According to one aspect of this disclosure, there is provided a multi-layer energy apparatus comprises: a transparent or semi-transparent substrate; a solar-cell layer coupled to the substrate, the solar-cell layer comprising a plurality of solar cells for receiving light through the substrate and converting energy of the received light to a first electrical energy; an energy-storage layer coupled to the solar-cell layer, the energy-storage layer comprising one or more energy-storage units for storing a second electrical energy; and a converter layer comprising a solar-input converter electrically connected to the solar-cell layer, a battery-input converter electrically connected to the energy-storage layer, and an output converter configured to receive the first electrical energy and the second electrical energy and convert the first electrical energy and the second electrical energy into a third electrical energy; wherein the solar-input converter, the battery-input converter, and the output converter are coupled to a ferrite core comprising a first ferrite loop, a second ferrite loop, and a third ferrite loop, each of the first and second ferrite loops sharing a portion of the third ferrite loop; and wherein the solar-input converter comprises coils winding around the first ferrite loop, the battery-input converter comprises coils winding around the second ferrite loop, and the output converter comprises coils winding around the third ferrite loop.

In some embodiments, the substrate comprises a flexible, transparent or semi-transparent material.

In some embodiments, the substrate comprises at least one of polyethylene terephthalate (PET) and poly(ether sulfones) (PES).

In some embodiments, the solar-cell layer is printed or deposited to the substrate.

In some embodiments, the energy-storage layer is printed or deposited to the solar-cell layer.

In some embodiments, the solar-cell layer comprises: a first conductive sublayer coupled to the substrate; a sublayer of zinc oxide (ZnO) coupled to the first conductive sublayer; a sublayer of poly(ethylenimine) and poly(ethylenimine) ethoxylated (PEIE) coupled to the sublayer of ZnO; a sublayer of organic solar cells coupled to the sublayer of PEIE; a sublayer of Molybdenum trioxide (MoO_3) coupled to the sublayer of solar cells; and a second conductive sublayer coupled to the sublayer of MoO_3.

In some embodiments, the sublayer of organic solar cells comprises polymer solar cells.

In some embodiments, the sublayer of solar cells comprises a sublayer of bulk heterojunctions (BHJs).

In some embodiments, the energy-storage layer comprises at least one of one or more battery cells and one or more semiconductor capacitors.

In some embodiments, each of the one or more battery cells comprises: a first current-collector sublayer; an anode sublayer coupled to the first current-collector sublayers; a solid-state electrolyte sublayer coupled to the anode sublayer; a cathode sublayer coupled to the solid-state electrolyte sublayer; and a second current-collector sublayer coupled to the cathode sublayer.

WHAT IS CLAIMED IS:

1. A multi-layer energy apparatus comprising:

a transparent or semi-transparent substrate;

a solar-cell layer coupled to the substrate, the solar-cell layer comprising a plurality of solar cells for receiving light through the substrate and converting energy of the received light to a first electrical energy;

an energy-storage layer coupled to the solar-cell layer, the energy-storage layer comprising one or more energy-storage units for storing a second electrical energy; and

a converter layer comprising a solar-input converter electrically connected to the solar-cell layer, a battery-input converter electrically connected to the energy-storage layer, and an output converter configured to receive the first electrical energy and the second electrical energy and convert the first electrical energy and the second electrical energy into a third electrical energy;

wherein the solar-input converter, the battery-input converter, and the output converter are coupled to a ferrite core comprising a first ferrite loop, a second ferrite loop, and a third ferrite loop, each of the first and second ferrite loops sharing a portion of the third ferrite loop; and

wherein the solar-input converter comprises coils winding around the first ferrite loop, the battery-input converter comprises coils winding around the second ferrite loop, and the output converter comprises coils winding around the third ferrite loop.

2. The multi-layer energy apparatus of claim 1, wherein the substrate comprises a flexible, transparent or semi-transparent material.

3. The multi-layer energy apparatus of claim 1, wherein the substrate comprises at least one of polyethylene terephthalate (PET) and poly(ether sulfones) (PES).

4. The multi-layer energy apparatus of any one of claims 1 to 3, wherein the solar-cell layer is printed or deposited to the substrate.

5. The multi-layer energy apparatus of any one of claims 1 to 4, wherein the energy-storage layer is printed or deposited to the solar-cell layer.

