

WHAT IS CLAIMED IS:

1. An electrical-energy storage device comprising:
 - a conductive or semi-conductive first metasurface layer;
 - a conductive or semi-conductive second metasurface layer; and
 - a dielectric layer sandwiched between the first and the second metasurface layers for electrically insulating the first metasurface layer from the second metasurface layer.
2. The electrical-energy storage device of claim 1, wherein the first metasurface layer comprises a plurality of nano-scale or micro-scale first structures;
 - wherein the second metasurface layer comprises a plurality of nano-scale or micro-scale second structures; and
 - wherein the first and the second structures extending into each other without electrical contact therewith.
3. The electrical-energy storage device of claim 2, wherein the first structures comprise a plurality of recesses at distal ends thereof; and
 - wherein at least a second set of the second structures are received in the recesses of the first structures without electrical contact therewith.
4. The electrical-energy storage device of claim 2, wherein the first structures comprise a plurality of first rods having recesses at distal ends thereof; and
 - wherein at least a portion of the second structures are received in the recesses of the first rods without electrical contact therewith.
5. The electrical-energy storage device of claim 2, wherein the first structures comprise a plurality of first rods; and
 - wherein the second structures comprise a plurality of second rods interleaved with the first rods.
6. The electrical-energy storage device of any one of claims 1 to 5, wherein at least a first set of the first and the second structures has a circular, elliptical, or rectangular cross-section.
7. The electrical-energy storage device of any one of claims 1 to 6, wherein one or more dimensions of each of the first and the second structures are in a nanometer range or in a micrometer range.

8. The electrical-energy storage device of claim 7, wherein the thicknesses of the first and the second structures are in the nanometer range or in the micrometer range.
9. The electrical-energy storage device of any one of claims 1 to 8 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.
10. The electrical-energy storage device of any one of claims 1 to 8, wherein at least one of the first and the second metasurface layers comprises an electrically conductive base forming an electrode.
11. A method of fabricating an electrical-energy storage device, the method comprising:
 - (i) depositing a first conductive layer onto a substrate;
 - (ii) spin-coating a photoresist layer onto the conductive layer;
 - (iii) applying a mask to the photoresist layer and exposing the masked photoresist layer under a light, the mask having a predefined pattern;
 - (iv) removing the un-exposed part of the photoresist layer with development;
 - (v) depositing a first conductive material to the photoresist layer for allowing the conductive material to fill the removed part of the photoresist layer;
 - (vi) dissolving the photoresist layer for forming a first set of conductive structures;
 - (vii) depositing a layer of a dielectric material to the deposited first conductive material for forming a dielectric layer thereon;
 - (viii) depositing a second conductive material to the dielectric layer forming a second set of structures, and
 - (ix) electroplating a third conductive material to the second set of structures.
12. The method of claim 11, wherein the substrate is silicon (Si).
13. The method of claim 11 or 12, wherein the first conductive layer comprises silver (Ag).
14. The method of claim 13, wherein the first conductive layer further comprises titanium (Ti).
15. The method of any one of claims 11 to 14, wherein the photoresist layer comprises SU-8.

16. The method of any one of claims 11 to 15, wherein the light comprises an ultraviolet (UV) light.
17. The method of any one of claims 11 to 16, wherein the first conductive material comprises Ag.
18. The method of any one of claims 11 to 17, wherein the dielectric material comprises fused silica (SiO₂).
19. The method of any one of claims 11 to 18, wherein the second conductive material comprises Ag.
20. The method of any one of claims 11 to 19, wherein the third conductive material comprises Ag.
21. An electrical power conversion apparatus comprising:
 - a first power conversion circuitry for receiving an input current from an electrical power source, converting a first portion of electrical power of the input current, and outputting the converted electrical power via at least one output, the first power conversion circuitry comprising a first transformer having a primary side for coupling to the electrical power source and a secondary side for coupling to the at least one output; and
 - at least one direct power transfer (DPT) channel electrically coupling to the first power conversion circuitry in parallel for bypassing the first power conversion circuitry and directly transferring a second portion of the electrical power received from the electrical power source to the secondary side of the first transformer for power-outputting via the at least one output.
22. The apparatus of claim 21, wherein the first power conversion circuitry comprises:
 - a current-switching structure coupling to the primary side of the first transformer for switching current.
23. The apparatus of claim 21 or 22, wherein the at least one DPT channel is coupled to the primary side of the first transformer via a second transformer.
24. The apparatus of claim 23, wherein the first and second transformers share a common core.

25. The apparatus of any one of claims 21 to 24, wherein the first power conversion circuitry comprise at least a pair of power semiconductors S_1 and S_2 adapted for operation under a zero-voltage switching (ZVS) condition.
26. The apparatus of claim 25, wherein the at least first and second power semiconductors comprise at least one pair of metal-oxide-semiconductor field-effect transistors (MOSFETs).
27. The apparatus of any one of claims 21 to 26 further comprising a plurality of output diodes adapted for operation under a zero-current switching (ZCS) condition.
28. The apparatus of claim 27 dependent from claim 25 or 26 further comprising an input switch for coupling the electrical power source to the first power conversion circuitry and the at least one DPT channel;
- wherein the plurality of output diodes comprises four diodes D_1 , D_2 , D_3 , and D_4 ;
- wherein a first end of D_1 is coupled to a first end of D_2 forming a first input end, and a first end of D_3 is coupled to a first end of D_4 forming a second input end, the first and second input ends are coupled to the secondary side of the first transformer and an output side of the at least one DPT channel;
- wherein a second end of D_1 is coupled to a second end of D_3 forming a first output end, and a second end of D_2 is coupled to a second end of D_4 forming a second output end, the first and second output ends are coupled to the at least one output; and
- wherein the apparatus is adapted for operation in a plurality of modes comprising:
- (i) a first mode in which D_1 and D_4 are ON, and S_1 is switched from ON to OFF under the ZVS condition,
- (ii) a second mode in which D_1 and D_4 are ON, and S_2 is switched ON under the ZVS condition,
- (iii) a third mode in which D_1 and D_4 turn OFF, D_2 and D_3 turn ON under the ZCS condition, and S_2 is ON,
- (iv) a fourth mode in which S_2 is switched OFF under ZVS condition,
- (v) a fifth mode in which S_1 is switched ON under ZVS condition, and D_2 and D_3 are ON,
- (vi) a sixth mode in which D_2 and D_3 turn OFF under ZCS condition, D_1 and D_4 turn ON under ZCS condition, and
- (vii) a seventh mode in which the input switch turns off for turning the input current to zero.

29. The apparatus of claim 28, wherein the input switch is a diode.
30. The apparatus of any one of claims 21 to 29, wherein the apparatus is adapted for operating the input current in a pseudo-continuous conduction mode (pseudo-CCM) for reducing the peak and/or root-mean-square (RMS) values thereof.
31. The apparatus of any one of claims 21 to 30, wherein the first power conversion circuitry comprises a first resonant tank.
32. The apparatus of any one of claims 21 to 31, wherein the at least one DPT channel comprises at least one second resonant tank.
33. The apparatus of any one of claims 21 to 32, wherein the input current is an alternate current (AC) or a direct current (DC).
34. The apparatus of any one of claims 21 to 33, wherein the at least one output comprises an AC output or a DC output.
35. The apparatus of any one of claims 21 to 34, wherein the at least one output comprises a plurality of outputs;
wherein the at least one DPT channel comprises a plurality of DPT channels; and
wherein at least two of the plurality of DPT channels are coupled to different ones of the plurality of outputs.