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Arnold et al.

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(54) **LASER-BASED TECHNIQUE FOR PRODUCING AND EMBEDDING ELECTROCHEMICAL CELLS AND ELECTRONIC COMPONENTS DIRECTLY INTO CIRCUIT BOARD MATERIALS**

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H01R 43/00 (2006.01)

(52) **U.S. Cl.** **29/832**; 29/825; 29/829

(58) **Field of Classification Search** 174/257, 174/261, 52.2; 29/832, 829, 825
See application file for complete search history.

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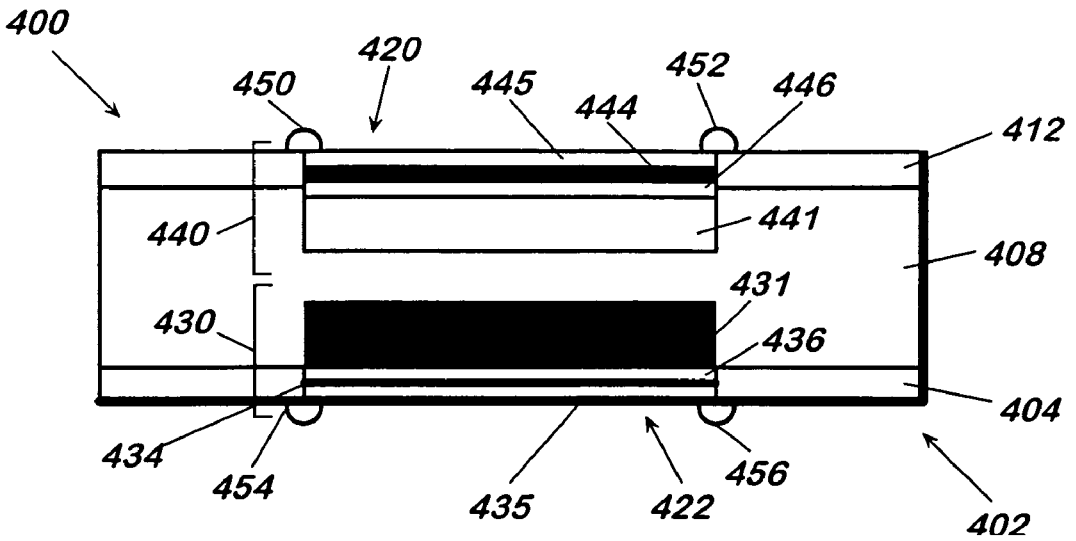
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(57) **ABSTRACT**

A method is provided for embedding electronic components including electrochemical cells within a circuit board substrate. The method includes micromachining the printed circuit board substrate to a selective depth to form a recess. A component is inserted into the recess and an electrical connection is established between the electrical component and a metallized pattern of the circuit board substrate using, e.g., laser direct-write.

24 Claims, 3 Drawing Sheets



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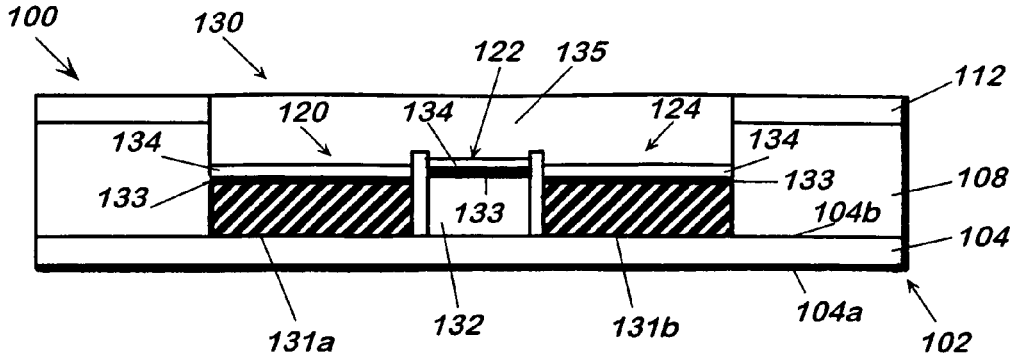


