Abstract: A power supply device consists of a rectifier and capacitor which share common elements facilitating the construction and application of the device to various types of substrates and, particularly, flexible substrates. Components of the device are fabricated from organic conductors.
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RECTIFYING CHARGE STORAGE ELEMENT

This invention relates to a rectifying charge storage element and, more particularly, to electronic circuits fabricated on various substrates, including flexible substrates by various means including printing or other deposition techniques using organic conductors, semiconductors and insulators and other electronic materials suitable for deposition and use in electronic circuits. The invention specifically relates to a power supply that extracts DC power (voltage and current) sufficient to power an electronic device from an AC input signal. The AC input signal may be derived from an inductive, capacitive, or L-C resonant circuit coupled to an external electromagnetic or electrostatic AC field. The electronic circuit thus powered may be an RFID circuit.

Background of the Invention

Most electronic circuits require a source of DC voltage with sufficient current output to power the circuit elements. Many of these circuits derive DC power by rectifying and filtering an AC power signal. Often the AC signal is provided to the circuitry by electromagnetic coupling.

For example, a passive RFID tag system must be capable of receiving power from an RFID reader to the RFID tag via inductive (H-field) or electric field (E-field) coupling, and transmitting data from the tag to the reader also via inductive or electric field coupling. Activation field frequency of RFID devices may be from under 100 kHz up to over 30 MHz if inductive or capacitive coupling to the activation source is utilized or up to multiple GHz if electric field coupling is utilized.

In current industry practice, operating power to a passive tag or other electronic circuit is derived by utilizing a rectifier device and a charge-storage device, typically a rectifier diode or combination of diodes connected to a charge storage capacitor or conservation of capacitors. Typically these elements are implemented as separate components within a discrete circuit or silicon integrated circuit.

New technology is developing for manufacturing circuitry such as RFID tags on flexible substrates using thin film materials such as polymer semiconductors and other substances that can be applied by techniques such as ink jet printing. A primary objective
is producing devices that have operating characteristics competitive with silicon technology while approaching the economy of printing processes.

Beigel patent US 4,333,072 describes an inductively coupled RFID system in which power to an RFID 25 tag is derived from an alternating magnetic field originating in a reader-energizer coupled inductively to the tag antenna, and rectified by a rectifier in the antenna with the resulting DC charge stored in a capacitor in the tag.

Beigel patent US 5,973,598 describes an RFID tag formed on a flexible substrate by depositing or printing conductive, semiconductive and insulating substances in an operative pattern on the substrate.


*Objects and Advantages of the Invention*

An object of the invention is the provision of a composite device that provides rectification and charge storage for converting AC signals to DC power supply voltages by structurally combining a rectifier diode and charge storage capacitor.

An additional object of the invention is the provision of a composite power supply which incorporates a diode rectifier and a capacitor, said rectifier and capacitor sharing a common component to facilitate the provision of the diode and rectifier in a single device.

Another object of the invention is the provision of a device of the aforementioned character which can be provided on a flexible substrate to facilitate the incorporation of the device in correspondingly flexible environments.

A further object of the invention is the provision of a device of the aforementioned character wherein various components of the device may be fabricated from organic and other conductors which constitute the interface between the conductors of the rectifier and capacitor components of the device.

Additionally, the device may incorporate a flexible substrate as an electrically operative component of the device.
**Brief Description of the Drawing**

Other objects and advantages of the invention will become apparent from the following specification and the accompanying drawings in which:

FIG. 1 shows a device constructed in accordance with the teachings of the invention;

FIG. 2 is a sectional view showing the device mounted on a flexible substrate;

FIG. 3 is a plan view of the device of FIG. 2;

FIG. 4 is a sectional view showing the incorporation in the device of a flexible substrate;

FIG. 5 is top plan view of the device of FIG. 45;

FIG. 6 is a view of an alternative embodiment of the device of the invention;

FIG. 7 is a sectional view of another embodiment of the invention; and

FIG. 8 is a schematic view, in plan, of yet another embodiment of the invention.

