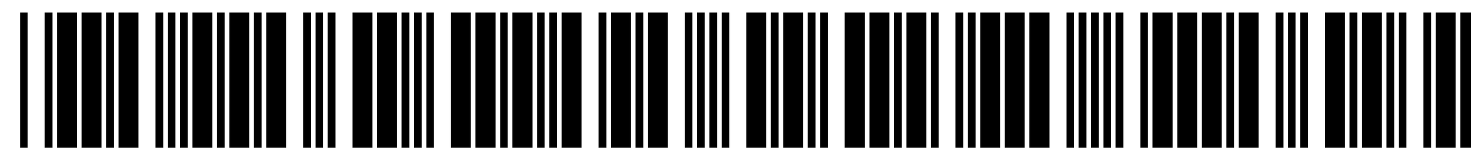

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(54) **METHODS FOR FORMING INTEGRATED CIRCUITS WITHIN SUBSTRATES**

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(22) Filed: **Dec. 10, 2003**

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See application file for complete search history.

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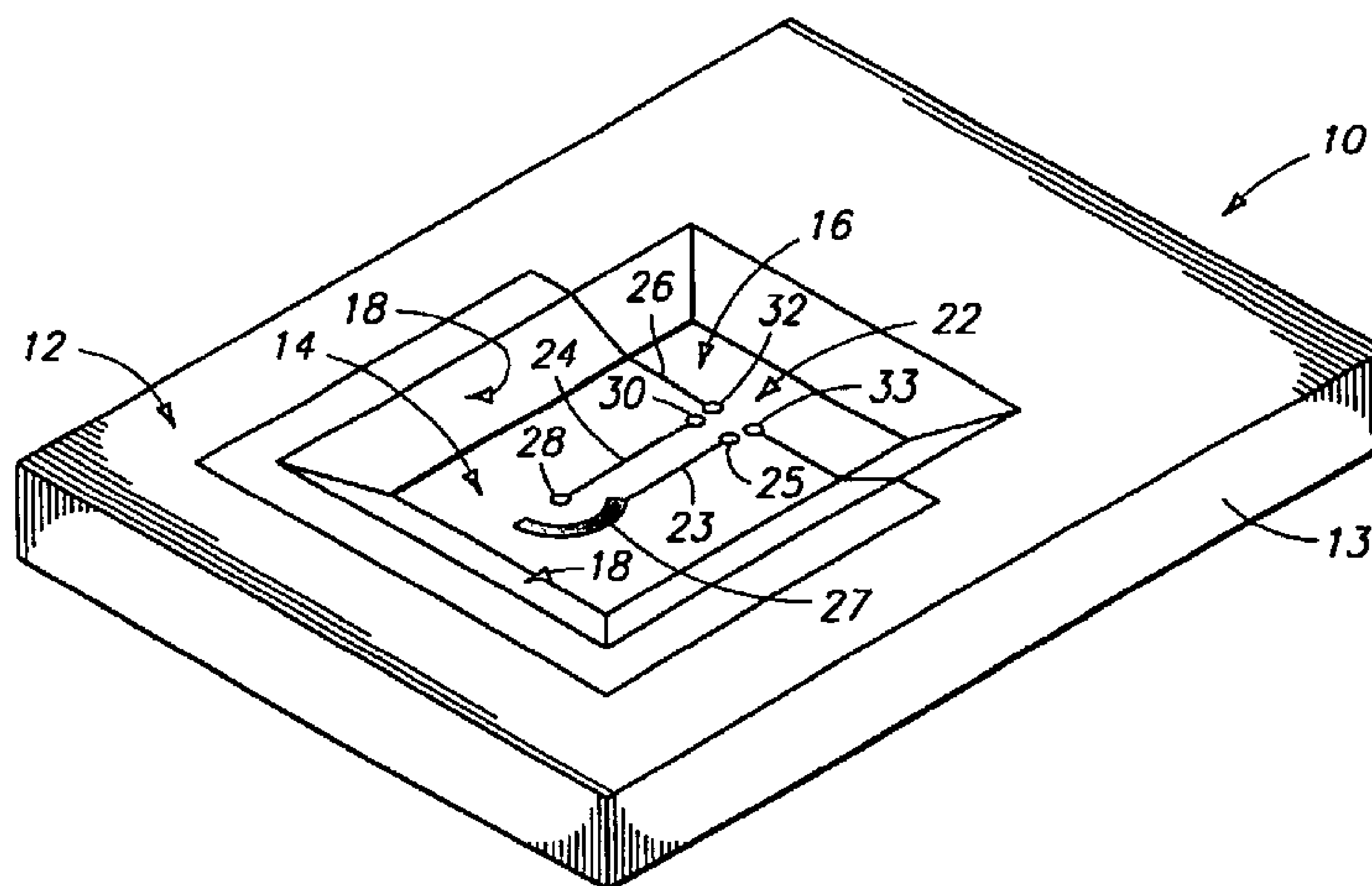
(57) **ABSTRACT**

[The invention includes methods for forming integrated circuits within substrates, and embedded circuits. In one aspect, the invention includes a method of forming an integrated circuit within a substrate comprising: a) providing a recess in a substrate; b) printing an antenna within the recess; and c) providing an integrated circuit chip and a battery in electrical connection with the antenna. In another aspect, the invention includes a method of forming an integrated circuit within a substrate comprising: a) providing a substrate having a first recess and a second recess formed therein; b) printing a conductive film between the first and second recesses and within the first and second recesses, the conductive film forming electrical interconnects between and within the first and second recesses; c) providing a first electrical component within the first recess and in electrical connection with the electrical interconnets therein; d) providing a second electrical component within the second recess and in electrical connection with the electrical interconnects therein; and e) covering the first electrical component, the second electrical component and the conductive film with at least one protective cover. In another aspect, the invention includes an embedded circuit comprising: a) a substrate having a recess therein, the recess having a bottom surface and a sidewall surface joined to the bottom surface; b) interconnect circuitry formed on the bottom and sidewall surfaces; and c) an integrated circuit chip within the recess and operatively connected to the interconnect circuitry.]

Method of forming a radio frequency identification (RFID) device. In one embodiment, a recess is provided in a plastic substrate containing an integrated circuit comprising RFID circuitry. A conductive material extends over a sidewall of the recess and is coupled to the integrated circuit in a first region and to an antenna in a second region. A flexible film may be disposed over the recess, the integrated circuit, and the conductive material.

58 Claims, 7 Drawing Sheets



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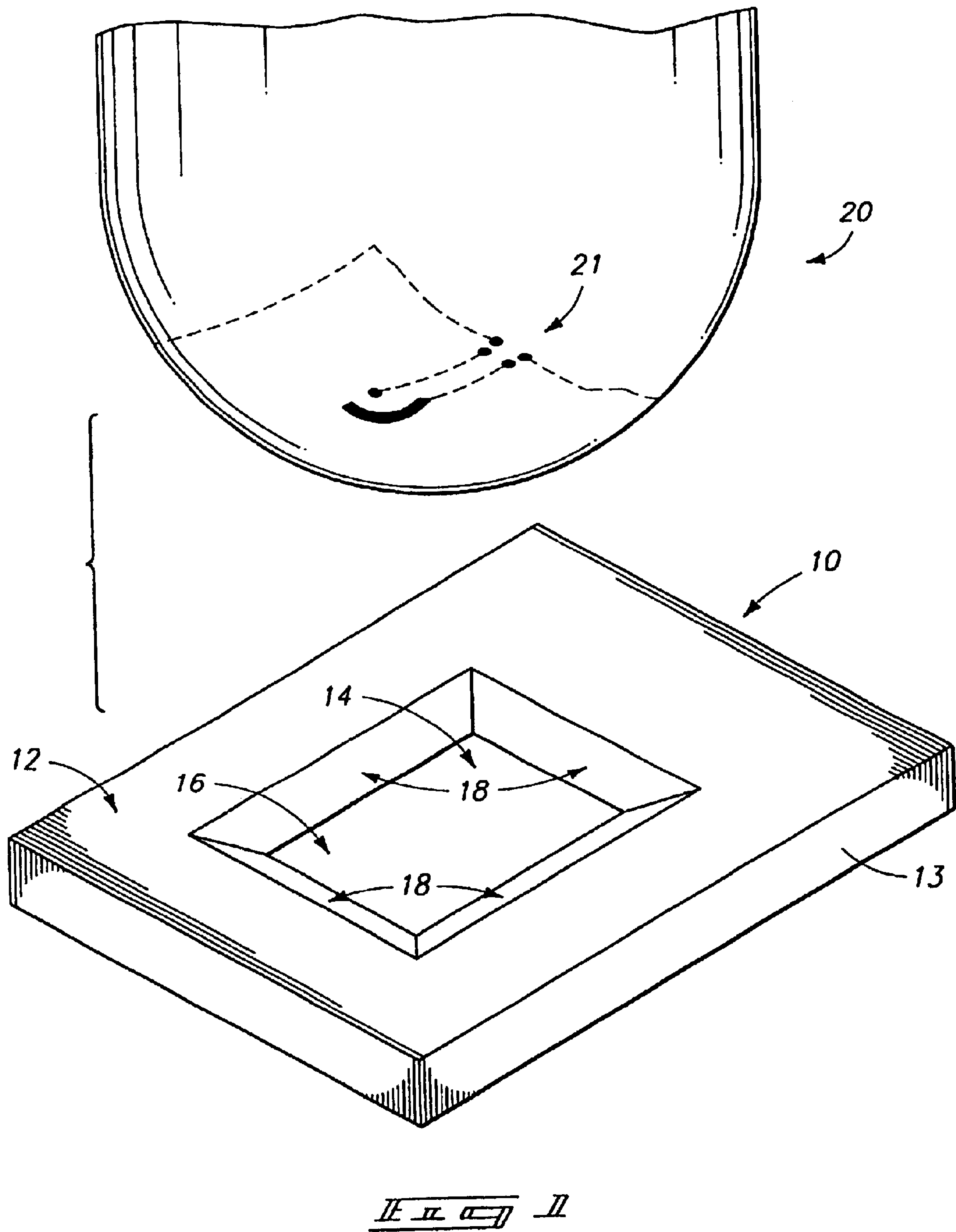


