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(54) **Electronic security means for security documents using a thermoelectric power generator**

Elektronisches Sicherheitsmittel für Sicherheitsdokumente mithilfe eines thermoelektrischen Leistungsgenerators

Dispositif de sécurité électronique pour documents de sécurité utilisant un générateur de puissance thermoélectrique

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**EP-A- 1 431 062 GB-A- 2 151 987
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Description

BACKGROUND OF THE INVENTION

1. Field of the invention

[0001] The present invention relates to electronic security means for banknotes, and more preferably to electronic security means comprising display means (such as liquid crystals, or microencapsulated electronic ink) to provide a visible display change when a temperature gradient is applied to the security document.

2. Description of the Related Art

[0002] The use of self-authenticating security features for producing documents serves for protecting them against unauthorized reproduction by forgers. This is necessary, in particular, for securities such as banknotes, checks, traveller's checks, stocks, etc. There is also a need for securing papers which do not have a direct monetary value, such as identification papers, passports etc., against unauthorized copying.

[0003] In particular, in the case of securities, which are circulated daily, for example, banknotes, a forger may succeed in copying the optically recorded document contents, for example, the optical printed image of the banknotes, in a deceptively precise way. A protection against this is the authenticity feature contained in the safety paper, used for producing the documents, as a result of the structure imparted to the safety paper during manufacture which authenticity feature supposedly practically cannot be copied by a forger with the means available to him. Moreover, the application of watermarks or the introduction of a safety thread into the paper is known. These conventional measures, however, can no longer be considered satisfactory in view of the advances of the working means employed by forgers. In particular, in the case of global political crisis regions the war-conducting groups or even entire countries employ forgery as warfare.

Accordingly, the resources employed for forgery are correspondingly great.

[0004] EP 1 431 062 suggests security documents comprising substrate means, on board-electrical power supply means, such as photovoltaic cells, and electronic security means using said on-board power supply means. However the security feature cannot be activated by the user of the feature, if necessary. In addition a security feature of that kind is limited by the capacity of the power supply means and/or the availability of the corresponding power generating source.

[0005] CN 1 184 303 describes an anti-counterfeiting feature that consists of power source, controller and driver circuit and panel display. The display is produced by means of semiconductor technology and fine processing and is said to be difficult to counterfeit. However the use of semiconductor technology and the necessity for a display controller and driver circuit will limit the size, flexibility and durability of this device.

[0006] There is also significant prior art in the design and manufacture of thin-film thermoelectric arrays for power generation:

[0007] D.M Rowe, D. V. Morgan and J. Kiely, Miniature low power/high voltage thermoelectric generators, Electronics Letters, Vol 25, No. 2, pp. 166, 1989 disclose the fabrication of a miniature low power/high voltage thermoelectric converter. The device, which has been arisen out of a requirement of the British gas industry for an autonomous source of electrical power for use in consumers gas monitoring systems, generates fractions of a microwatt at several volts.

[0008] US Patent 6,388,185 and US Patent Application 20030041892 describe a device for generating power to run an electronic component. The device includes a heat-conducting substrate (composed, e.g., of diamond or another high thermal conductivity material) disposed in thermal contact with a high temperature region. During operation, heat flows from the high temperature region into the heat-conducting substrate, from which the heat flows into the electrical power generator. A thermoelectric material (e.g., a BiTe alloy-based film or other thermoelectric material) is placed in thermal contact with the heat-conducting substrate. A low temperature region is located on the side of the thermoelectric material opposite that of the high temperature region. The thermal gradient generates electrical power and drives an electrical component.

[0009] Wenmin Qu et Al, Microfabrication of thermoelectric generators on flexible foil substrates as a power source for autonomous microsystems, J. Micromech. Microeng. 11 146-152, 2001 relates to a flexible thermoelectric generator with overall dimensions of 16 x 20 x 0.05 mm consisting of a multiplicity of micro Sb-Bi thermocouple strips embedded in a 50 μ m thick flexible epoxy film. The generator is capable of generating a voltage of 0.25 V at a temperature difference of 30 K.

[0010] US Patent Application 2003137500 describes a device comprising a thermoelectric unit and a micro controller unit and a flexible display unit and electrical connections between the aforementioned units, wherein the flexible display unit displays visual effects determined by the micro controller unit, and the device is powered primarily by means of a thermoelectric unit.

[0011] US Patent 5,786,875 discloses a thermally addressed liquid crystal display which uses thermoelectric elements to transition liquid crystal molecules from one optical state to another. The invention combines thermoelectric elements

as an integral part of the display and claims that the display can be manufactured on a flexible film.

[0012] However, none of these documents suggests the use of thermoelectric elements as power-generator means for electronic security means on a security document.