**Preferred Embodiments of the Invention**

Referring to the drawings and particularly to Fig. 1 thereof, I show a power supply device 10 including a diode rectifier 12 and a capacitor 14. The diode 12 includes a conductor 16 and a semiconductor 18. A common conductor 20 between the diode 12 and capacitor 14 is superimposed on a dielectric component 22 of the capacitor 14 which, in turn, is mounted on a conductor 24.

The conductor 16 is electrically connected to one terminal 30 of the AC source 32 and electrically connected to one surface of the semiconductor 18 at the surface interface 34. The opposite surface of the semiconductor 18 is electrically connected to the common conductor 20 at the surface interface 36.

The common conductor 20 is connected to the dielectric component 22 at surface interface 38 and the conductor 24 is connected to the dielectric component 22 at the surface interface 42. The conductor 24 is connected to the other terminal 46 of the AC source 32 and also serves as the ground output terminal 48. Rectification takes place between the conductor 16, the semiconductor 18, and the common conductor 20 through the interfaces 34 and 36. Charge storage takes place between the common conductor
20, the dielectric component 22, and the conductor 24. The surface area of the rectifying component and 16, 34, 18, 36, and 20 interfaces is preferably minimized to reduce internal parasitic capacitor characteristics inherent in rectification. The surface area of the capacitive component interface provided by the common conductor 20 may be maximized to increase DC charge storage.

The common conductor 20 provides the DC power at the junction 26 and the circuit being powered by the device 10 may be energized thereby inductively, magnetically, or directly.

The diode components may be fabricated from various materials, including inorganic semiconductor nanocrystals such as CdSe, InP, and others.

Furthermore, conjugated polymers may be used, such 25 as poly(phenylene-vinylene) (PPV), its derivatives and co-polymers; polyfluorene (PF), its derivatives and co-polymers; polyparaphenylene (PPP), its derivatives and co-polymers; polythiophene (PT), its derivatives and copolymers; and others.

The rectifying function of the diode 12 is implemented through the conductor 16 which serves as the anode and the common conductor 20 which serves as the cathode. The rectifying character of an organic or a polymeric diode usually requires different conductors for the anode and for the cathode. Organic and polymeric semiconductors are usually regarded as semiconductors with low doping concentration (usually in the range of $10^{13}$ cm$^{-3}$); hence the theory of p-n junction commonly used in inorganic semiconductor diodes is not applicable here.

For inorganic diodes, metal electrodes for the anode and the cathode can be the same material with ohmic contacts to the p-type and n-type semiconductor, respectively. The rectifying behavior is from the p-n junction.

For organic semiconductors, the relative position of the work functions (or the energy level) of the metal electrodes to the energy levels of the conduction band and valence band of the organic semiconductor determines the rectifying behavior. The choice of anode hence is preferentially to be high work function metals such as gold, nickel, and their alloys. Alternatively, some metal oxides, including but not limited to indium tin-oxide, indium oxide, are also candidates for the anode material.
For the cathode, the choice is preferentially low 5 work function metals, including but not limited to calcium, lithium, magnesium, and others. Recently, the metal alloys consisting of a small amount of low work function metals, such as aluminum: lithium 3% alloy and 97% Al:LiF bilayer electrode, have become alternatives for the choice of cathode material.

The materials for the capacitor dielectric 22 should be insulating materials, preferentially with a high dielectric constant to enhance its capacity. The structure of the capacitor 14 should provide a larger area compared to the diode. The dielectric 22 may be an organic and polymeric or inorganic insulator with reasonable dielectric constant. It should be large enough to hold enough charge, and it should also be small enough such that the device 10 has a fast response time. Currently, polymer materials such as polystyrene, polyethylene, and polycarbonate are ideal candidates. The dielectric 22 should be flexible where the other components of the device 10 are flexible.