Fig. 1

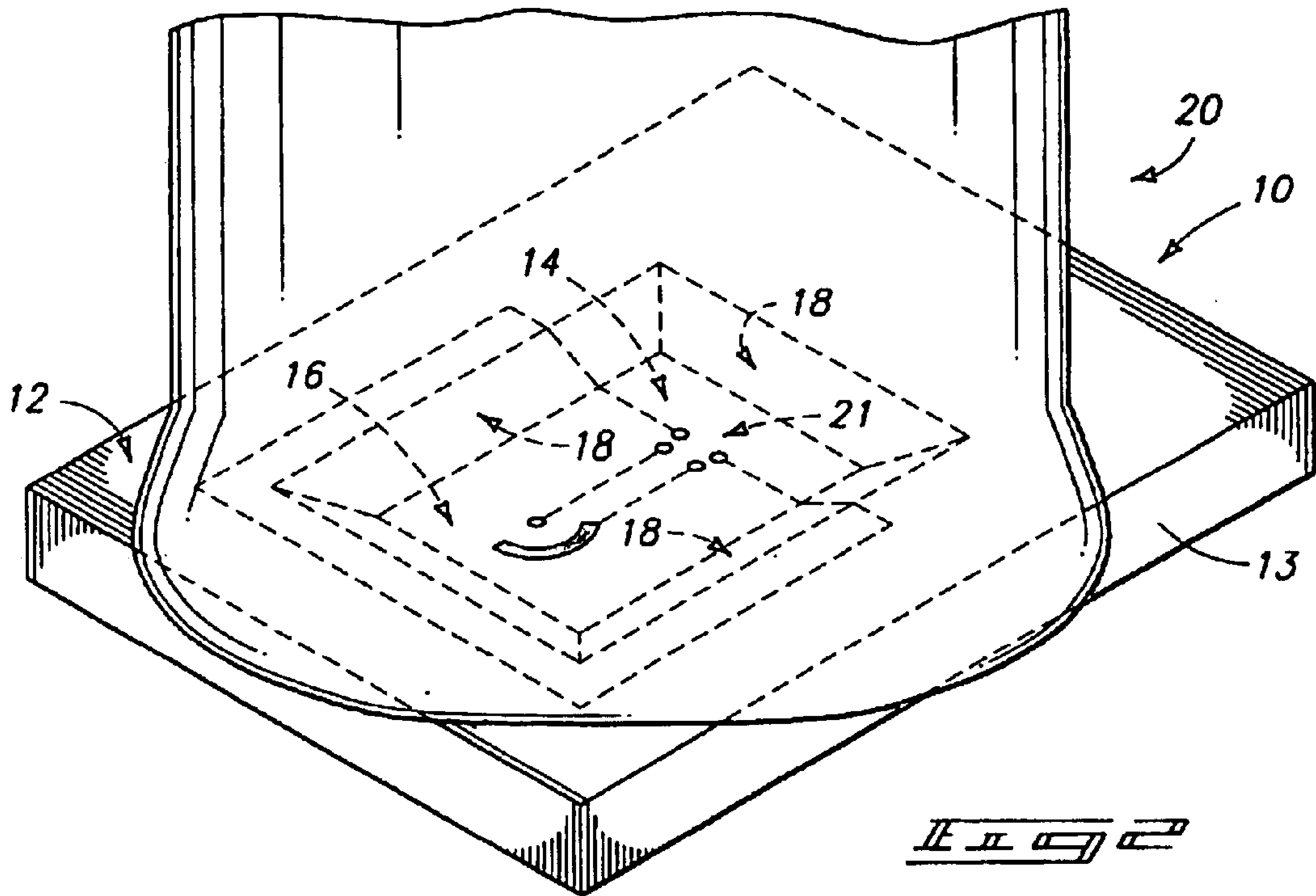


Fig 2

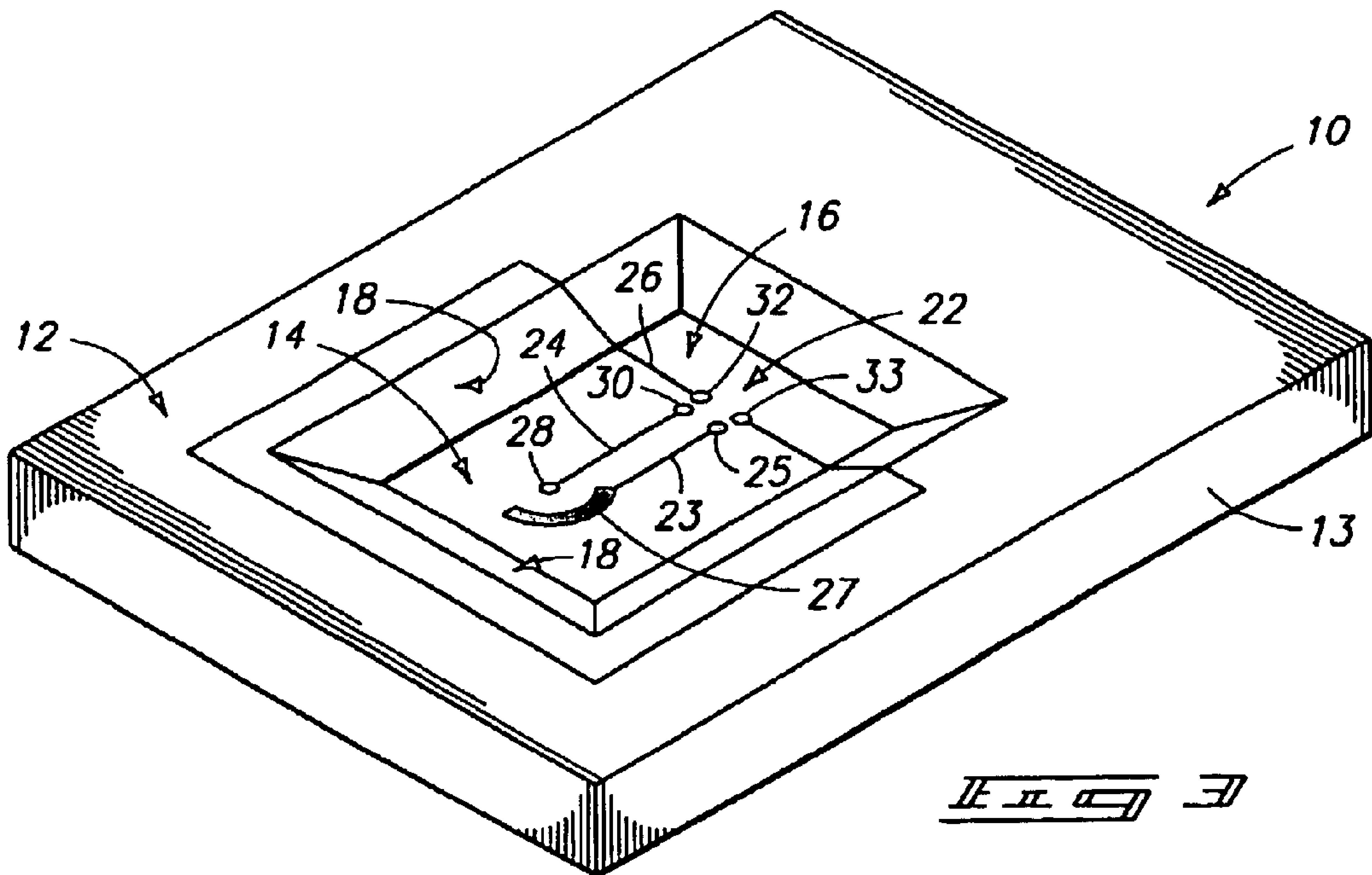


Fig 3

5 5
10 12 13 14 16 18 18 22 23 24 26 27 35 36 38

Fig 4

