module, and visual-indication device are affixed to at least one of the bonded components.

3. The system according to claim 1, wherein the energy-harvesting device, damage-detection module, and visual-indication device are integrated into at least one of the bonded components.

4. The system according to any one of claims 1 to 3, wherein the energy-harvesting device is configured to harvest non-electrical or renewable energy and convert the non-electrical energy into electrical energy, preferably the energy-harvesting device comprises a piezoelectric generator.

5. The system according to any one of claims 1 to 4, wherein the visual-indication device comprises a thermochromic marker that is visible only in non-ambient lighting conditions.

6. The system according to any one of claims 1 to 5, wherein the damage-detection module comprises a switch component configured to transmit electrical energy from the energy-harvesting device to only the electrically-conductive ink when a break in the electrically-conductive ink is not detected and to transmit electrical energy from the energy-harvesting device to only the visual-indication device when a break in the electrically-conductive ink is detected.

7. The system according to any one of claims 1 to 6, wherein the electrically-conductive ink zig-zags across the interface about a periphery of the interface.

8. A method of monitoring structural health of bonded components, the method comprising:

applying electrically-conductive ink onto bonded components and across an interface between the bonded components to form an electrical circuit;

converting non-electrical energy into electrical energy;

transmitting the electrical energy through the electrical circuit;

detecting a break in the electrically-conductive ink; and

visually indicating a break in the electrically-conductive ink on a visual-indication device, powered by the electrical energy, in response to the break in the electrically-

conductive ink being detected, wherein the visual-indication device is configured to generate a permanent visual indication of damage to the bonded components.

9. The method according to claim 8, wherein applying the electrically-conductive ink onto the bonded components and across the interface between the bonded components to form the electrical circuit comprises applying multiple passes of electrically-conductive ink having an least one of a square, triangular, or sinusoidal shape across the interface about a periphery of the interface.

10. The method according to claim 8 or 9, wherein converting non-electrical energy into electrical energy comprises converting kinetic energy into electrical energy using at least one piezoelectric generator.