FIG. 1

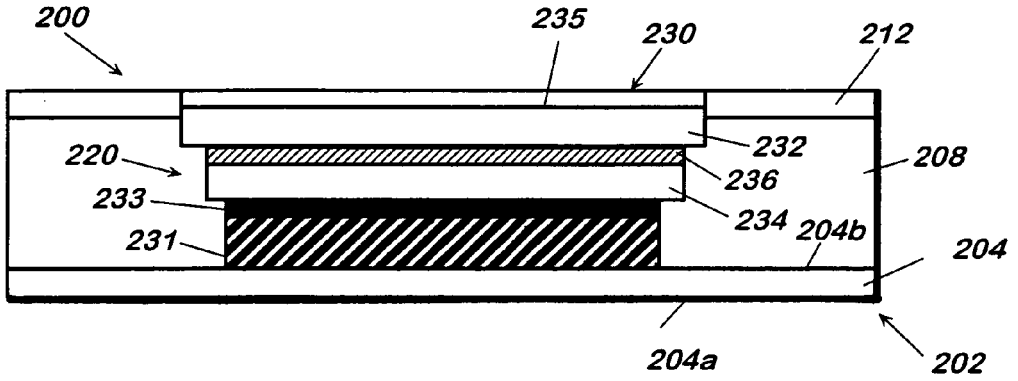


FIG.2

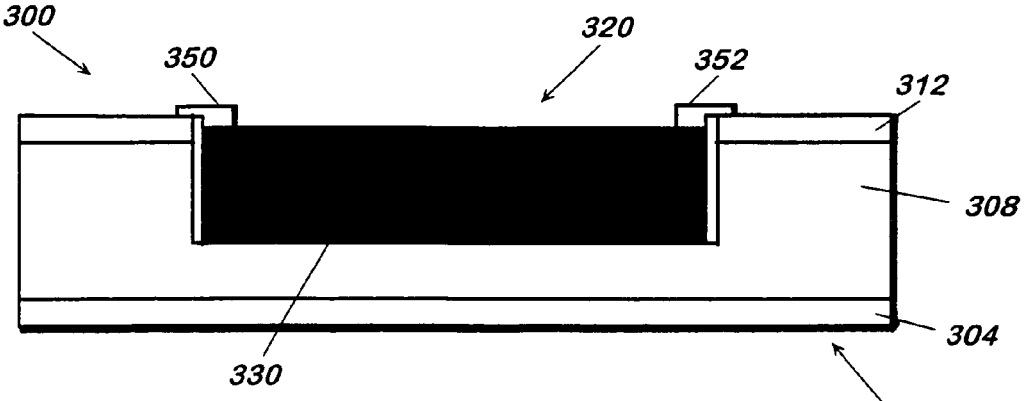


FIG. 3

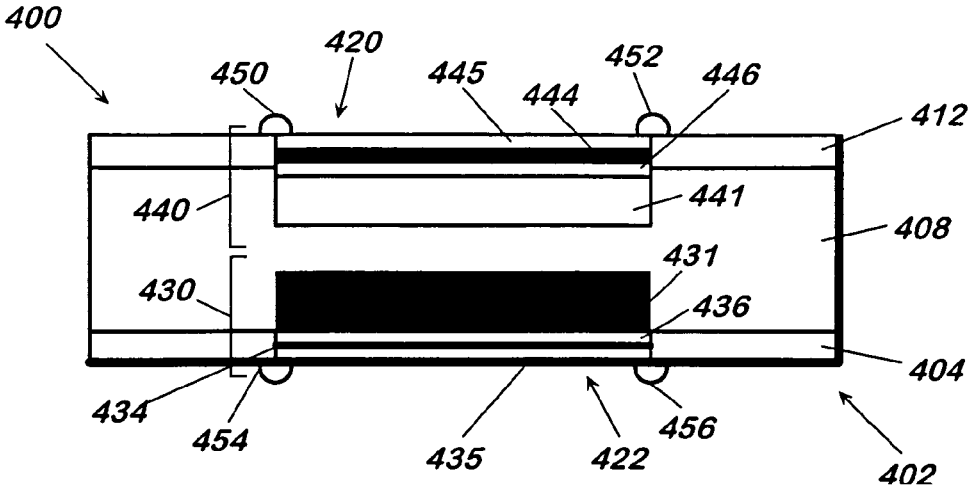

400
420
450
445
452
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412
440
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408
431
430
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434
454
435
422
456
402