10 11 12 13 14 16 18 18 22 26 35 38

Fig 5

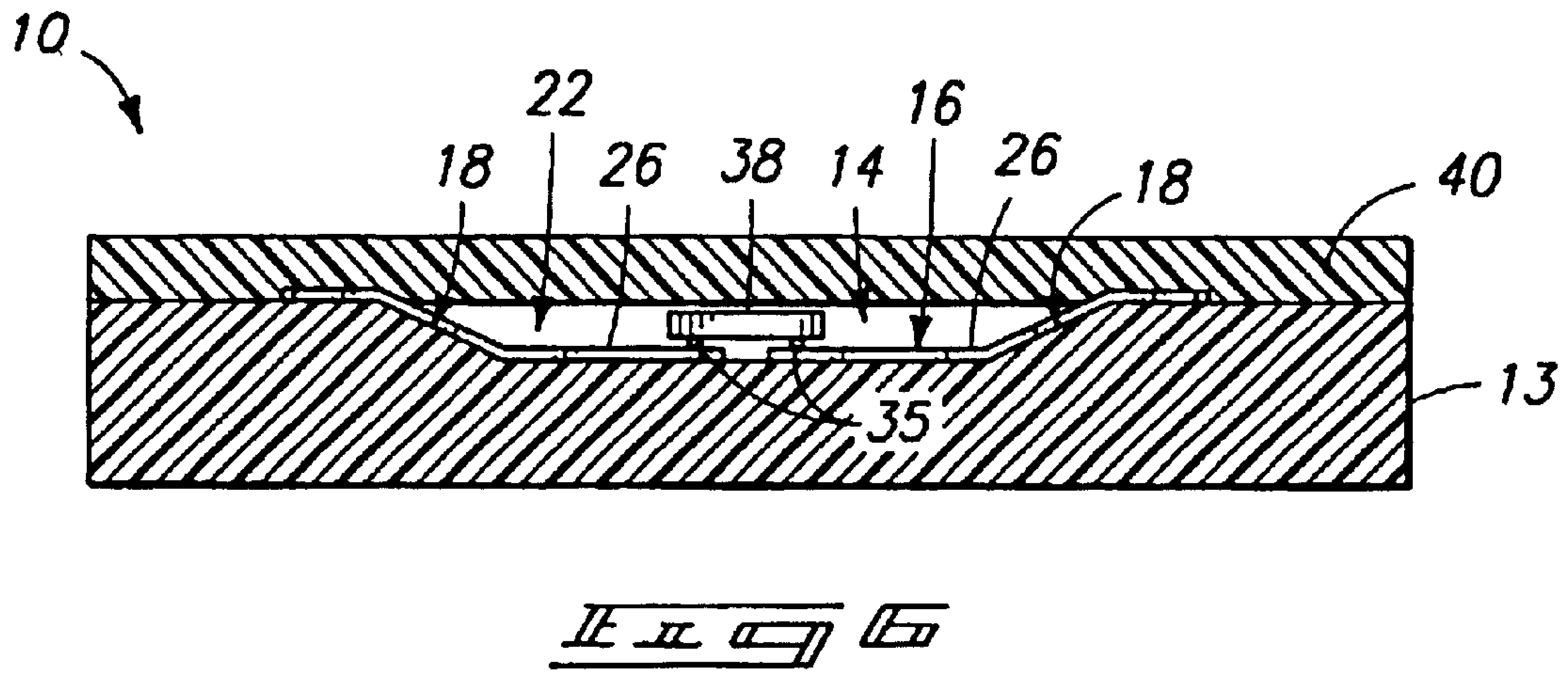


Fig 6

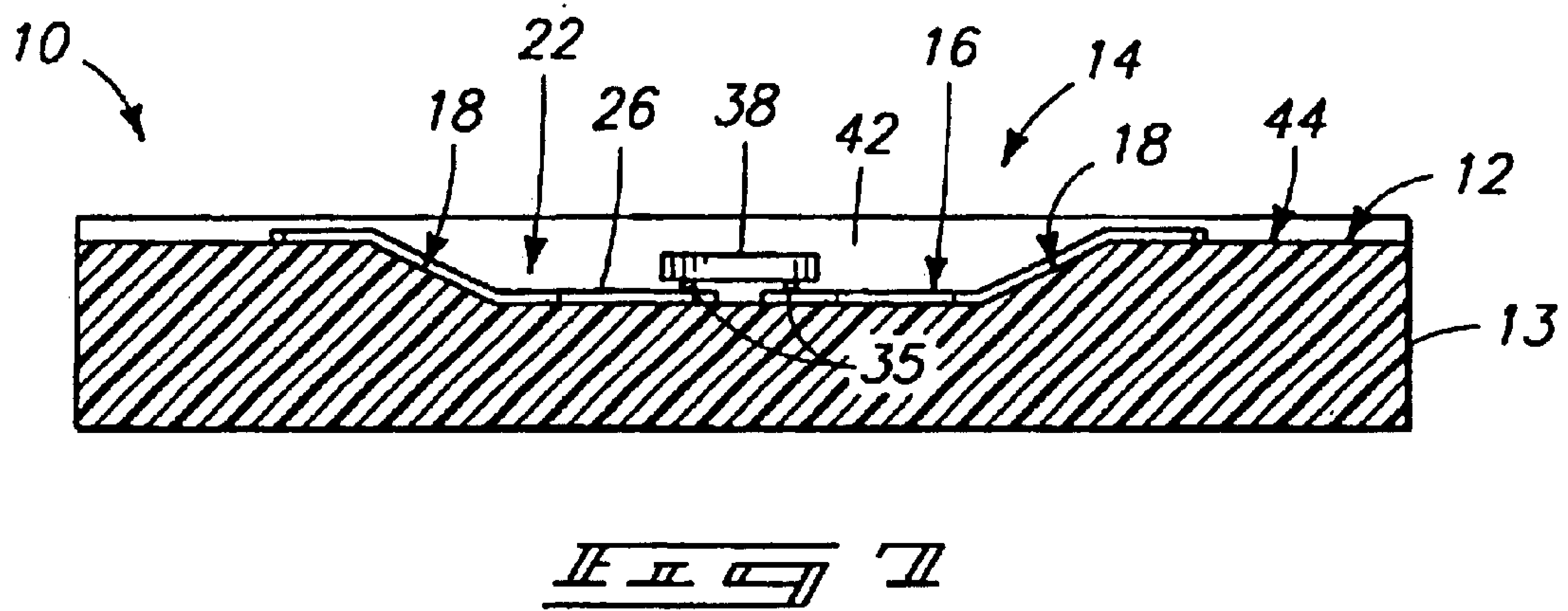
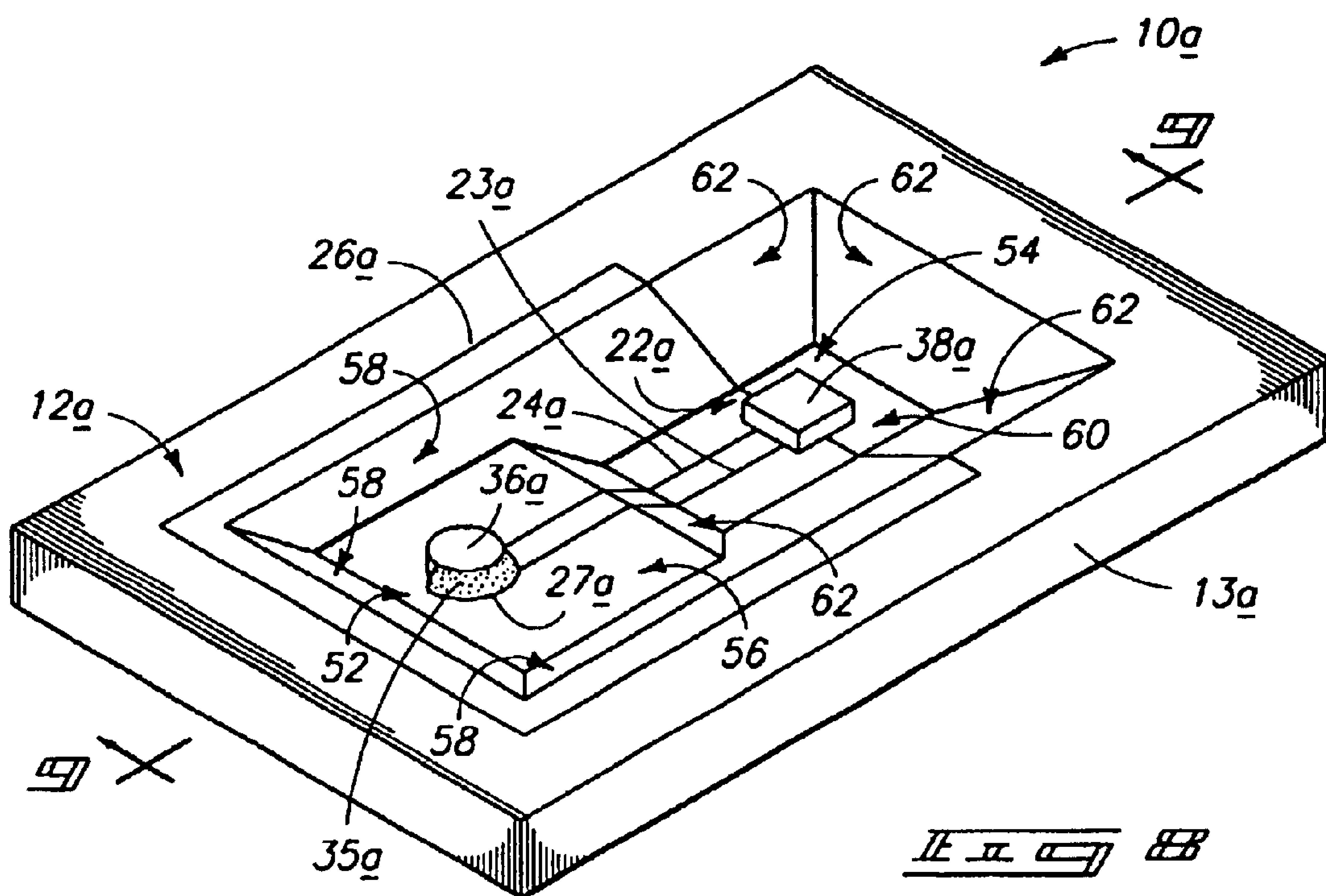


