SUMMARY

According to one aspect of this disclosure, there is provided an ultra-high density energy-storage apparatus and system with high lifetime (e.g., in the range of hundreds of thousands cycles) and very high energy/power density.

According to one aspect of this disclosure, there is provided an electrical-energy storage device for storing electrical energy for use as a power source, the electrical-energy storage device comprising: a conductive or semi-conductive first metasurface layer comprising a plurality of nano-scale or micro-scale first structures extending from a first conductive base; a conductive or semi-conductive second metasurface layer comprising a plurality of nano-scale or micro-scale second structures extending from a second conductive base; and a dielectric layer disposed between the first metasurface layer and the second metasurface layer for electrically insulating the first metasurface layer from the second metasurface layer; wherein each first structure comprises a recess extending inwardly from a distal end thereof. At least a portion of a corresponding second structure extends into the recess of the corresponding first structure without electrical contact therewith. Opposing surfaces of the corresponding first and second structures are separated by the dielectric layer. The recess extends around the corresponding second structure over at least a portion of an axial length thereof. The first structures and the second structures together form a plurality of nested pairs distributed across the first and second metasurface layers.

In some embodiments, the first metasurface layer comprises a plurality of nano-scale or micro-scale first structures; the second metasurface layer comprises a plurality of nano-scale or micro-scale second structures; and the first and the second structures extending into each other without electrical contact therewith.

In some embodiments, the first structures comprise a plurality of recesses at distal ends thereof; and at least a second set of the second structures are received in the recesses of the first structures without electrical contact therewith.

In some embodiments, the first structures comprise a plurality of first rods having recesses at distal ends thereof; and at least a portion of the second structures are received in the recesses of the first rods without electrical contact therewith.

In some embodiments, the first structures comprise a plurality of first rods; and the second structures comprise a plurality of second rods interleaved with the first rods.

In some embodiments, at least a first set of the first and the second structures has a circular, elliptical, or rectangular cross-section.

In some embodiments, one or more dimensions of each of the first and the second structures are in a nanometer range or in a micrometer range.

In some embodiments, the thicknesses of the first and the second structures are in the nanometer range or in the micrometer range.

In some embodiments, the electrical-energy storage device further comprising at least one of: a first electrode coupled to the first metasurface layer; and a second electrode coupled to the second metasurface layer.

In some embodiments, at least one of the first and the second metasurface layers comprises an electrically conductive base forming an electrode.

According to one aspect and in some embodiments, there is provided a method of fabricating an electrical-energy storage device; the method comprises: (i) depositing a first conductive layer onto a substrate; (ii) spin-coating a photoresist layer onto the conductive layer;

WHAT IS CLAIMED IS:

1. An electrical-energy storage device for storing electrical energy for use as a power source, comprising:

a conductive or semi-conductive first metasurface layer comprising a plurality of nano-scale or micro-scale first structures extending from a first conductive base;

a conductive or semi-conductive second metasurface layer comprising a plurality of nano-scale or micro-scale second structures extending from a second conductive base; and

a dielectric layer disposed between the first metasurface layer and the second metasurface layer for electrically insulating the first metasurface layer from the second metasurface layer;

wherein each first structure comprises a recess extending inwardly from a distal end thereof

wherein at least a portion of a corresponding second structure extends into the recess of the corresponding first structure without electrical contact therewith;

wherein opposing surfaces of the corresponding first and second structures are separated by the dielectric layer;

wherein the recess extends around the corresponding second structure over at least a portion of an axial length thereof; and

wherein the first structures and the second structures together form a plurality of nested pairs distributed across the first and second metasurface layers.

2. The electrical-energy storage device of claim 1, wherein the first structures comprise first rods and the second structures comprise second rods.

3. The electrical-energy storage device of claim 2, wherein each first rod comprises a hollow distal portion defining the recess.

4. The electrical-energy storage device of any one of claims 1 to 3, wherein each second structure extends into a corresponding recess along a longitudinal axis.

5. The electrical-energy storage device of any one of claims 1 to 4, wherein the dielectric layer surrounds the portion of the second structure extending into the recess.

6. The electrical-energy storage device of any one of claims 1 to 5, wherein at least a subset of the first structures and the second structures has a circular, elliptical, rectangular, polygonal, or tubular cross-sections.

7. The electrical-energy storage device of any one of claims 1 to 6, wherein dimensions of the first and the second structures are in a nanometer range or a micrometer range.

8. The electrical-energy storage device of any one of claims 1 to 7, further comprising a first electrode coupled to the first metasurface layer and a second electrode coupled to the second metasurface layer.

9. The electrical-energy storage device of any one of claims 1-8, wherein at least one of the first and second conductive bases forms a corresponding electrode.

10. The electrical-energy storage device of any one of claims 1-9, wherein each recess receives only one corresponding second structure.