6. The multi-layer energy apparatus of any one of claims 1 to 5, wherein the solar-cell layer comprises:

a first conductive sublayer coupled to the substrate;

a sublayer of zinc oxide (ZnO) coupled to the first conductive sublayer;

a sublayer of poly(ethylenimine) and poly(ethylenimine) ethoxylated (PEIE) coupled to the sublayer of ZnO;

a sublayer of organic solar cells coupled to the sublayer of PEIE;

a sublayer of Molybdenum trioxide (MoO_3) coupled to the sublayer of solar cells; and

a second conductive sublayer coupled to the sublayer of MoO_3.

7. The multi-layer energy apparatus of claim 6, wherein the sublayer of organic solar cells comprises polymer solar cells.

8. The multi-layer energy apparatus of claim 6, wherein the sublayer of solar cells comprises a sublayer of bulk heterojunctions (BHJs).

9. The multi-layer energy apparatus of any one of claims 6 to 8, wherein the energy-storage layer comprises at least one of one or more battery cells and one or more semiconductor capacitors.

10. The multi-layer energy apparatus of claim 9, wherein each of the one or more battery cells comprises:

a first current-collector sublayer;

an anode sublayer coupled to the first current-collector sublayers;

a solid-state electrolyte sublayer coupled to the anode sublayer;

a cathode sublayer coupled to the solid-state electrolyte sublayer; and

a second current-collector sublayer coupled to the cathode sublayer.

11. The multi-layer energy apparatus of claim 10, wherein the solid-state electrolyte sublayer comprises $LiBrF_4$ with Al_2O_3 and a first semi-interpenetrating polymer network (semi-IPN) skeleton material.

12. The multi-layer energy apparatus of claim 10, wherein the solid-state electrolyte sublayer is made of 1 Molar (mol per liter) $LiBF_4$ in Sebaconitrile (SBN) and a first semi-IPN skeleton material at a ratio of 85/15 weight-by-weight (w/w), mixed with about 300 Molar Al_2O_3 at a ratio of 60/40 w/w.

13. The multi-layer energy apparatus of any one of claims 10 to 12, wherein the anode sublayer comprises activated $Li_4Ti_5O_{12}$ (LTO) with a first carbon material and a second semi-IPN skeleton material, and the cathode sublayer comprises activated $LiCoO_2$ (LCO) with a second carbon material and a third semi-IPN skeleton material.

14. The multi-layer energy apparatus of claim 13, wherein the first and/or the second carbon comprises at least one of single-walled carbon nanotubes (SWCNT) and carbon powder, the activated LTO is SWCNT-coated LTO, and the activated LCO is SWCNT-coated LCO..

15. The multi-layer energy apparatus of any one of claims 12 to 14, wherein the semi-IPN skeleton material comprises an ultraviolet (UV) curable polymer.

16. The multi-layer energy apparatus of claim 15, wherein the UV-curable polymer comprises ethoxylated trimethylolpropane triacrylate (ETPTA) incorporating 1.0 weight percent (wt%) 2-hydroxy-2-methylpropiophenone (HMPP) and poly(vinylidene fluoride-co-hexafluoropropylene) (PVdF-HFP) with HFP of six mole percent (mol%) and ETPTA/PVdF-HFP at a ratio of 75/25 weight-by-weight (w/w).

17. The multi-layer energy apparatus of any one of claims 9 to 16, wherein each of the one or more semiconductor capacitors comprise n aluminum gallium arsenide (AlGaAs)

sublayers interleaved with (n+1) gallium arsenide (GaAs) sublayers, n>0 being an integer, with each AlGaAs layer sandwiched between two neighboring GaAs layers.

18. The multi-layer energy apparatus of any one of claims 1 to 17, wherein the converter layer comprises a multi-input electronic power converter having a solar-input converter, a battery-input converter, and an output converter.

19. The multi-layer energy apparatus of claim 18, wherein at least one of the solar-input converter, the battery-input converter, and the output converter comprises coils winding about a ferromagnetic or ferrimagnetic core.

20. The multi-layer energy apparatus of claim 18, wherein at least one of the solar-input converter, the battery-input converter, and the output converter comprises a core layer made of a ferrite material and sandwiched between two wiring layers; wherein each of the wiring layers comprises electrically conductive wirings on a base; and wherein the wirings of the two wiring layers are interconnected through one or more vias thereon to form the coils winding about the ferrite core.