The fabrication of the device 10 where traditional polymer and organic device fabrication processes may be utilized. Polymer and organic thin films can be processed by spin-coating, ink-jet printing, roll-to-roll coating, and other coating methods. Organic thin films can also be deposited by thermal sublimation, chemical vapor deposition, and analogous methods. Metal electrodes can be deposited on a substrate by thermal deposition under high vacuum or by the ink-jet printing process.

Where conventional materials are utilized, the components of the device 10 can be assembled by the use of materials and processes well known to those skilled in the art.

The device 10 of Fig. 1 is shown in Fig. 2 as mounted on a flexible substrate 50 with all of the other components of the device 10 bearing the same reference numerals as the device 10 of Fig. 1.

Fig. 3 is a top plan view of the device 10 of Fig. 2 and shows the device 10 superimposed on the top surface of a flexible substrate 50. The flexible substrate 50 may be manufactured from any type of material. Where a flexible substrate, such as the substrate 50, is provided, it is desirable that all of the components of the device 10 be correspondingly flexible so that the device 10 may be mounted, through the flexible substrate 50, in environments where such flexibility is indicated. Typical substrates are sheets or strips of polyethylene, polyvinylchloride, or the like.
An alternative embodiment 60 of the device 10 is shown in Fig. 4 in cross section and includes elements identical with or similar to the corresponding elements of Fig. 1-3, said elements being provided with the same reference numerals as those of Figs. 1-3.

The major difference between the device 60 of Fig. 4 and the device 10 lies in the provision of a dielectric 62 which is incorporated in a flexible substrate 64. Once again, the flexible substrate can be manufactured from strip or sheet plastic material such as polyvinylchloride, polystyrene, polyethylene, and the like.

The device of Fig. 4 is shown in plan in Fig. 5. Although the flexible substrate 62 is shown as protruding beyond the limits of the remaining elements of the device 60, it is not intended that the actual commercial device be limited to that particular configuration since it is contemplated that the devices be extremely miniaturized.

An alternative embodiment 70 of the power supply device 10 is shown in Fig. 6 and functions in the same manner as the devices of Figs. 1-5. However, the various elements of the embodiment 70 are disposed in a planar rather than a superimposed relationship which is characteristic of the previously discussed embodiments of Figs. 1-5.

The planar relationship of the various components minimizes the rectifier capacitance of the diode and also provides for various advantages in device fabrication. The device 70 incorporates a conductive layer 71 having a low work function and terminating to create a gap 72. The conductive layer 71 forms the anode terminal 73 of the rectifying diode 74.

A common conductive layer 76 having a high work function and larger surface area than the first conductive layer 71 is provided at the gap 72 and constitutes the cathode of the diode 74 as well as the top layer 78 of the capacitor 80.

A dielectric substrate 90 is provided below the conductors 71 and 76 and an organic or other molecular semiconductor 110 is provided in the gap 72 to establish a current path across the gap and permit the performance of the rectifier function of the device 70.

A conductive layer 112 underlies the dielectric substrate 90 and the completion of the capacitor 70 is accomplished. An AC circuit 120 is connected at one side to the
conductive layer 71 and at the opposite side to the layer 112 which acts as the ground of the circuit. The DC output is located at 124 on the layer 76.

The planar structure of the device 70 permits the 25 formation of a power supply of opposite polarity by using opposite combinations of high and low work function conductors such as the layers 71 and 76.

A planar device 120 is shown in Fig. 7 as including the layers 71 and 76 of the device 70 of Fig. 6. However, instead of incorporating the flexible dielectric 110 of the device 70, a common layer 122 is provided which serves as a semiconductor connection to the common layer 76 and as a dielectric between the common layers 76 and the layer 126 of a capacitor 127.

Therefore, there are two elements of the device 120 serving a common function, namely, the semiconductor/dielectric layer 122 and the common conductive layer 76. The layer 126 is a high work function layer and serves as the ground for the circuit of the device 120. The provision of the coplanar layers 71 and 76 and the common performance of the layer 76 and the layer 122 greatly simplify the fabrication of the device 120 on the flexible substrate 128.

