Title: ELECTRONIC BAR CODE DEFINED BY POLYMER PRINTING PROCESS

Abstract: An electronic bar code includes a bar code circuit (112) and an access interface (110) for a bar code reader (102) to access the bar code circuit. The bar code circuit stores a code that is readable by a bar code reader. The code is determined by a polymer printing process. The bar code circuit is disposed on a substrate (207). The bar code circuit preferably includes a radio frequency identification circuit (206) that is remotely powered and accessed via an over-the-air interface to return the stored code. The access circuit preferably includes electrostatic antenna elements (202, 204).
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

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ELECTRONIC BAR CODE DEFINED BY POLYMER PRINTING PROCESS

Field of the Invention

The invention generally relates to electronic bar codes, and in particular, to electronic bar codes implemented with radio frequency identification tags made by a polymer printing process.

Background of the Invention

Bar codes are well known and widely used for the identification of articles and things. In particular, bar codes are used to identify products for point-of-sale and inventory control applications. Paper bar codes typically consist of precisely printed lines, wherein the pattern of lines determines the code. A laser is required to "read" the code based on the lines. Unfortunately, due to prevailing standards and physical limitations, paper or printed bar codes are limited. Also, bar code reading often requires precise alignment of the bar code with the reader.

Electronic bar codes are prevailing as an opportunity to expand on printed bar codes. The term "electronic bar code" is somewhat of a misnomer, since no actual printed bars are typically required or desired for electronic bar codes. Electronic bar codes hold the promise of flexibility in the size and number of bar codes. However, semiconductor integrated circuits, which are generally a basic building block for electronics, are relatively expensive in comparison to printed bar codes, limiting the ability of electronic bar codes to replace printed bar codes.

Radio frequency identification ("RFID") tags are readily adapted to perform as electronic bar codes. RFID tags include remotely powered devices which use electromagnetic or electrostatic coupling to derive power from a remote source and then uses electromagnetic or electrostatic coupling to transmit stored data to a receiver often collocated with the remote source. It is understood that the term electromagnetic refers to systems that primarily send and receive magnetic fields and are primarily inductively coupled. It is also understood that the term electrostatic refers to systems that primarily send and receive electric fields and are primarily capacitively coupled.

Electrostatic RFID tags are particularly well adapted to perform as electronic bar codes due in part to the ease of manufacture and low cost of the antenna elements used.
for electrostatic coupling. For electrostatically coupled RFID tags, the antenna coil or antenna coil and capacitor, which are necessary for electromagnetic coupling, are eliminated and replaced with cheaper electrostatic antennas which may be as simple as conductive ink printed on paper. Nonetheless, the semiconductor integrated circuit attached to the electrostatic antennas in electrostatic RFID tags presents a substantial obstacle to obtaining a low cost electronic bar code that competes with printed bar codes.

Organic semiconductors are emerging as alternatives to traditional inorganic and silicon semiconductors. Organic semiconductor circuits variously include polymers for transistor components and interconnections. Direct printing of organic circuits has been demonstrated. However, the low speed and relatively large size of organic semiconductors limits the opportunities for such circuits. Since RFID tags typically operate at low frequencies (125 kHz) the low speed of organic semiconductors do not limit their use in RFID tags.

In light of the shortcomings described above, a need exists for a low-cost electronic bar code and associated system for reading the electronic bar codes.

**Brief Description of the Drawings**

FIG. 1 is a block diagram of an electronic bar code system in accordance with the present invention.

FIG. 2 is a block diagram of an electronic bar code comprising an electrostatic radio frequency identification tag in accordance with the present invention.

FIG. 3 is a block diagram of a memory of the electrostatic radio frequency identification tag of FIG. 2.

FIG. 4 is a block diagram of an exemplary memory cell array for the memory of FIG. 3.

FIG. 5 is a block diagram of an alternate memory cell array for the memory of FIG. 3.

FIG. 6 is a cross-sectional view of an organic transistor for implementing components of an electronic bar code in accordance with the present invention.

**Description of the Preferred Embodiments**

In accordance with the present invention, an electronic bar code includes a memory device that stores a data stream (e.g., code, and hereinafter referred to as the
"code" for purposes of the present invention) that is electronically readable. The code is defined by a polymer printing process. An access interface is coupled to the memory that allows a bar code reader to access the code stored in the memory device.