FIG. 4

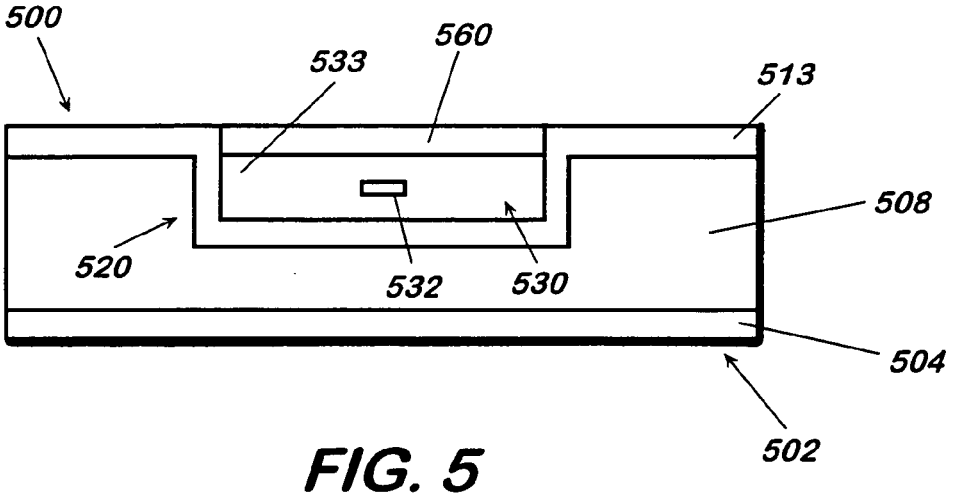

500
560
533
513
508
520
532
530
504
502

FIG. 5

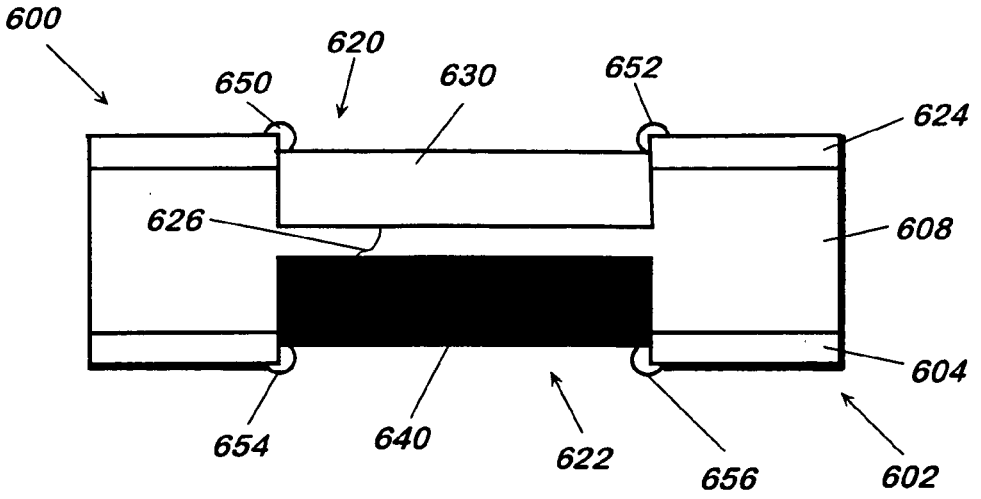

600
620
650
630
652
624
626
608
604
654
640
622
656
602

FIG. 6

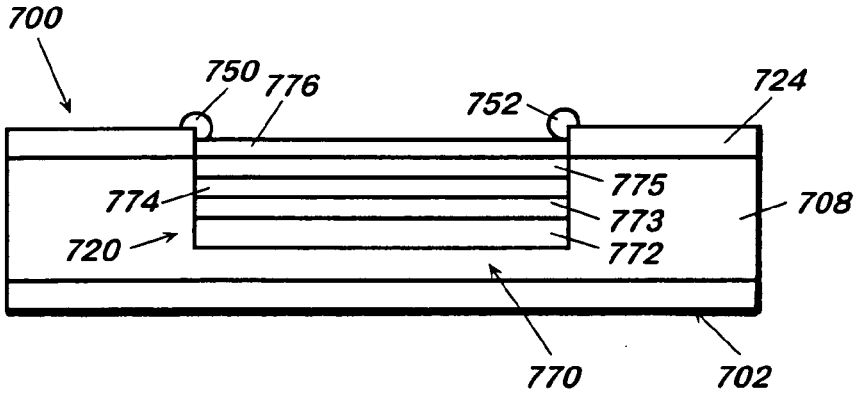

700
750
776
752
724
774
775
773
772
708
720
770
702

FIG. 7

LASER-BASED TECHNIQUE FOR PRODUCING AND EMBEDDING ELECTROCHEMICAL CELLS AND ELECTRONIC COMPONENTS DIRECTLY INTO CIRCUIT BOARD MATERIALS

This application claims priority from Provisional Application No. 60/478,471, filed Jun. 11, 2003. Provisional Application No. 60/478,471 is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to electronic devices and components and methods for fabricating electronic devices and components, and in particular, to embedded electronic devices and components and methods for fabricating electronic devices and components by embedding an electrical component in a recess formed in a circuit board substrate.

BACKGROUND OF THE INVENTION

The size and weight of small, unobtrusive devices is dominated by the size and weight of the internal circuit boards, the electrical components which are mounted on the surface of circuit boards, and by the energy storage devices such as batteries that supply the power to the various electronic components. The surface area of the internal circuit board is considered very valuable as there is only a finite amount of space for adding components. Of course, as components are added to the internal circuit board, the height and mass of the device increases.