Fig 7


10a
9
62
62
23a
26a
54
62
22a
38a
58
12a
24a
60
58
36a
27a
62
13a
52
56
58
9
35a
Fig 8

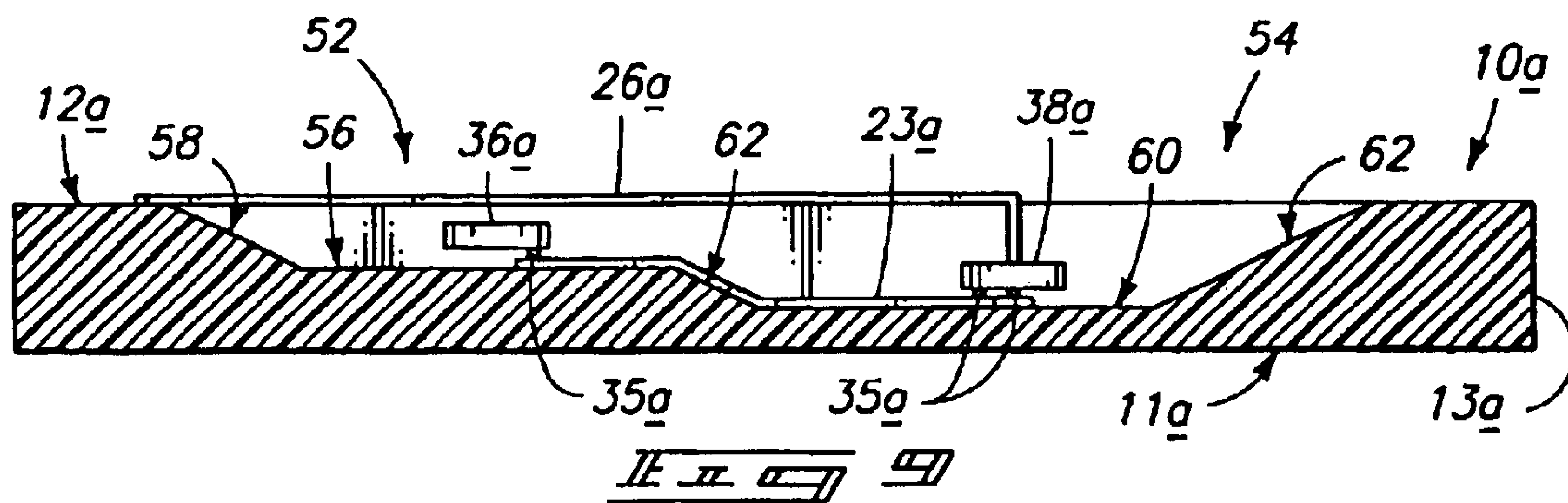

52
54
10a
26a
12a
58
56
36a
62
23a
38a
60
62
35a
35a
11a
13a
Fig 9

FIG. 10

FIG. 11

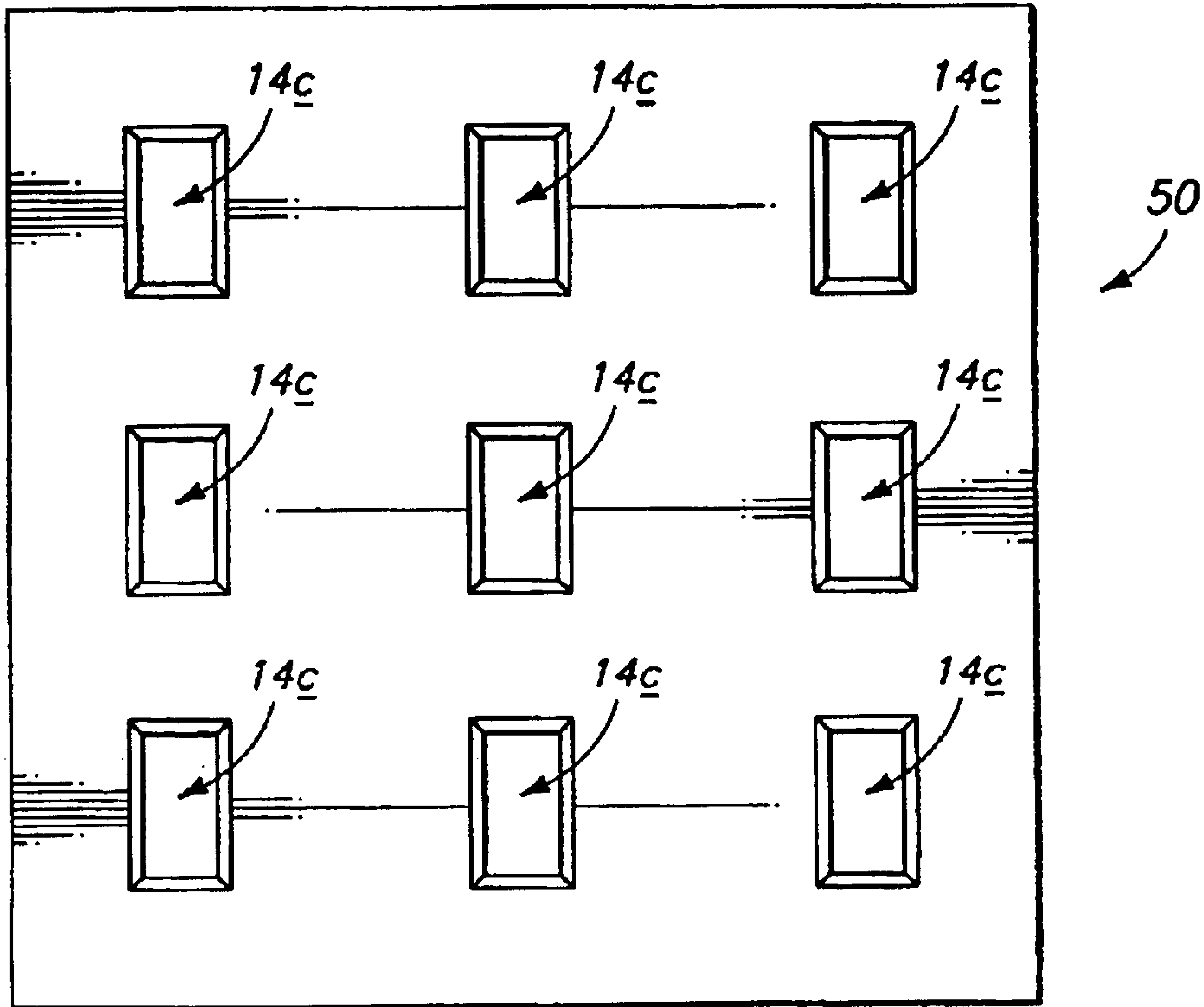


Fig 12

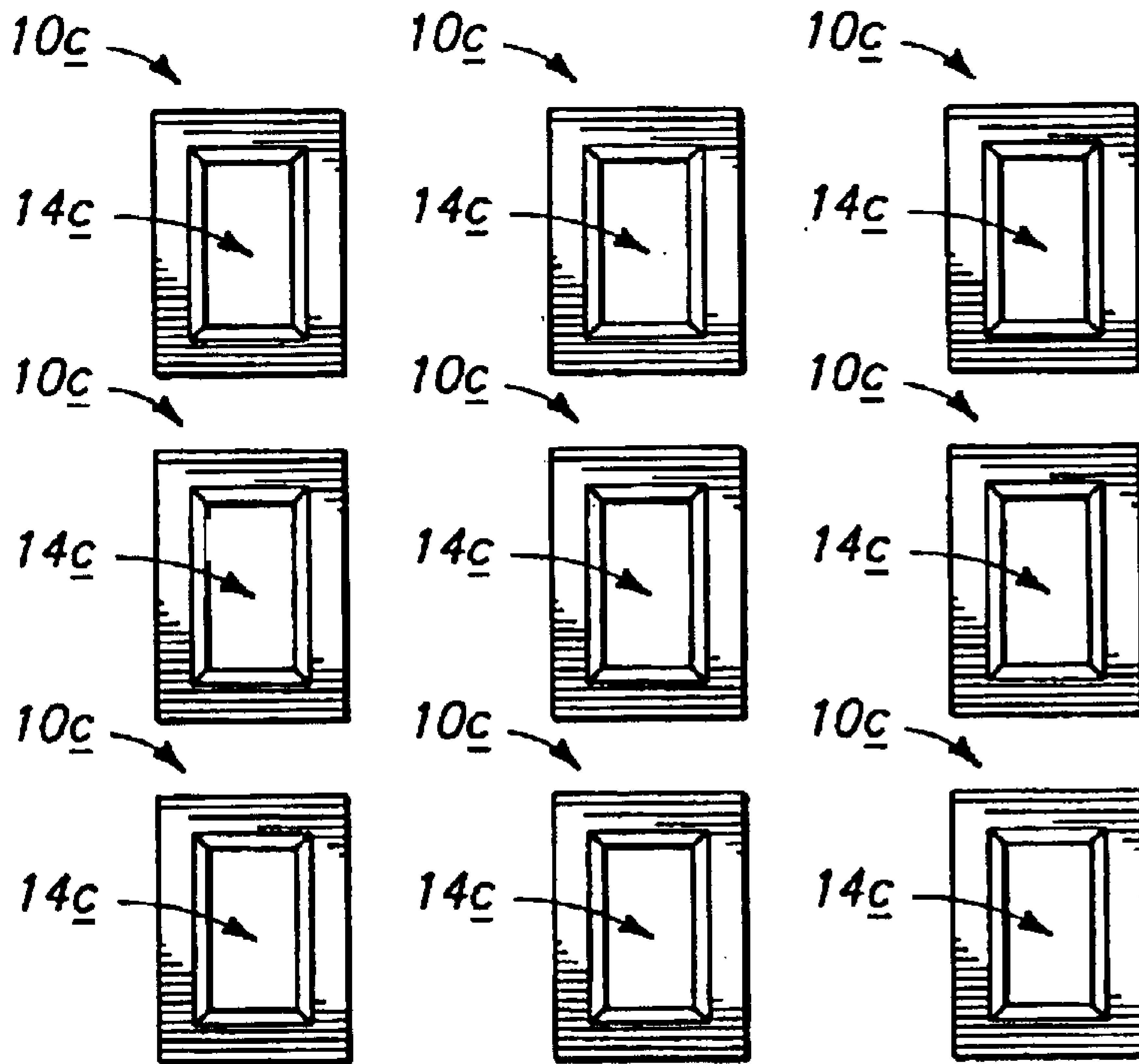


Fig 13

METHODS FOR FORMING INTEGRATED CIRCUITS WITHIN SUBSTRATES

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

More than one reissue application has been filed for the reissue of U.S. Pat. No. 6,329,213 B1. The reissue applications are application Ser. Nos. 10/734,072 (the present application), 11/302,543, and 11/496,088, all of which are continuation reissues of U.S. Pat. No. 6,329,213 B1.