 Preferably, the electronic bar code comprises an electrostatic radio frequency identification ("RFID") tag that includes an access interface that is comprised of a first electrostatic antenna element and a second electrostatic antenna element, the second electrostatic antenna element being electrically isolated from the first antenna element. The first and second antenna elements are coupled to a RFID circuit that includes the memory defined by the polymer printing process. The antenna elements and the RFID circuit are disposed on a substrate. Most preferably, the RFID circuit includes transistors having conductive and insulating regions, the conductive and insulating regions comprising polymers.

 Turning to the figures, FIG. 1 is a block diagram of an electronic bar code system 100 in accordance with the present invention. Electronic bar code system 100 includes a bar code reader 102 and an electronic bar code 104. Bar code reader 102 includes a reader 106 and an access interface 108. Bar code reader 102 initiates access to and receives codes from the electronic bar code 104. Bar code reader 102 electronically reads, writes, interrogates, and/or powers electronic bar codes without visual or optical perception means, such as a laser or the like.

 Electronic bar code 104 includes an access interface 110 and a bar code circuit 112. Bar code circuit 112 sends a code to the bar code reader 102 through access interface 110. Bar code circuit 112 includes a modulator/demodulator 114, a control circuit 116, and a memory 120, which all vary to some degree based on the implementation. In general, modulator/demodulator 114 is connected to the access interface 110 to receive signals from and transmit signals to the bar code reader 102. Preferably, the signals transmitted from the electronic bar code 104 to the bar code reader 102 are wireless, radio frequency signals, permitting a wireless and contactless interface between the bar code reader 102 and the electronic bar code 104. This contactless interface may include electrostatic or electromagnetic coupling.

 Alternatively, the access interface may require physical contact whereby an electrical connection is required for the bar code reader 102 to access the electronic bar code 104. Modulator/demodulator 114 modulates signals that are to be received by the bar code reader 102 to conform to a predetermined protocol for the access interface. Similarly,
modulator/demodulator 114 demodulates signals received from bar code reader 102 for use by the other components of bar code circuit 112.

Control circuit 116 receives signals from modulator/demodulator 114 and executes commands corresponding to the signals. For example, a read signal from the bar code reader 102 that is received by the access interface 110 and successfully demodulated by modulator/demodulator 114 is interpreted by the control circuit 116 to execute a read of memory 120. Control circuit 116 also sends signals to modulator/demodulator 114. For example, following the receipt of the read command and a read of memory 120 as described above, control circuit 116 returns the appropriate contents of memory 120 to modulator/demodulator 114 for further transmission to bar code reader 102.

Memory 120 stores data. Memory 120 is accessible by control circuit 116. The contents of memory 120 vary according to the application, but typically include at least a code representing the "bar code". Memory 120 can be any type of memory device, but is preferably programmable, readable, and writable, depending on the application. In accordance with the present invention, memory 120 has some contents that are determined by a polymer printing process. Typically, a connection or component that comprises an organic or polymer conductor or component determines the contents of memory 120. For example, the code or "bar code" of the electronic bar code 104 is determined by whether an organic component is printed or not.

FIG. 2 is a block diagram of a preferred embodiment of an electronic bar code implemented as an electrostatic RFID tag 200 in accordance with the present invention. RFID circuit 206 includes a first electrostatic antenna element 202 and a second electrostatic antenna element 204. The first electrostatic antenna element 202 is isolated from the second electrostatic antenna element 204. The first and second electrostatic antenna elements are coupled to a RFID circuit 206. First electrostatic antenna element 202 and second electrostatic antenna element 204 provide an access interface for a bar code reader 102 to access RFID tag 200. RFID circuit 206 receives and transmits signals from and to the first electrostatic antenna element 202 and the second electrostatic antenna element 204. In particular, RFID circuit 206 receives signals from the bar code reader 102 indicative of reading a bar code and returning a predetermined code stored in the RFID circuit 206 to the bar code reader 102. A substrate 207 provides a physical
base or support for first electrostatic antenna element 202, second electrostatic antenna element 204, and RFID circuit 206.

Substrate 207 is preferably comprised of a non-conductive component. Suitable materials for substrate 207 include, but not limited to, paper, acetate, polyester, polyethylene, polypropylene, polypropylene with calcium carbonate, polyvinyl chloride, or plastic. The selection of material for substrate 207 varies depending upon the application. For example, for an application wherein tag 200 is disposable, substrate 207 is preferably paper. For an application where tag 200 is durable and reusable substrate 207 is preferably plastic, polyvinyl chloride or polyester.