In order to address the dimensional limitations of electronic devices, previous techniques, such as the use of thin film printing techniques as well as techniques for embedding electronic components in to a circuit board, have been developed to reduce the thickness of electronic components. However, previous techniques for embedding components have relied primarily on the addition of material around the discrete electronic components, thereby effectively building a laminated circuit board from the bottom up.

These prior art approaches are inherently limited as they require special development and optimization for each individual circuit design, involve a significant cost increase to circuit board manufactures and reduce the ability to add additional components to an existing circuit board or modify the circuit design.

SUMMARY OF THE INVENTION

The present invention relates to a method for embedding electronic components including electrochemical cells into a circuit board. The method can be adapted to use a standard commercially available circuit board which is then micromachined, in one embodiment using a laser, for example, to form a recess to a controlled depth. The recess provides a location within the thickness of the circuit board for a thin, electronic component. After micromachining, the electric component or components such as, for example, a surface mount capacitor or resistor, are placed in the machined region of the circuit board. Electrical contacts to the component are made using a non-contact, low-temperature, direct-write technique that connects the surface mount component disposed in the machined region to metallized patterns on the circuit board. One important feature of the invention is that the method can be carried out using a single machine, in contrast to prior art methods wherein additional processing steps/machines are required.

In accordance with one aspect form of the present invention, a method is provided for fabricating an electronic device. The method includes providing a substrate having a metallized or conductive pattern on a top surface and micromachining the substrate from the top surface to a selected depth so as to form a first recess in the substrate. At least one electronic component is inserted into the first recess, and electrical connections are established between at least one electrical component and the metallized pattern on the substrate using laser directed writing (or any other method) of conductive material. It will be understood that while in the foregoing description the substrate is described as having a metallized pattern thereon, any conductive pattern can be used and the conductive pattern can, in general, be added at any time.

In accordance with another aspect form of the present invention, a method is provided for fabricating an electronic device which includes providing a substrate having a metallized or conductive pattern on a top surface. The substrate is micromachined from the top surface to a selected depth so as to form a recess in the substrate, and conductive material is deposited into the recess to form a first conductive line. A dielectric material is added into the recess on top of the conductive line and a second conductive line is written on the dielectric material using laser (or other means of) directed writing of conductive material. In one embodiment, this method is used for the fabrication of embedded waveguides for the transmission of RF signals and also for other RF structures.

According to yet another aspect of the invention, there is provided an embedded electronic device which comprises a substrate having a metallized pattern on a top surface. A micromachined first recess is formed in the substrate and at least one electronic component is disposed in the first recess. An electrical connection connects at least one electronic component and the metallized pattern together.

One important feature of the invention is that it allows the embedding of dissimilar components such as passive and active electronic components as well as electrochemical cells using a common approach or method.

Further features and advantages of the present invention will be set forth in, or apparent from, the detailed description of preferred embodiments thereof which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-section schematic view of an embedded electronic component in the form of an electrochemical cell in accordance with one embodiment of the present invention;

FIG. **2** is a cross-section schematic view of another electrochemical cell in accordance with a further embodiment of the present invention;

FIG. **3** is a cross-section schematic view of an embedded surface mount electronic component in accordance with another embodiment of the present invention;

FIG. **4** is a cross-section schematic view of a stacked electronic component in accordance with yet another embodiment of the present invention;

FIG. **5** is a cross-section schematic view of an embedded coaxial waveguide electronic component;

FIG. **6** is a cross-section schematic view of a stacked two-component embedded electronic component device; and

FIG. **7** is a cross-section schematic view of an embedded multilayered electronic component in accordance with a further embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will now be described in relation to the preferred embodiments thereof as depicted in the several figures wherein similar components have the same reference number increased by one hundred so as to correspond with the figure number.

Referring now to FIG. **1**, device **100** includes an electrochemical cell formed in a circuit board substrate **102**. Substrate **102** can, for example, be any suitable circuit board, including but not limited to, metals, semiconductors, insulators, ceramics, and multilayered structures which include previously embedded structures. Advantageously, the substrate **102** may be chemically resistant and have low processing temperatures such as is characteristic of many plastics or commonly available circuit board materials. The shape of the substrate **102** although depicted as planar, may be of any arbitrary three-dimensional shape, including planar, spherical or complex curved.

Substrate **102** includes a bottom metallic layer **104** having an exterior surface **104***a* and interior surface **104***b*, an intermediate insulating layer **108** and a top surface layer **112** which includes a metallized pattern. The metallized pattern includes but is not limited to passive and active electronic circuits or opto-electronic circuits.