TECHNICAL FIELD

The invention pertains to methods of forming integrated circuits within substrates, and to embedded circuits. The invention is thought to have particular application towards methods of forming integrated circuits within personal cards, such as personal identification cards and credit cards.

BACKGROUND OF THE INVENTION

Smart cards typically include an integrated circuit providing both memory and processing functions, have words or pictures printed on them, and control who uses information stored in the integrated circuit and how the information is used.

Some smart cards have length and width dimensions corresponding to those of credit cards. The size of such smart cards is determined by an international standard (ISO 7816). ISO 7816 also defines the physical characteristics of the plastic, including temperature tolerance and flexibility. ISO 7816 also defines the position of electrical contacts and their functions, and the protocol for communications between the integrated circuit and readers (vending machines, pay phones, etc.) The term "smart card", as used herein, is meant to include cards that include microprocessors. Such cards might not conform to ISO 7816.

Several types of plastic are used for the casings or housings of smart cards. PVC and ABS are typical. PVC can be embossed, but is not recyclable. ABS is not readily embossed, but is recyclable.

Smart cards have many different applications. For example, smart cards can be pre-paid cards used instead of money for making purchases from vending machines, gaming machines, gas stations, car washes, photocopiers, laundry machines, cinemas, fast-food restaurants, retail outlets, or anywhere where cash is used. For example, they are commonly used in Europe with public telephones. A timer is used to detect a balance from the card automatically while a conversation continues. Smart cards can be used as food stamps, or for redeeming other government-provided benefits. Because the transaction is electronic, the telephone, vending machine, etc. does not need to store cash, so risk of loss due to theft can be reduced. Change does not need to be stored and disbursed, and received payment can be directly wired to a bank. Pre-paid cards can be a form of advertising, because they can have logos or other information printed on them. The user would typically carry the card for weeks before using up the value on the card.

To authenticate a conventional credit card, a telephone call must be made to verify that sufficient funds are available. Smart cards permit such verification to be performed off-line, thus saving telecommunication charges. Smart cards thus provide an advantage over conventional credit cards. Smart cards can also be used as keys to gain access to restricted areas, such as secure areas of buildings, or to access parking lots.

Radio frequency identification devices (RFIDs) can also be considered smart cards if they include an integrated circuit. RFIDs are described in detail in U.S. patent application Ser. No. 08/705,043, filed Aug. 29, 1996, and incorporated herein by reference. RFIDs comprising integrated circuits may be referred to as intelligent RFIDs or as remote intelligent communication (RIC) devices.

Smart cards will typically contain an integrated circuit, typically provided as a packaged integrated circuit chip (IC chip). The smart card may also comprise electrical interconnects for connecting the IC chip to terminals. In other instances, the electronic interconnects will comprise an antenna, such as, for example, when the integrated circuit comprises radio frequency identification device circuitry. In other instances, an antenna, battery and IC may be inserted into smart cards. As smart cards are intended to be conveniently carried by persons, it is desirable to produce smart cards which are relatively thin, preferably having a size and shape similar to credit cards. This enables the cards to be carried on a person, such as, for example, in a persons's wallet.

SUMMARY OF THE INVENTION

The invention encompasses methods for forming integrated circuits within substrates, and embedded circuits.

In one aspect, the invention encompasses a method of forming an integrated circuit within a substrate. A recess is formed in the substrate, and an antenna is printed within the recess. An integrated circuit chip and a battery are provided in operative electrical connection with the antenna.

In another aspect, the invention encompasses a method of forming a plurality of cards. A substrate sheet is provided and a plurality of recesses are formed within the substrate sheet. The individual recesses have bottom surfaces and sidewall surfaces joined to the bottom surfaces. A conductive film is printed within the recesses to form electrical interconnects within the recesses. The electrical interconnects extend along the bottom surfaces and the sidewall surfaces of the recesses, and also on top surfaces of the substrate sheet. Integrated circuit chips are placed within the recesses and in electrical connection with the electrical interconnects. The integrated circuit chips and the conductive film within the recesses are covered with a protective cover. The substrate sheet is divided into a plurality of cards.

In another aspect, the invention encompasses an embedded circuit. The embedded circuit includes a substrate having a recess therein; a conductive circuit printed within the recess and an integrated circuit chip bonded to the conductive circuit.

In another aspect, the invention encompasses an embedded circuit. The embedded circuit includes a substrate having a recess therein; a conductive circuit provided within the recess; an integrated circuit chip bonded to the conductive circuit; and a battery in electrical connection with the integrated circuit chip.

In accordance with another embodiment, a recess is provided in a plastic substrate containing an integrated circuit comprising RFID circuitry. A conductive material extends over a sidewall of the recess and is coupled to the integrated circuit in a first region and to an antenna in a second region. A flexible film may be disposed over the recess, the integrated circuit, and the conductive material.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

FIG. **1** is a schematic perspective view of a card and a printing pad at a preliminary step of a first embodiment method of the present invention.

FIG. **2** is a schematic perspective view of the FIG. **1** card and printing pad shown at a processing step subsequent to that of FIG. **1**.

FIG. **3** is a perspective view of the FIG. **1** card shown at a processing step subsequent to that of FIG. **2**.

FIG. **4** is a perspective view of the FIG. **1** card shown at a processing step subsequent to that of FIG. **3**.

FIG. **5** is a cross-sectional view of the FIG. **4** card taken along line **5**—**5** in FIG. **4**.

FIG. **6** is a cross-sectional view of the FIG. **1** card taken along line **5**—**5** in FIG. **4**, and shown at a processing step subsequent to that of FIG. **5**.

FIG. **7** is a cross-sectional view of the FIG. **1** card taken alone line **5**—**5** in FIG. **4**, and shown at a processing step subsequent to that of FIG. **5**.

FIG. **8** is a perspective view of a card being produced according to a second embodiment method of the present invention.

FIG. **9** is a cross-sectional view of the FIG. **8** card taken along the line **9**—**9** in FIG. **8**.

FIG. **10** is a perspective view of a card being produced according to a third embodiment method of the present invention.

FIG. **11** is a cross-sectional view of the FIG. **10** card taken along the line **11**—**11** in FIG. **10**.

FIG. **12** is an elevational view of a substrate sheet processed according to a method of the present invention.

FIG. **13** is an elevational view of the sheet of FIG. **12** at a processing step shown subsequent to that of FIG. **12**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

A first embodiment method of the present invention is described with reference to FIGS. **1**–**7**. Referring to FIG. **1**, a substrate **10** is shown at a preliminary step of the first embodiment method. Substrate **10** is preferably a card substrate in the approximate shape of a credit card. Substrate **10** can comprise any of a number of materials known to persons of ordinary skill in the art, such as for example, PVC or ABS plastic. As will become apparent from the following discussion, substrate **10** might ultimately be used for a radio frequency card, smart card, or other card built with multiple, interconnected composites, including an integrated circuit. Accordingly, substrate **10** preferably comprises a configuration suitable for one or more of the above-discussed ultimate uses.

Substrate **10** comprises a substrate body **13**, a front surface **12**, and an opposing back surface **11** (shown in FIG. **5**). A recess **14** is provided through front surface **12** and into substrate **10**. Recess **14** can be formed by conventional methods. Examples include cutting with a blade, grinding wheel or laser. Another example method for forming recess **14** is to form the recess in situ at a time of card creation by injection molding the card in a shape comprising recess **14**. Recess **14** has a bottom surface **16** and sidewall surfaces **18** joined to bottom surface **16**. As most clearly shown in FIGS. **5**–**7**, sidewall surfaces **18** preferably extend non-perpendicularly from bottom surface **16**. Such non-perpendicular orientation of sidewall surfaces **18** relative to bottom surface **16** can simplify a below-discussed printing of a circuit **22** (shown in FIG. **3**) over such sidewall surfaces. It is noted, however, that the present invention also encompasses applications in which sidewall surfaces **18** extend perpendicularly from bottom surface **16**.

Still referring to FIG. **1**, a printing pad **20** is elevated above substrate **10**. Printing pad **20** preferably comprises a deformable material, such as for example, foam, sponge, or silicone rubber. A circuit pattern **21** is formed on printing pad **20**, and comprises, for example, a conductive film. Circuit pattern **21** can be formed by, for example, pressing pad **20** onto a plate having a shape corresponding to circuit pattern **21** etched within it.