First and second electrostatic antenna elements 202, 204 are formed from numerous suitable conductive materials. Suitable materials for antenna elements 202, 204 include conductive ink, wire, or a conductive metal material. More specifically, suitable materials for antenna elements 202, 204 include, but is not limited to, copper, graphite, metalized polyester, aluminum, silver ink and carbon ink. Antenna elements 202, 204 are placed on substrate 207 using any suitable process including printing, lamination, adhesively securing, and deposition. The shape of antenna elements 202, 204 is not limited, but preferably, for optimal performance, antenna elements 202, 204 consume substantially all of the available surface area on substrate 207.

RFID circuit 206 preferably includes a RF modem 208, a control circuit 210, and a memory 212. In the preferred embodiment, memory 212 is a read-only memory (ROM) 212, however, it can be any type of suitable memory (e.g., EEPROM, etc.). Preferably, modem 208 modulates signals on antenna elements 202, 204 in response to signals from control circuit 210 to conform to a predetermined protocol expected by a bar code reader, however, any other suitable component of the RFID circuit 206 can perform the modulation function. The first and second antenna elements radiate signals from modem 208. Modem 208 also demodulates signals received via antenna elements 202, 204 into commands for control circuit 210. Modem 208 is preferably a radio frequency modem, which uses amplitude, frequency, phase modulation, or any combination thereof.

Control circuit 210 receives signals from modem 208 that are representative of commands that are to be executed. Preferably, control circuit 210 is a state machine or other sequential and combinatorial logic. Alternatively, control circuit 210 is a microcontroller that executes commands or a stored program. The commands or stored
programs for control circuit 210 are stored in a memory on control circuit 210 or in ROM 212. Control circuit 210 accesses ROM 212 in accordance with the commands it receives.

RFID circuit 206 also includes a power circuit 214. Power circuit 214 is coupled to antenna elements 202, 204 to receive electrostatic signals that capacitively power RFID circuit 206. Receipt of the appropriate electrostatic or capacitively powered signals results in the power circuit rectifying, and conditioning a voltage Vcc that is used to power the components of RFID circuit 206. Power circuit 214 may also include means for modulating signals on antenna elements 202, 204 in response to signals from control circuit 210 to conform to a predetermined protocol expected by a bar code reader.

The contents of ROM 212 include the data that represents a “bar code” that is variously used to identify articles. The code varies in size, depending on the application. In one example, the code is ten bytes to conform to an existing UPC (Universal Product Code) standard.

Traditionally, ROM’s for RFID tags implemented with silicon integrated circuits have their contents determined during fabrication of the device. More specifically, at least one mask level for the silicon integrated circuit determines the contents of the ROM, that is, whether a bit of the ROM is a “one” or a “zero.” This is accomplished in some technologies by the presence or absence of a gate, source, or drain for a transistor comprising a bit cell. In other technologies and implementations, the content of the ROM is determined by the presence or absence of a connection or conductor, which is selectively fabricated or etched. This method of defining the contents of a ROM is not well suited for applications where every device requires unique data.

In a preferred embodiment of the present invention, ROM 212 is implemented with organic integrated circuits. Organic integrated circuits are well suited for bar code applications due to the flexibility of manufacture. In particular, the selection of substrate and the ease of manufacture permit actual printing of the circuit. The printing process is alternatively ink jet printing, die sublimation printing, flexographic printing, and the like. The printing process readily permits each instantiation of an electronic bar code (i.e., ROM contents) to be different, permitting the unique identification of articles.

A preferred arrangement for a polymer printed ROM in accordance with the present invention is illustrated by the block diagram in Fig. 3. ROM 212 of Fig. 3 includes address logic 302, column select logic 304, row select logic 306 and memory
cell array 308. Address logic 302 receives data from control circuit 210 through address bus 310. Based upon the data on address bus 310, address logic 302 translates the signals on address bus 310 to the appropriate column and row addresses. The column and row addresses are connected to the column select logic 304 and row select logic 306, respectively. Column select logic 304 determines which column of memory cell array 308 is to be activated. Similarly, row select logic 306 determines which row of memory array 308 is to be activated. The contents of the activated memory cells are then delivered to control circuit 210 via data bus 312.

Preferably, ROM 212 is implemented as an organic semiconductor with polymer-based components. Most preferably, a polymer printing process is used to define the contents of the memory cell array 308 that includes the bar code. The polymer printing process may include an etching process. The polymer printing process is in contrast to a mask level process required in silicon integrated circuits. This advantageously allows for flexibility in printing, including the ability to determine unique bar codes for every instantiation of a particular item, as opposed to one bar code for each item type.