The top surface **112** is micromachined to form multiple adjacent recesses **120**, **122**, and **124**. A micromachining system suitable for forming the recesses **120**, **122**, and **124** includes an apparatus which can remove top surface **112** and insulating material which composes intermediate layer **108**. Advantageously, this can be done by using a dual-laser system in which one high peak-power (pulsed) laser removes the metallic material and a second pulsed or cw laser, operating at a different wavelength, removes the insulating material either solely or with the aid of the first laser. The laser beams from the two lasers co-propagate along or nearly along the same optical axis towards the sample. A second laser operating in pulsed mode and at a wavelength with a higher absorption in the insulating material than the first laser can have enough fluence to completely ablate and remove this material. Alternatively, the second laser can operate in cw mode (and also at a different wavelength than the first laser) to convert part or all of the insulating material into a liquid and/or vapor phase before the other high peak-power laser beam arrives to completely remove the material.

One advantage of using the dual-laser system is that the time and spatial offset between the laser pulses coming from each laser is variable in duration and in order. Therefore, the amount and duration of thermal and ablative processes acting on the sample can be controlled. Advantageously, in one preferred dual-laser system, the temperature of the machined substrate **102** is monitored by a temperature sensor whose output is fed back to control theinteraction time, and power of the dual-laser system. This feedback is used to prevent catastrophic damage to the substrate during the machining processes.

It will be understood that although the dual laser system has advantages in certain applications (e.g., when used with particular substrate materials), a single laser is, in general, sufficient for the purposes of the invention.

In an alternative method of machining substrate **102** to form the recesses **120**, **122**, and **124** and depositing material, rather than using laser micromachining, any available machining process known in the art for manufacturing circuit boards may be employed, including but not limited to, mechanical machining or milling, etching, and laser machining combined with an additive direct-write process which includes ink-jet, micro-pen and laser direct-write.

After the recesses **120**, **122**, and **124** are formed, individual electronic components are inserted into the recesses **120**, **122**, and **124** to form an electrochemical cell **130**. First, electrically conductive materials are deposited in the recesses **120**, **122**, and **124** to form an electrochemical cathode **131***a*, **131***b* and anode **132**. Electrochemically active material **133** is deposited on cathode **131***a*, **131***b* and anode **132**, and an electrolyte material **134** is deposited on top of the electrochemically active material **133**. The electrolytic material **134** can be either a solid or an aqueous material. Finally, an encapsulating potting material **135** is deposited over the electrolytic material **134**.

It will be understood that in a workable implementation the metallized layer **104** would not short circuit the anode region **132** and cathode regions **131***a*, **131***b* as appears to be shown in FIG. **1**. In practice, the metallized layer **104** is machined or patterned such that the anode **132** and cathode **131***a*, **131***b* are electrically isolated. Thus, in FIG. **1**, material (not shown) would be removed from layer **104** below the separating walls between anode **132** and cathode **131***a*, **131***b*.

It will also be appreciated that the order of formation described above (cathode, then separator and then anode) can be reversed so that the anode is formed first, then the substrate and finally the cathode. Alternatively, the entire final sample can be "dipped" in a liquid (e.g., a thermosetting or thermoplastic liquid or the like) which would completely seal and cover up the embedded components upon drying.

Referring now to FIG. **2**, an alternative electrochemical cell is fabricated using the present method in which electronic device **200** comprises a circuit board **202** in which recess **220** is micromachined from top surface **212** through intermediate insulating layer **208** to an interior surface **204***b* of a bottom metallic layer **204** which also has an exterior surface **204***a*. In forming recess **220**, the circuit board **202** is micromachined using a dual wavelength laser which incorporates ultraviolet laser light and infrared laser light to remove substrate materials of the intermediate insulating layer **208** and top layer **212** in a method similar to the one used in accordance with the embodiment depicted in FIG. **1**.

An electronic component in the form of electrochemical cell **230** is inserted into the recess **220** by depositing a single multilayer film which comprises layers of a current collector **231**, an electrochemically active material **233**, an electrolyte **234**, a second electrochemically active material **236**, a second current collector **232** and an encapsulating material **235**. The first current collector **231** layer forms a cathode and the second current collecting layer **232** forms the anode of the embedded electrochemical cell **230**.

It is pointed out that the drawing in FIG. **2** can be simplified. Because the circuit board is metallized, element **231** can be viewed as the electrochemically active materials, elements **233**, **234** and **236** lumped together as the electrolyte/separator, **232** as the other electrochemical material and **235** as the current collector. In this case the current collector acts as the encapsulating material.

Examples of some electrochemical cells which can be embedded using the present method include hydrous ruthenium oxide supercapacitors, lithium-ion batteries and other alkaline cells.