Referring to FIG. **2**, printing pad **20** is pressed against substrate **10** to transfer circuit pattern **21** to substrate **10** and thereby print a circuit **22** (shown in FIG. **3**) upon substrate **10** and within recess **14**. In the shown embodiment, printing pad **20** is configured to print the circuit pattern on bottom surface **16**, on two of sidewall surfaces **18**, and on upper surf ace **12**. In alternate embodiments which are not shown, printing pad **20** can be configured to print on less than all of surfaces **16**, **18** and **20**. For instance, in such alternate embodiments, printing pad **20** may be configured to print only on bottom surface **16**, or only on bottom surface **16** and one of the sidewall surfaces **18**. Suitable materials which may be pad printed to form circuit **22** are conductive films, such as, for example, printed thick film (PTFs) comprising silver-filled organic material. It is noted that, although pad printing is shown, the printing can comprise other printing methods known to persons of ordinary skill in the art, including, for example, stencil printing, screen printing spray printing, needle dispense printing etc. After conductive circuit **22** is printed, the circuit can be cured by conventional methods.

After curing, circuit **22** will have a thickness and associated degree of conductivity. If the conductive is lower than desired as may occur if, for example, conductive material of circuit **22** is too thin, or not adequately a low resistance material, the conductivity can be enhanced by providing an electroless plated metal, such as copper or nickel, against substrate **10** and circuit **22**. The electroless plated metal selectively plates conductive circuit **22**, while not plating non-conductive surfaces of substrate **10**. The electroless plating of metal can be accomplished by conventional methods.

Referring to FIG. **3**, circuit **22** preferably comprises conductive interconnects **23** and **24**, and an antenna **26**. Interconnect **23** comprises nodes **25** and **27**, interconnect **24** comprises nodes **28** and **30**, and antenna **26** comprises nodes **32** and **33**. Nodes **25**, **27**, **28**, **30**, **32** and **33** are illustrated as being wider than the rest of interconnects **23** and **24**, and antenna **26**. However, as will be appreciated by persons of ordinary skill in the art, nodes **25**, **27**, **28**, **30**, **32** and **33** could also be a same size as the rest of interconnects **23**, **24** and antenna **26**; or narrower than the rest of interconnects **23**, **24** and antenna **26**. Note **27** preferably comprises the shown arcuate shape complementary to an outer surface of a battery **36** (shown in FIG. **4**), which is to be joined to node **27**. In the shown preferred embodiment, antenna **26** is a loop antenna comprising a predominant portion outside of recess **14** and on substrate surface **12**. In other embodiments (not shown), antenna **26** could be entirely within recess **14**, or comprise a predominate portion within recess **14**.

In the preferred embodiment, antenna **26** constitutes a part of, and is formed at the same time as, the other integrated

circuitry. It is noted that antenna **26** could be formed in two steps, with a portion of antenna **26** being formed before or after pad printing of circuit **22**. For instance, the portion of antenna **26** extending along upper surface **12** could be formed prior to printing circuit **22**. Then, a portion of antenna **26** could be printed as part of circuit **22** to create nodes **32** and **33**, and to connect the previously formed portion of antenna **26** with nodes **32** and **33**. In such circumstances, the portion of antenna **26** which is not formed as part of circuit **22** could be formed by methods other than those utilized to form circuit **22**. For instance, if circuit **22** is pad printed, the portion of antenna **26** not formed as part of circuit **22** could be formed by a method other than pad printing. Such other methods will be recognized by persons of ordinary skill in the art.

Referring to FIG. **4**, electrical components **36** and **38** are bonded to one or more of nodes **25**, **27**, **28**, **30**, **32** and **33** (shown in FIG. **3**). By way of example only, electrical component **36** comprises a battery and component **38** comprises a monolithic integrated circuit formed on a chip. Components **36** and **38** may be bonded to nodes **25**, **27**, **28**, **30**, **32** and **33** (shown in FIG. **3**), utilizing a conductive adhesive **35** which is cured after provision of components **36** and **38**. An example conductive adhesive **35** is a conductive epoxy. Battery **36** could alternatively be provided directly bonded to integrated circuit chip **38**. In such circumstances, the bonding of battery **36** to integrated circuit **38** can occur either before or after placing integrated circuit **38** and battery **36** within recess **14**. Also, as will be recognized by persons of ordinary skill in the art, at least one of the electrical components **36** or **38** could be provided externally of recess **14**.

In the illustrated embodiment, interconnects **23** and **24** connect battery **36** to integrated circuit **38**, and antenna **26** connects with integrated circuit **38**. Battery **36**, interconnects **23** and **24**, integrated circuit **38** and antenna **26** together form a radio frequency identification device (RFID).

After provision of circuit **22** and one or both of components **36** and **38** within recess **14**, a protective cover is ideally formed over circuit **22** and recess **14**. FIGS. **6** and **7** illustrate two methods of protectively covering circuit **22** and the components within recess **14**. Referring first to FIG. **6**, a cap **40** can be adhered over substrate **10** and over recess **14**. Cap **40** may be adhered, for example, by adhesive, such as glue, or by mechanical fasteners, such as staples or screws. Example materials for cap **40** include plastic metal, and flexible or rigid adhesive tape. In the shown embodiment, portions of loop antenna **26** are between cap **40** and substrate body **13**. Such portions of loop antenna **26** are generally thin enough that they do not interfere with bonding of cap **40** to substrate body **13**. To further minimize interference of such portions of loops antenna **26** with bonding of cap **40** to substrate body **13**, cap **40** can be formed of a material which conforms over and around loop antenna **26**, such as, for example, a deformable material. Also, in embodiments which are not shown, antenna **26** can be formed entirely within recess **14** to minimize interference of antenna **26** with bonding of cap **40** to substrate body **13**.

Referring to FIG. **7**, circuitry **22** and components **36** and **38** can be covered with an encapsulant **42**. Such encapsulant may comprise, for example, a low temperature curing insulating material, such as, for example, a two-part epoxy or urethane. Encapsulant **42** will preferably be provided initially as a liquid material and to overfill recess **14** and overlay antenna **26**. Encapsulant **42** can then be cured into a solid mass, and either milled or sanded to form the shown preferred substantially planar upper surface **44**.

It is noted that the methods of FIGS. **6** and **7** are merely example methods for covering circuitry proximate and within recess **14**. The invention encompasses other methods for covering such circuitry which will be recognized by persons of ordinary skill in the art. The methods of FIGS. **6** and **7** could also be combined. For instance, a recess could be partially filled with an encapsulant and then covered. Such combined methods may have particular application toward sealing cards containing multiple recesses which are discussed below. In such cases, an integrated circuit could be within one recess and a battery within another. The integrated circuit could be covered with encapsulant and/or a cap, and the battery covered only with a removable cap. In such applications the integrated circuit would be well-protected and the battery could be easily replaceable.

After provision of a protective cover over recess **14**, the construction of a card is substantially finished. The card may then be covered with a laminating film for cosmetic, printability, or logo reasons. An example laminating film would be a thin (less than about one mil) PVC sheet bonded to substrate **10** with an adhesive.

A second embodiment method of the present invention is described with reference to FIGS. **8** and **9**. In describing FIGS. **8** and **9**, numbering similar to that utilized above in describing FIGS. **1**–**7** will be used, with differences indicated by the suffix “a” or by different numerals.

Referring to FIGS. **8** and **9**, a substrate **10**a is illustrated. Substrate **10**a comprises a first recess **52** and a second recess **54**. In the illustrated and preferred embodiments, first recess **52** is formed in the substrate and second recess **54** is formed within first recess **52** and essentially constitutes a part thereof. A conductive circuit **22**a is formed within recesses **52** and **54** and comprises interconnects **23**a and **24**, and antenna **26**a. Antenna **26**a is a loop antenna which extends beyond recesses **52** and **54**. Interconnects **23**a and **24**a connect electrical components **36**a and **38**a. Interconnects **23**a and **24**a, and antenna **26**a, are preferably formed by printing a conductive film within first and second recesses **52** and **54**, utilizing procedures analogous to those discussed above with reference to FIGS. **1**–**3**.

In the illustrated embodiment, components **36**a and **38**a are each within a recess, with component **36**a being within first recess **52** and component **38**a being within second recess **54**. First recess **52** comprises a bottom surface **56** and sidewall surfaces **58**. Second recess **54** comprises a bottom surface **60** and sidewall surfaces **62**. Sidewall surfaces **58** and **62** can extend non-perpendicularly form bottom surfaces **56** and **60**, respectively, to simply printing of circuit **22**a over such sidewall surfaces. First recess **52** is separated from second recess **54** by one of the sidewall surfaces **62**. The separating sidewall **62** extends non-perpendicularly from both of bottom surface **56** and bottom surface **60**. Interconnects **23**a and **24**a extend over the separating sidewall surface **62** and along bottom surfaces **60** and **56**. Interconnects **23**a and **24**a thus extend continuously from electrical component **36**a to electrical component **38**a.

Substrate **10**a comprises a front surface **12**a and an opposing back surface **11**a. Preferably, first recess **52** and second recess **54** both extend through the same of either front surface **12**a or back surface **11**a. In FIGS. **8** and **9**, recesses **52** and **54** are illustrated as both extending through front surface **12**a.