The AC input 132 is connected on one side to the 20 anode layer 71 and on the other side to the common conductor layer 76 with the DC output being connected to the layer 76 at 134.

An alternative embodiment 140 of the device is shown in Fig. 8 of the drawings as including an AC input at 142 which is connected to an anode 144. The anode 144 communicates with one side 146 of an interdigitate capacitor unit 150. The interdigitate capacitor layers or fingers 152 of said one side fit between corresponding layers or fingers 154 of the other side 156. The entire assemblage is encapsulated or overlaid by semiconductor/dielectric material 158 to create the rectification and capacitance effects. The device 150 is particularly suited to deposition on a flexible substrate and is susceptible to various well-established methods of deposition conductors such as conductive inks, organic polymers, or the like.
I CLAIM:

1. In a power supply, the combination of:
   a rectifier;
   a common conductor connected to one side of said rectifier; and
   a capacitor incorporating said common conductor whereby it receives
   rectified current from said rectifier.

2. The power supply of claim 1 in which said rectifier incorporates diode
   elements and said common conductor is one of said elements.

3. The power supply of claim 1 in which said common conductor is the
   primary conductor for said capacitor.

4. The power supply of claim 1 in which rectifier is a diode-type rectifier and
   said common conductor is the output of said rectifier and the input of said capacitor.

5. The power supply of claim 1 in which said rectifier incorporates an organic
   semiconductor and said common conductor is connected to said semiconductor.

6. In a power supply, the combination of:
   a rectifier, said rectifier having an anode and a semiconductor connected to
   said anode;
   a common conductor connected to said semiconductor; and
   a capacitor incorporating said common conductor on one side, said
   capacitor having a dielectric component; and
   a conductor on the other side of said dielectric element.

7. The power supply of claim 6 which incorporates a flexible substrate
   supporting the components of said power supply.

8. The power supply of claim 6 in which said semiconductor is an organic
   conductor and said organic conductor communicates with said common conductor.

9. The power supply of claim 6 in which said dielectric element is an organic
dielectric.

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10. The power supply of claim 6 in which said power supply is supported on a flexible substrate and said rectifier and capacitor are imprinted on said flexible substrate.

11. In a power supply, the combination of:
   a rectifier having an input anode;
   a semiconductor component connected to said anode;
   a common conductor disposed in electrical communication below said semiconductor;
   a dielectric component disposed below said common conductor; and
   another conductor in electrical communication with said dielectric component and having said dielectric component superimposed thereupon to provide a capacitor, said anode and said common conductor being electrically connected to the source of rectifiable current and said common conductor providing the output of said power supply.

12. The power supply of claim 11 in which said semiconductor component is fabricated from an organic conductor.

13. The power supply of claim 11 in which said dielectric component is fabricated from organic material.

14. The power supply of claim 11 in which said semiconductor and said dielectric component are fabricated from organic materials.

15. The power supply of claim 11 in which the components of said power supply are supported on a flexible substrate.

16. The power supply of claim 15 in which said 5 components are imprinted on said flexible substrate.

17. The power supply of claim 11 in which said rectifier and said capacitor are supported by a flexible substrate.

18. The power supply of claim 17 in which the flexible substrate is the dielectric component.
19. In a power supply, the combination of:
   a rectifier, said rectifier having an anode;
   a common conductor in coplanar relationship with said anode, said
   common conductor being spaced from said anode to create a gap;
   a semiconductor located in said gap;
   a dielectric element adjacent said common conductor; and
   a conductor on the other side of said dielectric.

20. A power supply including:
   a rectifier having an anode;
   a capacitor including a common conductor serving as the cathode of said
   rectifier, said common conductor having a first set of interdigitate fingers or layers;
   a ground conductor having a second set of interdigitate layers or fingers
   internested with said first set; and
   a dielectric between said conductors and said fingers.