Referring now to FIG. **3**, the present method may be used to form the electronic device **300** which includes an embedded surface mount component **330**. The electronic component **300** is formed in substrate **302** which includes bottom layer **304**, intermediate insulating layer **308** and top surface **312** having a metallized pattern. Recess **320** is formed by micromachining using the technique described above with regard to the embodiments of FIGS. **1** and **2**. The surface mount component **330** is embedded or inserted into recess **320** as a complete electronic or opto-electronic component. Subsequently, connection tabs **350** and **352** are deposited on the electronic device **300** by laser direct-write deposition of metal or conductive ink, although other methods can also be used. The connection tabs **350**, **352** provide an electrical connection between the surface mount component **320** and the metallized pattern present on the top surface **312**.

The surface mount component **330** may be any known electronic or opto-electronic component known to one of ordinary skill in the art which can be embedded into the recess of a circuit board machined as described herein. Such components include but are not limited to a capacitor, resistor, inductor, active device such as LEDs, diodes, transistors and other semiconductor devices, microdevices such as MEMS or MOEMS, or IC dies and other RF components.

Referring now to FIG. **4**, the present method is used to form an electronic device **400** which includes a stacked structure formed from two multilayer films **430**, **440**. The electronic device **400** is formed by micromachining two recesses **420**, **422** in the top surface **412** and bottom layer **404**, respectively, using the method described above with regard to the embodiments of FIGS. **1** and **2**. A single multilayer film **430**, **440** is inserted into recesses **420**, **422**, respectively. The multilayer film **430**, **440** is composed of layers: current collection layer **431**, **441** electrochemically active layer **436**, **446**, electrolyte layer **434**, **444** and encapsulating layer **435**, **445**. Current collector **431** forms a cathode and current collector **441** forms an anode. The intermediate substrate **408** acts as a separator between the cathode and the anode.

Viewing FIG. **4** differently, **441** and **431** could be the electrochemically active materials and **436** and **446** the current collectors; separate electrolyte layers are not actually necessary in that the electrolyte is mixed in with the electrochemically active materials.

Next, metallic connection tabs **450**, **452** and **454**, **456** are deposited on films **440**, **430**, respectively, so as to make contact with the rest of the circuit board **402** and in particular a metallized pattern on the top surface **412** and a metallized pattern in bottom layer **404**, respectively. The metallic connection tabs **450**, **452**, **454**, and **456** are preferably deposited using the same method described above with regard to the device **300** of FIG. **3**.

Referring now to FIG. **5**, an electronic device **500** is provided which preferably comprises an embedded coaxial waveguide or stripline or transmission line, indicated generally at **530**.

The device **500** is fabricated by first forming recess **520** by micromachining through the substrate layer **508** of the circuit board substrate **502**. Next, insulating layer **513** is deposited over the substrate including in the recess **520**. Then a complete coaxial waveguide **530** which includes a feed line **532** and dielectric material **533** is inserted into recess **520**. Subsequently, a second conductive line **560** is laser written on the dielectric material **533** of the coaxial waveguide **530** within the recess **520**.

It will be appreciated that the specific embodiment shown in FIG. **5** is an inverted microstrip line. By changing layer **513** (or at least the portion thereof in recess **520**) to metal, a coaxial waveguide or stripline transmission line results. With additional layers, an embedded coplanar waveguide or coplanar strip transmission line is produced. Thus, it will be understood that the invention is not in any way limited to the specific embodiment illustrated in FIG. **5**.

Referring now to FIG. **6**, in yet another embodiment, device **600** is formed in circuit board substrate **602** having recess **620** micromachined through a top surface **624** and a second recess **622** formed through bottom layer **604** in accordance with the method described above with regard to device **100**.

An electronic component **630** is inserted in recess **620** and electronic component **640** is inserted in recesses **622**. A via **624** is formed in the intermediate layer **608** separating the recesses **620** from recess **622** using any conventional via fabrication method known in the art. Electrical connection **626** electrically couples electronic component **630** with the electronic component **640**.

Metallic connection tabs **650**, **652** and **654**, **656** are deposited using the same method as described above with regard to device **300** of the embodiment depicted in FIG. **3**.

Referring now to FIG. **7**, electronic device **700** is formed in circuit board substrate **702** which has a recess **720** formed therein using the method described above with regard to the embodiment depicted in FIG. **1**. An electrically conductive layer **772**, an electrically insulating layer **773**, an electrically conducting layer **774**, an electrically insulating layer **775**, and an electrically conducting layer **776** are deposited in order in the recess **720**. Metallic connection tabs **750**, **752** are formed using non-contact, low-temperature, laser (or non-laser) direct-write technique to conductively connect the component **770** to the metallized pattern on the top surface **724** of the circuit board substrate **702**.