Subsequent processing of substrate **10**a can be performed in accordance with the processing of either FIG. **6** or FIG. **7** to cover first and second electrical components **36**a and **38**a, and electrical circuit **22**a, with at least one protective cover.

A third embodiment method of the present invention is described with reference to FIGS. **10** and **11**. In describing FIGS. **10** and **11**, numbering similar to that utilized above in describing FIGS. **1**–**7** will be used, with differences indicated by the suffix "b" or by different numerals.

A substrate **10**b comprises a substrate body **13**b, a front surface **12**b, and an opposing back surface **11**b. A recess **14**b is provided through front surface **12**b and into substrate **10**b. Electrical components **36**b and **38**b are within recess **14**b and connected by interconnects **23**b and **24**b. A loop antenna **26**b is electrically connected with component **38**b. Loop antenna **26**b extends from component **38**b, out of recess **14**b, and along surface **12**b of substrate **10**b. Antenna **26**b crosses over itself at a bypass **70**. Antenna **26**b comprises a first portion **66** and a second portion **68** at bypass **70**, with second portion **68** crossing over first portion **66**. Bypass **70** comprises an insulative material **72** separating first portion **66** from second portion **68**. Insulative material **72** can comprise, for example, silicon dioxide.

Methods for forming antenna **26**b will be recognized by persons of ordinary skill in the art. Such methods could include, for example, printing methods similar to those discussed above in discussing FIGS. **1**–**3**, with the exception that two printing steps would be utilized in forming antenna **26**b. More particularly, a first printing step would be utilized to form the portion of antenna **26**b underlying insulative material **72**, and a second printing step would be utilized to form the portion of antenna **26**b overlying material **72**. Insulative material **72** would be formed between the two printing steps. Insulative material **72** can be formed by conventional methods.

Although the embodiment of FIGS. **10** and **11** is illustrated with only two loops and only one bypass **70**, persons of ordinary skill in the art will recognize that alternate embodiments could be formed comprising more than two loops and a plurality of bypasses **70**. The utilization of one or more bypasses **70** can advantageously permit relatively long loop antennas to be formed on a card substrate.

It is noted that although antenna second portion **68** is illustrated as being substantially perpendicular to antenna first portion **66** at bypass **70**, the invention encompasses other embodiments (not shown) in which an antenna second portion is non-perpendicular to an antenna first portion at a bypass of the antenna portions.

The processing described above with reference to FIGS. **1**–**11** forms embedded circuits within substrates. Such embedded circuits can comprise, for example, circuitry **22**, **22**a or **22**b, and one or more of components **36**,**36**a,**36**b,**38**, **38**a and **38**b.

Although FIGS. **1**–**11** illustrate formation of a single card, the invention encompasses methods in which a plurality of cards are formed. Such plurality of cards may be formed by forming a number of recesses within a single sheet, and then dividing the sheet into singulated cards. The division into singulated cards may occur before or after any of the steps illustrated in FIGS. **1**–**11**. For example, the division into singulated cards may occur after printing of conductive circuitry (shown in FIG. **2**), and prior to provision of components **36** and **38** within a recess. The division of a large sheet into singulated sheets can be performed by a number of methods known to persons of ordinary skill in the art, including, for example, sawing or cutting mechanically or by a laser.

The formation of a number of individual cards from a single sheet substrate is illustrated in FIGS. **12** and **13**. In referring to FIGS. **12** and **13**, similar numbering to that utilized above in describing FIGS. **1**–**7** is utilized, with differences being indicated by the suffix "c" or with different numerals. Referring to FIG. **12**, a sheet substrate **50** comprises a plurality of recesses **14**c. Referring to FIG. **13**, the sheet substrate **50** (shown in FIG. **12**) is divided into a number of singular card substrates **10**c. The individual card substrates **10**c comprise at least one recess **14**c. It is noted that the invention encompasses methods in which not all of the individual substrates **10**c comprise equal numbers of recesses **14**c, and encompasses embodiments in which some of the individual substrates comprise no recess **14**c. However, generally at least two of the formed substrates **10**c will comprise at least one recess **14**c.

In compliance with the statue, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.

What is claimed is:

1. A method of forming a radio frequency communication device comprising:

providing a recess within a substrate;

providing at least a portion of an antenna within the recess;

providing an integrated circuit at least partially within the recess and in operative electrical connection with the antenna; and

wherein the antenna is a loop antenna which crosses itself at a bypass, said bypass comprising dielectric material between crossing portions of the loop antenna.

2. A method of forming an integrated circuit within a substrate comprising:

providing a recess in a substrate;

providing substantially an entirety of an antenna within the recess; and

providing an integrated circuit chip and a battery supported by the substrate and in operative electrical connection with the antenna.

3. A method of forming an integrated circuit within a substrate comprising:

providing a recess in a substrate;

providing at least a portion of an antenna within the recess;

providing an integrated circuit chip and a battery supported by the substrate and in operative electrical connection with the antenna; and

wherein the antenna is provided within the recess and on a portion of the substrate outside of the recess.

4. The method of claim **3** wherein the antenna comprises a predominate portion within the recess.

5. The method of claim **3** wherein the antenna comprises a predominate portion outside of the recess.

6. A method of forming an integrated circuit within a substrate comprising:

providing a recess in a substrate;

providing at least a portion of an antenna within the recess;

providing an integrated circuit chip and a battery supported by the substrate and in operative electrical connection with the antenna; and

wherein the antenna is a loop antenna which crosses itself at a bypass, said bypass comprising dielectric material between crossing portions of the loop antenna.

7. The method of claim **3** wherein at least one of the battery and the integrated circuit chip are provided at least partially within the recess.

8. The method of claim **3** wherein the battery is bonded to the substrate within the recess.

9. The method of claim **3** wherein the step of providing the antenna comprises printing a conductive film.

10. The method of claim **3** wherein the step of providing the antenna comprises pad printing a conductive film.

11. A method of forming an integrated circuit within a substrate comprising:

providing a recess in a substrate;

providing at least a portion of a loop antenna within the recess, the loop antenna comprising a bypass where portions of the antenna cross one another, the bypass comprising a dielectric material between the crossing portions of the antenna; and

providing an integrated circuit chip in operative electrical connection with the antenna.

12. The method of claim **11** wherein the portions of the antenna which cross one another are substantially perpendicular to one another.

13. A method of forming an integrated circuit within a substrate comprising:

providing a recess in a substrate;

pad printing a conductive material within the recess to form at least a portion of a conductive circuit within the recess and to form at least a portion of an antenna within the recess;

placing an integrated circuit chip within the recess and bonding the integrated circuit chip to the conductive circuit and the antenna; and

placing a battery within the recess and in electrical connection with the integrated circuit chip.

14. The method of claim **13** wherein the substrate is a card configured for carrying on a person.

15. The method of claim **13** further comprising, after the printing, providing an electroless metal within the recess to selectively plate the conductive circuit.

16. The method of claim **13** further comprising, after bonding the chip to the conductive circuit, filling the recess with a liquid encapsulation material and curing the encapsulation material into a solid mass.

17. The method of claim **13** further comprising, after bonding the chip to the conductive circuit, covering the recess with a protective cover.

18. A method of forming an integrated circuit within a substrate comprising:

providing a substrate having a recess formed therein, said recess having a bottom surface and a sidewall surface joined to the bottom surface;

pad printing a conductive film within the recess to form electrical interconnects within the recess and to form at least a portion of an antenna, the electrical interconnects extending along the bottom surface and the sidewall surface of the recess;

placing an integrated circuit chip within the recess and in electrical connection with the electrical interconnects;

covering the integrated circuit and the conductive film within the recess with a protective cover; and

wherein the integrated circuit comprises radio frequency identification device circuitry, and further comprising placing a battery within the recess and in electrical connection with the radio frequency identification device circuitry through the electrical interconnects.

19. A method of forming a device comprising:

providing a recess within a substrate;

providing at least a portion of an antenna within the recess;

providing an integrated circuit at least partially within the recess and in operative electrical connection with the antenna;

wherein the antenna crosses itself at a bypass, said bypass comprising dielectric material between crossing portions of the antenna; and

wherein the antenna includes a connection between the integrated circuit and a first antenna portion, the first antenna portion extending from at least partially within the recess to outside the recess, a second connection between the integrated circuit and a second antenna portion, the second antenna portion extending from at least partially within the recess to outside the recess, and a third antenna portion outside of the recess and coupled to the first and second antenna portions.

20. A method comprising:

forming a recess in a plastic substrate, the recess having an approximately planar bottom surface and four sidewall surfaces that slope outward from the bottom surface toward an upper surface of the substrate; and subsequently performing the steps of:

providing a monolithic integrated circuit chip within the recess, the chip comprising RFID circuitry coupled to first and second antenna ports to provide memory and processing functions, the first and second antenna ports configured to be electrically coupled together via an antenna and, subsequent to the forming of the recess:

providing a first conductive layer coupled to the first antenna port of the chip and extending over at least a portion of a first of the sidewall surfaces; and

providing a second conductive layer coupled to the second antenna port of the chip and extending over at least a portion of a second of the sidewall surfaces.

21. The method of claim 20, wherein providing the first and second conductive layers comprises printing.

22. The method of claim 20, further comprising forming a conductive adhesive between the first conductive layer and the first antenna port and forming a conductive adhesive between the second conductive layer and the second antenna port.

23. The method of claim 20, further comprising:

providing at least a portion of an antenna over the upper surface of the substrate and coupling the antenna to the first and second conductive layers; and

providing a flexible plastic film over the recess, the chip, and the antenna, the flexible plastic film being bonded to the portion of the antenna.