[0013] US 2005/0139250 A 1 refers to high performance thin film thermoelectric couples which allow fabrication of at least microwatt to watt-level power supply devices operating at voltages greater than one volt even when activated by only small temperature differences. Thereby, this document teaches that in certain embodiments, p-type and n-type TE thermoelements are deposited onto a flexible substrate. However, it does not disclose that said thermoelements are connected to electronic security means also located on said substrate.

[0014] This reference states that the thermoelectric couples may be used to power sensors for military weapons proliferation control, battlefield operations, intelligence gathering, safeguards and security activities. It aims at intrusion detection, weapon detection in mailboxes, monitoring and so on. The use of said thermoelectric couples for a security feature which can be activated by the user by touching is not contemplated.

SUMMARY OF THE INVENTION

[0015] The main objective of the present invention is to provide a more flexible and reliable overt security feature for banknotes that can be authenticated by a member of the general public, and which has improved forgery-proof properties. In addition the security feature shall be highly flexible, comparable small in thickness and highly durable.

[0016] In carrying out these and other objects of the present invention, there is provided a security document comprising substrate means and at least one electronic security means, wherein said security document also comprises at least one thermoelectric power generator means electrically connected to said electronic security means, wherein said security document is a banknote, wherein said security feature of the banknote can be activated by a user by touching the thermoelectric power generator means, and wherein the thickness of said security document is smaller than 100 μm .

[0017] Thereby a highly flexible and reliable overt security feature for banknotes is made available that can be authenticated by a member of the general public in a very simple way, and which has improved forgery-proof properties.

[0018] In particular, the security feature of the document can be activated by the user in a comparatively simple way, e.g. by touching the thermoelectric power generator means. This results in the generation of small amounts of electrical power that operate the electronic security means and display the security feature.

[0019] In addition, the present invention overcomes the size, flexibility and durability limitations of conventional electro-optic displays, electrical power sources and electrical interconnects. The security document of the present invention is extremely thin. Furthermore the security document of the present invention exhibits a very high flexibility, and a very high durability.

[0020] Especially suitable variations of the security document of the present invention are described in the dependent products claims.

[0021] The process claims describes particularly suitable methods for the manufacture of the security document of the present invention and the use claims refer to particularly favourable ways of using the security document of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

FIG. 1 is a plan view illustrating a preferred embodiment of the security document of the present invention.

FIG. 2 is a perspective view (with the thickness of the components greatly enhanced) of a preferred embodiment of the thermoelectric power generator means used in the present invention.

FIG. 3 is a perspective view (with the thickness of the components greatly enhanced) of another preferred embodiment of the thermoelectric power generator means used in the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0023] The following is a detailed description of the present invention. It provides a security document comprising substrate means and at least one electronic security means, wherein said security document is a banknote.

[0024] According to the present invention the security document also comprises at least one thermoelectric power generator means electrically connected to said electronic security means. Thermoelectric power generator means are well known in the art and refer to all kind of power generator means using the Seebeck effect. Said effect can be observed when two dissimilar conductors (thermoelement legs) are joined together to form a junction or thermocouple.

[0025] If two materials with different charge capacities are brought together and exposed to a source of heat, then current flows between the two and produces a measurable voltage. Thus, the connection of two dissimilar conductors with different Fermi levels will result in the flow of electrons from the conductor with the higher level to the lower one, until the change in electrostatic potential brings the two Fermi levels to the same value. The voltage created is described as the Seebeck effect.

[0026] The thermoelectric power generator means of the present invention preferably use semiconductor junctions instead of metals, so that - as heat flows into the semiconductor - charge carriers are generated and are carried across the junction to produce a Seebeck voltage at the boundary.

[0027] The magnitude of the voltage is governed by the n- and p-type materials that are preferably employed, and the extend of band-bending caused by the Fermi level adjustment between them. The ratio of the temperature difference to the voltage is the Seebeck coefficient (α), and is normally expressed in units of $\mu\text{V K}^{-1}$.