In an alternative embodiment of the one shown in FIG. **7**, rather than depositing electrically conducting material **772**, layer **772** may alternatively be a resistive, semiconducting, piezoelectric, dielectric, ferrite or any other type of depositable material known in the art and in keeping with the spirit and scope of the present method.

Referring to any of the embodiments, the present laser micromachining method is adapted to micromachine to a particular depth which if desired can remove all circuit board material and leave only exposed the metallic layer from a bottom layer of a circuit board. Such is the case in the electronic device **200** of FIG. **2**. Subsequently, interconnects can be made through the resulting circuit board using low temperature laser or other direct-write techniques described herein to make contact between both sides of the circuit board, i.e., from both bottom layer **204** and top surface **212**. For example, this technique may be used for radio frequency (RF) and antenna applications.

In addition, the present method may be adapted to form a recess for components on opposite sides of a single substrate which may be either electrically isolated from one another or electrically connected through conductive vias or through holes.

Further, the present method may be adapted for use with particularly porous circuit board materials where the circuit boards can be presoaked with a polymer solution to fill in pores making the circuit board more able to contain aqueous components of electrochemical cells.

In order to provide a better understanding of the present method, the following non-limiting embodiments provide further examples of modifications and adaptations of the present method and resulting electronic and electrochemical cells formed using the various adaptations of the present method.

The present method may be used for forming an embedded transmission line within a substrate which includes micromachining a substrate to form a recess, depositing an electrically conducting layer in the recess, depositing an electrically conducting material, depositing an additional insulting material and depositing additional conductive material.

The present method may be adapted to make an embedded antenna or transmission line within a substrate which includes micromachining the substrate to form a recess, depositing electrically conducting, resistive, superconducting, piezoelectric, dielectric, ferrite or any other type of material into the recess, and depositing an encapsulating material into the recess.

Further, the present method may be used for forming an embedded sensor within a substrate which includes micromachining a substrate to form a recess, depositing a sensor material into the recess, depositing one or more electrical contacts into the recess, depositing selective porous encapsulating material into the recess.

As should now be apparent to one of ordinary skill in the art, the present method may be used to form an electronic device having an electronic component which includes but are not limited to an alkaline battery, lithium battery, ultracapacitor, transmission line or strip, resonator, passive or active antenna, sensor, and a passive and active electronic circuit or opto-electronic circuit.

Further, the present method may be adapted to remove and add components at various locations on a substrate using the present laser system.

As will be further apparent to one of ordinary skill in the art, the present method provides features and advantages not present in prior methods. For example, the present method provides for embedding electronic components, such as electrochemical cells to reduce the size and weight of devices utilizing circuit boards or other substrates with surface mount components. By directly embedding the electronic component into the circuit board, the resulting device is more autonomous while having a lower profile. Unlike prior devices wherein components are embedded directly into circuit boards and materials are added to the surface to build up a component in and around the circuit board, the present method provides for using any currently available circuit board or substrate and modifying that board as necessary to embed the component using techniques including both the removing of portions of the existing circuit board using micromachining and then building up other portions of that circuit board using laser writing or other means of direct writing.

Further, using the present laser micromachining process, one is able to accurately control the depth by which one produces a recess in the circuit board substrate. Further, using the present laser direct-write process, one can add metallic conducting lines above an embedded element to make electric contact to the rest of the circuit board.

An additional feature and advantage of the present method is provided through using a low temperature process for making electrical contact.

Further, the present method can produce electrochemical cells which may be either layered or planar structures embedded within the circuit board material.

A further feature relates to now being able to embed electrochemical cells having aqueous electrolyte material whereas prior techniques for embedding electrochemical cells permitted only solid electrolytes.

In addition, unlike prior embedded electrochemical cells which required large areas, the present method provides for a reduction in size of these components to a sub-millimeter scale.

Further, the present method in one form or embodiment uses a dual wavelength laser to accurately micromachine and remove circuit board material down to the metal layer of the bottom surface of a circuit board. Prior techniques have used screen printing and contact methods for adding material to existing circuit boards but these methods are not viable for use on existing circuit boards with attached components. However, the present method provides for adding material which is non-contact and conformable so one can add material on almost any circuit board substrate.

In addition, the present method allows for laser direct-write technique for adding material directly where required thus eliminating the need for lithography or patterning. Further, the present laser machining and laser direct-write deposition have advantages over other prior non-lithographic techniques in that the present laser machine and laser direct-write deposition provides for higher resolution such as around approximately 10 micrometers.