24. The method of claim 20, further comprising:

providing at least a portion of an antenna formed using a first process over the upper surface of the substrate;

coupling the antenna to the first and second conductive layers, the first and second conductive layers having been formed using a second process; and

providing a flexible plastic film over the recess, the chip, and the antenna.

25. A method comprising:

providing a plastic substrate comprising a plurality of recesses, each of the recesses having a bottom surface

and four sidewall surfaces that extend non-perpendicularly from the bottom surface toward an upper surface of the substrate; and subsequently performing the steps of:

disposing a plurality of integrated circuits within the plurality of recesses such that each of the recesses contains an integrated circuit, each of the integrated circuits comprising RFID circuitry coupled to first and second antenna ports to provide memory and processing functions, the first and second antenna ports configured to be electrically coupled together via an antenna; and

providing a plurality of continuous conductive films, each of the continuous conductive films having a first portion and a second portion, the first portion being coupled to respective ones of the integrated circuits disposed within the recesses and the second portions extending above the upper surface of the substrate.

26. The method of claim 25, wherein the substrate comprises a plurality of rows of recesses and a plurality of columns of recesses.

27. The method of claim 25, further comprising covering the plurality of integrated circuits and the plurality of continuous conductive films with an insulting material initially provided as a liquid material that is subsequently cured into a non-liquid material, and wherein each of the continuous conductive films is disposed over at least one respective sidewall surface between the first and second portions.

28. The method of claim 25, wherein the continuous conductive films comprise printed films.

29. The method of claim 25, wherein the first portion of each of the continuous conductive films is coupled to respective ones of the integrated circuits using a conductive adhesive.

30. A method comprising:

forming a recess in a plastic substrate, the recess having a bottom surface and four sidewall surfaces that extend non-perpendicularly from the bottom surface toward an upper surface of the substrate; and subsequently performing the steps of:

providing an antenna portion disposed outside of the recess;

disposing an integrated circuit within the recess, the integrated circuit comprising RFID circuitry coupled to first and second antenna ports to provide memory and processing functions;

disposing a conductive material layer over at least one of the four sidewall surfaces to couple the integrated circuit to the antenna portion outside the recess, wherein the antenna portion is configured to electrically couple the first antenna port to the second antenna port; and

providing a flexible film over the recess, the integrated circuit, and the conductive material layer.

31. The method of claim 30, wherein depositing the conductive material layer comprises printing a film.

32. The method of claim 30, further comprising coupling the integrated circuit to the conductive material layer using a conductive adhesive.

33. The method of claim 32, wherein the conductive material layer is disposed over the bottom surface at a first end and over the upper surface at a second end.

34. The method of claim 33, further comprising covering the conductive material layer with an insulating material and bonding the flexible film directly on at least a portion of the insulating material.

35. The method of claim 34, wherein the antenna comprises a material layer that is different from the conductive material layer.

36. The method of claim 30, further comprising covering the conductive material layer with an insulating material and bonding the flexible film over the insulating material.

37. The method of claim 36, wherein covering the conductive material layer with the insulating material comprises forming the insulting material directly on the conductive material layer and over the upper surface of the substrate.

38. The method of claim 37, wherein covering the conductive material layer with the insulating material includes depositing a liquid material and curing the liquid material to form the insulting material.

39. The method of claim 38, wherein depositing the conductive material layer comprises printing a film.

40. The method of claim 39, wherein the film is less than about one mil in thickness.

41. A method comprising:

providing a plastic substrate comprising a recess, the recess having a bottom surface and sidewall surfaces that extend non-perpendicularly from the bottom surface toward an upper surface of the substrate, each of the sidewall surfaces sloping outward from the bottom surface toward the upper surface;

providing an antenna, at least a portion of which is a first conductive film disposed above the upper surface;

providing an integrated circuit within the recess, the integrated circuit comprising RFID circuitry coupled to first and second antenna ports to provide memory and processing functions;

providing a second conductive film, separate from the first conductive film, having a first region coupled to the integrated circuit and a second region coupled to the portion of the antenna; and

disposing a flexible film above the recess, the antenna, the integrated circuit, and the second conductive film, and electrically coupling the first and second antenna ports together via the antenna.

42. The method of claim 41, wherein the second conductive film comprises a printed film.

43. The method of claim 41, wherein the first region of the second conductive film is disposed above the bottom surface.

44. The method of claim 41, wherein the second conductive film is disposed above at least one of the sidewall surfaces between the first and second regions.

45. The method of claim 41, further comprising bonding a conductive adhesive to the integrated circuit and to the first region of the first conductive film.

46. The method of claim 41, further comprising covering the second conductive film with an insulating material and disposing the flexible film over the insulating material.

47. The method of claim 41, wherein at least one of the sidewall surfaces slopes in at least a generally linear manner from the bottom surface.

48. The method of claim 47, further comprising covering the second conductive film with an insulating material and disposing the flexible film over the insulating material.

49. A method comprising:

providing a plastic substrate comprising a plurality of recesses, each of the recesses having a bottom surface and four sidewall surfaces that extend non-perpendicularly from the bottom surface toward an upper surface of the substrate; and subsequently performing the steps of:

disposing a plurality of integrated circuits within the plurality of recesses such that each of the recesses contains no more than a single respective integrated circuit, each respective integrated circuit comprising respective RFID circuitry to provide memory and processing functions, the respective RFID circuitry coupled to respective first and second antenna ports configured to be coupled together via a respective antenna; and

forming a plurality of continuous conductive films, each of the continuous conductive films having a first portion and a second portion, the first portion being coupled to respective ones of the integrated circuits disposed within the recesses and the second portion extending above the upper surface of the substrate.

50. The method of claim 49, wherein the substrate comprises a plurality of rows of recesses and a plurality of columns of recesses, and further comprising dividing the substrate into a plurality of singular substrates after forming the plurality of conductive films, each of the singular substrates comprising a single recess.

51. The method of claim 50, wherein each of the continuous conductive films is disposed above at least one respective sidewall surface between the first and second portions, and each of the singular substrates comprises two continuous conductive films.

52. The method of claim 51, wherein forming the plurality of continuous conductive films comprises printing a conductive material.

53. The method or claim 52, wherein the first portion of each of the continuous conductive films is coupled to respective ones of the integrated circuits using a conductive adhesive.

54. A method comprising:

providing a substrate comprising a recess, the recess having a bottom surface and four sidewall surfaces that extend non-perpendicularly from the bottom surface toward an upper surface of the substrate, each of the sidewall surfaces sloping outward from the bottom surface toward the upper surface;

providing an antenna, at least a portion of which is a first conductive material disposed above the upper surface;

providing an integrated circuit within the recess, the integrated circuit comprising RFID circuitry to provide memory and processing functions and coupled to first and second antenna ports of the integrated circuit;

providing a second conductive material, separated from the first conductive material, having a first region coupled to the integrated circuit and disposed above the bottom surface, having a second region coupled to the portion of the antenna and disposed above the upper surface, and having a third region between the first and second regions and disposed above one of the sidewall surfaces; and

disposing a flexible film over the recess, the integrated circuit, the antenna, and the second conductive material, wherein the first and second antenna ports are electrically coupled together via the antenna.

55. The method of claim 54, further comprising bonding a conductive adhesive to the integrated circuit and to the first region of the second conductive material.

56. The method of claim 55, wherein providing the second conductive material comprises printing the second conductive material.

57. The method of claim 56, further comprising the second conductive material with an insulating material and disposing the flexible film over the insulating material.

58. The method of claim 57 wherein at least one of the sidewall surfaces slopes in at least a generally linear manner from the bottom surface.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : RE 40,137 E
APPLICATION NO. : 10/734072
DATED : March 4, 2008
INVENTOR(S) : Mark E. Tuttle et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In column 11, line 17, in Claim 25, delete "portions" and insert -- portion --, therefor.

In column 11, line 24, in Claim 27, delete "insulting" and insert -- insulating --, therefor.

In column 12, line 9, in Claim 37, delete "insulting" and insert -- insulating --, therefor.

In column 12, line 15, in Claim 38, delete "insulting" and insert -- insulating --, therefor.

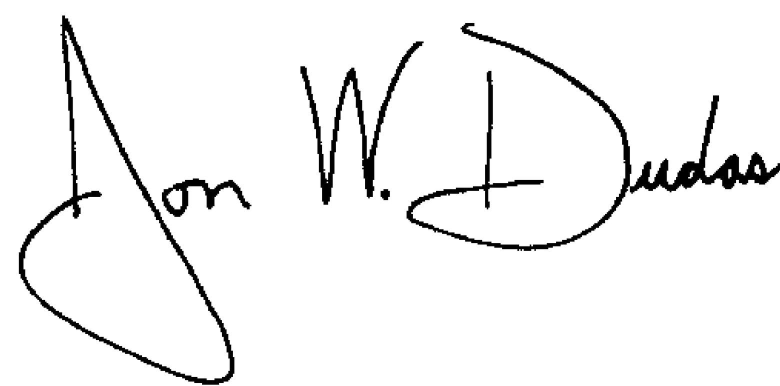
In column 13, line 30, in Claim 53, after "method" delete "or" and insert -- of --, therefor.

In column 14, line 11, in Claim 54, delete "separated" and insert -- separate --, therefor.

In column 14, line 29, in Claim 57, after "comprising" insert -- covering --.

Signed and Sealed this

Eighth Day of July, 2008



JON W. DUDAS
Director of the United States Patent and Trademark Office