FIG. 4 is a block diagram showing an exemplary portion of memory cell array 308 in further detail. In particular, FIG. 4 shows one bit line of a two column by two row (2X2) memory cell. One of four bit cells 402a-d is enabled to drive bit line 404. Column transmission gates 406a-d and row transmission gates 408a-d control which bit cell 402a-d drives bit line 404. Column transmission gates 406a-d are controlled or enabled by column select logic 304 and row transmission gates 408a-d are controlled by row select logic 306. Preferably, each bit cell 402a-d includes a polymer-based conductor 420 that is connected by a printing process to a supply voltage or ground to produce a logic zero or a logic one. Alternatively the polymer-based conductor 420 can be connected to any voltage below the supply voltage or above ground to produce a logic zero or logic one. As shown in FIG. 4, bit cells 402a and 402b are tied to Vdd, and bit cells 402c and 402d are tied to ground.

Alternatives to the memory arrangements shown in FIG. 3 and FIG. 4 are known in the art and are adaptable to provide a bar code in accordance with the present invention. FIG. 5 shows an alternate arrangement of a memory cell 500 in accordance with the present invention. Memory cell 500 shows 8 bits of a memory data bus 504, wherein the content of each bit is determined by whether there is a transistor or switch 502 connecting the bit to the high supply voltage, Vdd, or the low supply voltage, Vss.
Alternatively the transistor switch 502 can be connected to any voltage below the supply voltage or above ground to produce the appropriate voltage to activate the switch. The transistors are preferably printed, at least in part, by a polymer printing process used to fabricate organic semiconductors. Transistors 502 are preferably printed only where necessary. For the exemplary memory cell 500, bits 7, 4 and 0 are switched to Vdd or a logic one. Bits 6, 5, 3, 2, and 1 are switched to Vss or a logic zero.

FIG. 6 is a cross-sectional view showing schematically an organic transistor 600 for use with the polymer-based circuits in accordance with the present invention. Using terms that are common to CMOS integrated circuit processing, transistor 600 includes a source 602, a gate 604, and a drain 606. Source 602, gate 604 and drain 606 are conductive regions. A molecular or polymeric channel 608 connects the source and drain contacts. Channel 608 is a semiconducting region. An organic or inorganic gate insulator 610 is shown below the source 602 and drain 606. Gate insulator 610 is an insulating region. A substrate 612, which is preferably an organic or inorganic material, provides the base for the transistor components. Direct printing is the preferred method for fabricating the organic transistors. Preferably, polymers are used for the interconnections between organic transistors.

In accordance with a preferred embodiment of the present invention, all the components of the electronic bar code 200 are on a substrate, such as substrate 612, and are made from printable materials such as, carbon nanotubes or carbon fullerenes (e.g. C60, etc.), conjugated semiconducting polymer (e.g. polythiophene, etc.), a high-density pi-bond organic oligomer (e.g., pentacene, etc.), self assembled nanoparticles (e.g., CdSe, ZnO, etc.), a ceramic filled polymer dielectric (e.g., BaTiO, etc.), and the like. The polymer-based circuits and components of the present invention are generally more flexible and lower in cost when compared to silicon-based integrated circuits. Moreover, the polymer-based components of the present invention are ideally suited for integration into or attachment onto both flexible and rigid products, such as, for example, product packages, labels, forms, identification tags made from papers, fabrics, glass, wood, plastics, rubber, and other flexible and rigid non-conductive materials. The components and interconnections are preferably printed or selectively etched to achieve the desired functionality. In particular, a memory that holds a bar code is selectively printed or etched to determine its contents.
In operation, bar code reader 102 reads electronic bar code 200. In particular, the bar code reader 102 generates an excitation signal received by at least one of the first and second antenna elements 202, 204 of the electronic bar code 200. In response to the excitation signal, power circuit 214 powers the electronic bar code components. In response to powering up, modem 208 modulates a signal on at least one of antenna elements 202, 204. Alternatively, modem 208 may demodulate a command signal from the electronic bar code reader prior to sending a response. The response data from the RFID tag may include the data stored in ROM 212.

While the invention has been described in conjunction with specific embodiments thereof, additional advantages and modifications will readily occur to those skilled in the art. The invention, in its broader aspects, is therefore not limited to the specific details, representative apparatus, and illustrative examples shown and described. Various alterations, modifications and variations will be apparent to those skilled in the art in light of the foregoing description, but embraces all such alterations, modifications and variations in accordance with the spirit and scope of the appended claims.
Claims

We claim:

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1. An electronic bar code comprising:
   a bar code circuit that stores a code that is electronically readable, wherein the code is defined by a polymer printing process; and
   an interface coupled to the bar code circuit to allow a bar code reader to access the code stored in the bar code circuit.