Although the invention has been described above in relation to preferred embodiments thereof, it will be understood by those skilled in the art that variations and modifications can be effected in these preferred embodiments without departing from the scope and spirit of the invention.

What is claimed:

1. A method for fabricating an electronic device, said method comprising the steps of:

providing a substrate having a top surface;

micromachining the substrate from the top surface to a selected depth so as to form a first recess in the substrate;

inserting at least one electronic component into the first recess;

establishing an electrical connection between the at least one electrical component and a conductive pattern provided on the top surface of the substrate, using laser directed writing of conductive material.

2. The method of claim **1**, wherein the at least one electronic component comprises an electrochemical cell.

3. The method of claim **2**, wherein said inserting step comprises inserting a film comprising layers of an electrochemically active material, an electrolyte, a current collector and an encapsulating material.

4. The method of claim **2**, wherein said inserting step comprises inserting a film comprising layers of a first current collector, a first electrochemically active material, a first electrolyte or separator, a second electrochemically active material, a second current collector, and an encapsulating material.

5. The method of claim **2**, wherein said inserting step comprises depositing an electrically conductive material into said first recess, depositing an electrochemically conductive material into said first recess so as to form a current collector, depositing an electrochemically active material in the first recess, adding an electrolyte material to the first recess, and depositing an encapsulating material into the recess.

6. The method of claim **5**, further comprising micromachining a second recess from the top surface adjacent to the first recess and depositing an electrically conductive mate-

rial in the second recess to form a second current collector, depositing an electrochemically conductive material in the second recess, depositing an electrochemically active material in the second recess, adding an electrolyte material to the second recess and depositing an encapsulating material in to the recess.

7. The method of claim **1**, wherein the at least one electrical component is selected from the group consisting of a capacitor, an inductor and a resistor.

8. The method of claim **1** wherein said inserting step comprises inserting a complete electronic or opto-electronic device into the recess.

9. The method of claim **1**, wherein the at least one electronic component comprises a transmission line.

10. The method of claim **9**, wherein said inserting step comprises depositing a first electrically conducting layer in the recess, depositing a first electrically insulating layer in the recess on top of the first electrically conducting layer, depositing a second electrically conducting layer on the first insulating layer, depositing a second insulating layer on the second electrically conducting layer, and depositing a third conducting layer on the second insulting layer.

11. The method of claim **1**, wherein said inserting step comprising depositing one of an electrically conducting material, a resistive material, semi-conducting, a piezoelectric material, a dielectric material, and a ferrite material in the recess and depositing an encapsulating material in the recess.

12. The method of claim **1**, wherein said inserting step comprises depositing a sensor material in the recess, depositing electrical contacts, and depositing selectively porous encapsulating material.

13. The method of claim **1**, wherein the substrate has a bottom metallic layer on a side opposite the top surface, the bottom metallic layer having an exterior surface facing away from the substrate and an interior surface facing toward an interior portion of the substrate; and

said micromachining step comprises micromachining from the top surface, into the substrate, up to the interior surface of the bottom metallic layer.

14. The method of claim **13**, further comprising establishing an electrical interconnection through the bottom metallic layer using laser directed writing of conductive material to thereby establish the electrical interconnection through the substrate.

15. The method of claim **1**, wherein said inserting at least one component step comprises inserting at least two electronic components in the recess.

16. The method of claim **15**, wherein a second of the two electronic components is stacked on a first of the two electrical components.

17. The method of claim **16**, wherein said establishing electrical connection step comprises establishing an electrical connection between the second electronic component and the metallized pattern of the substrate using a laser directed writing of conductive material.

18. The method of claim **1**, wherein said micromachining step comprises micromachining the substrate using a laser.

19. The method of claim **18**, wherein the laser comprises a dual wavelength laser system including a first laser having an ultraviolet wavelength and a second laser having an infrared wavelength.

20. The method of claim **1**, further comprising micromachining the substrate from a bottom surface of the substrate to form a second recess.

21. The method of claim **20**, wherein said inserting step comprising depositing one of an electrically conducting, resistive, semi-conducting, piezoelectric, dielectric, and ferrite material in the recess and depositing an encapsulating material in both the first recess and the second recess.

22. The method of claim **20**, further comprising establishing an electrical interconnect between the two recesses.

23. The method of claim **1**, further comprising micromachining a substrate from the top surface to form a second recess adjacent to the first recess.

24. A method for fabricating an electronic device, said method comprising the steps of:

providing a substrate having a top surface thereof;

micromachining the substrate from the top surface to a selected depth so as to form a recess in the substrate;

depositing conductive material into the recess to form a first conductive line;

adding dielectric material into the recess on top of the conductive line; and

writing a second conductive line on the dielectric material using laser directed writing of conductive material.

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