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2. The electronic bar code of claim 1 wherein the interface is selected from a group consisting of: a contacted interface, contactless interface, a wireless interface, and a radio frequency interface.

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3. The electronic bar code of claim 1 wherein the interface comprises a first antenna element and a second antenna element, the first antenna element being isolated from the second antenna element and wherein the first antenna element and the second antenna element are connected to the bar code circuit.

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4. The electronic bar code of claim 1 wherein the bar code circuit is energized by electrostatic coupling.

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5. The electronic bar code of claim 1 wherein the bar code circuit includes a memory that stores the code.

6. The electronic bar code of claim 5 wherein the memory comprises a bit cell, and contents of the bit cell is determined by a polymer-based conductor.

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7. The electronic bar code of claim 5 wherein the memory comprises an electrically programmable bit cell.
8. The electronic bar code of claim 5 wherein the memory comprises at least a transistor, and the transistor comprises polymers.

9. The electronic bar code of claim 5 wherein the memory comprises a polymer-based circuit that defines a content of the memory.

10. The electronic bar code of claim 9 wherein the polymer based circuit comprises at least one of: carbon nanotubes, carbon fullerenes, conjugated semiconducting polymer, a high-density pi-bond organic oligomer, self assembled nanoparticles, and ceramic filled polymer dielectric.

11. The electronic bar code of claim 1 wherein the bar code circuit is disposed on a substrate.

12. The electronic bar code of claim 1 wherein the polymer printing process is accomplished by at least one of: ink jet printing, die sublimation printing, and flexographic printing.

13. The electronic bar code of claim 1 wherein the bar code circuit comprises at least a transistor and the transistor includes conducting regions and insulating regions and at least one of the conductive regions and insulating regions comprises polymers.

14. The electronic bar code of claim 1 wherein the polymer printing process includes an etching process.

15. A method for making an electronic bar code comprising the steps of:
   providing a substrate; and
   printing on the substrate at least a portion of a bar code circuit using a polymer-based material, wherein the at least a portion of the bar code circuit determines a contents of a code that is readable by a bar code reader.

16. The method of claim 17 providing an interface, having a first antenna element and a second antenna element, for reading the code with the barcode reader; further comprising the steps of:
isolating the first antenna element from the second antenna element; and
coupling the first antenna element and the second antenna element to the bar
code circuit.

17. The method of claim 15 further comprising the step of energizing the bar code
circuit by electrostatic coupling.

18. The method of claim 15 wherein the step of printing is accomplished by at least
one of: ink jet printing, die sublimation printing, and flexographic printing.

19. The method of claim 15 further comprising the step of etching the bar code
circuit to determine the code.
FIG. 3

FIG. 4
FIG. 5

FIG. 6
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
    IPC(7) : G06K 7/10, 15/00, 17/00
    US CL.  : 125/462.01, 462.13, 462.14, 462.15, 472.01; 343/866, 867
    According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
    Minimum documentation searched (classification system followed by classification symbols)
    U.S.  :  235/462.01, 462.13, 462.14, 462.15, 472.01; 343/866, 867
    Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
    NONE
    Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
    EAST. WEST, DERWENT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<tbody>
<tr>
<td>Y</td>
<td>US 5,754,816 A (HOWARD) 19 May 1998 (19.05.1998), col. 4, lines 11-54.</td>
<td>1-19</td>
</tr>
<tr>
<td>Y</td>
<td>US 5,751,257 A (SUTHERLAND) 12 May 1998 (12.05.1998), col. 10, lines 6-42.</td>
<td>1-19</td>
</tr>
<tr>
<td>X</td>
<td>US 6,104,311 A (LASTINGER) 15 August 2000 (15.08.2000), col. 6, lines 7-54.</td>
<td>1-4, 11-13, 15-18</td>
</tr>
<tr>
<td>Y,P</td>
<td>US 6,170,748 B1 (HASH et al) 09 January 2001 (09.01.2001), col. 6, lines 34-42.</td>
<td>5, 6, 7, 9, 10</td>
</tr>
<tr>
<td>Y</td>
<td>US 4,960,984 A (GOLDENFIELD et al) 02 October 1990 (02.10.1990), col. 4, lines 48-62.</td>
<td>14, 19</td>
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</table>

☐ Further documents are listed in the continuation of Box C.  ☐ See patent family annex.

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Date of the actual completion of the international search 13 NOVEMBER 2001

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