[0028] In principle, there are no particular restrictions on the n- and p-type materials used in the present invention. However particularly suitable materials are selected from the group consisting of AlInN, Boron Carbide (B_4C), A170,8Pd20,9Mn8,3 , SiGe superlattice, InP, SiC, Sb_2Te_3 , Bi_2Te_3 , $\text{Bi}_2\text{Te}_3/\text{Sb}_2\text{Te}_3$, $\text{SnO}_2:\text{F}$, FeS_2 , ZnO, Bi, BiTe (0,14% in porous vycor glass), HfFe_5 , ZrTe_5 , Pb modified Ge-Se-Te, Ge doped with B, Ge doped with Sb, Ge doped with Au, Fe, Si, $(\text{Ca}_2\text{CoO}_3)\text{X}(\text{CoO}_2)$, AgCoO_2 , CuAlO_2 , a combination (type B) of Platinum - 6 % Rhodium (p type metal) and Platinum - 30 % Rhodium (n type material), a combination (type E) of Nickel - 10 % Chromium (p type metal) and Constantan (n type material), a combination (type N) of Iron (p type metal) and Constantan (n type material), a combination (type K) of Nickel - 10 % Chromium (p type metal) and Nickel (n type material), a combination (type N (AWG14)) of Nicrosil (p type metal) and Nisil (n type material), a combination (type N (AWG28)) of Nicrosil (p type metal) and Nisil (n type material), a combination (type R) of Platinum - 13 % Rhodium (p type metal) and Platinum (n type material), a combination (type S) of Platinum - 10 % Rhodium (p type metal) and Platinum (n type material), a combination (type T) of Copper (p type metal) and Constantan (n type material) and a combination (type W-Re) of Tungsten - 5 % Rhenium (p type metal) and Tungsten - 26 % Rhenium (n type material).

[0029] In the present invention semiconductors are especially preferred. These are preferably manufactured by directional crystallization from a melt, or from pressed powder metallurgy.

[0030] Especially suitable semiconductor materials for the n-type semiconducting materials include $\text{Bi}_2\text{Te}_{3-x}\text{Se}_x$, wherein x is a number in the range of 0 to 3, SiGe, InP or Ge doped with Sb.

[0031] Especially suitable semiconductor materials for the p-type semiconducting materials include $\text{Bi}_{2-y}\text{Sb}_y\text{Te}_3$, wherein y is a number in the range of 0 to 2, Sb_2Te_3 , SiGe or Ge doped with B.

[0032] The choice of the semiconductor materials will be based on a combination of thermoelectric effect, ease of deposition and manufacture, physical robustness and resistance to chemical attack.

[0033] The voltage output (even from semiconductor thermocouples) is relatively low, and therefore it is preferred that a number of thermocouples are connected electrically in series and thermally in parallel. These thermocouples are preferably covered by a high thermal conductivity, low electrical conductivity plate.

[0034] In another especially preferred embodiment of the present invention the security document comprises at least two thermoelectric power generator means electrically connected in parallel.

[0035] The thermoelectric power generator means may be impregnated and over-coated with a soft, flexible polymer material to both enhance robustness and flexibility and provide a protective layer.

[0036] The actual shape of the thermoelectric power generator means is not critical and can be square, rectangular, round or oval in shape, for example.

[0037] When operating the security document at ambient temperature (20°C) and applying a temperature gradient of 10 K the voltage generated by the thermoelectric power generator means is preferably at least 0.5 V, more preferably at least 1.0 V, and in particular at least 1.5 V.

[0038] Further details regarding thermoelectric power generator means can be found in the technical literature, especially in

- D.M Rowe, D. V. Morgan and J. Kiely, Miniature low power/high voltage thermoelectric generators, Electronics Letters, Vol 25. No. 2, pp. 166, 1989;
- US Patent 6,388,185; and US Patent Application 20030041892;
- Wenmin Qu et Al, Microfabrication of thermoelectric generators on flexible foil substrates as a power source for autonomous microsystems, J Micromech. Microeng. 11 146-152, 2001;
- US Patent Application 2003137500; and
- US Patent 5,786,875

[0039] In the present invention the thermoelectric power generator means is connected to the electronic security means, preferably via one or more electrically conducting tracks. Thereby the electrically conducting tracks can be made of any electrically conducting material, but preferably have a resistivity ρ of less than $10^6 \Omega \cdot \text{cm}$, very preferably of less

than $10^{-2} \Omega \cdot \text{cm}$, when measured at 25°C . The use of copper tracks has proven of particular advantage.

[0040] The electronic security means of the security document is not particularly limited and can be any known in the art. However, it is particularly advantageous that the security means is an overt security feature, when activated. The term "overt feature", as used herein refers to a feature can be simply verified by a member of the general public using just the feature itself, and with no requirement for additional apparatus. Features in which the feature can only be read by special machine apparatus are so-called "covert features" which are not preferred for the purposes of the present invention.

[0041] In addition, the electronic security means is preferably a low power display means having an electric power consumption of preferably 1 mW or less, and in particular of 10^{-5} W or less.

[0042] Particularly suitable electronic security means for the purposes of the present invention include electrophoretic ink display means, liquid crystal display means and/or polymer light emitting diodes.

[0043] The kind of the substrate means used in the present invention is not critical. However the use of substrate means comprising paper, plastic, polymer, elemental metallic foils, metallic alloy foils and/or synthetic paper is preferred.

[0044] The security document of the present invention is comparatively thin and its thickness is smaller than $100 \mu\text{m}$. In one especially preferred embodiment, the overall thickness of the thermoelectric power generator means, not including the substrate thickness, is between approximately 10 to $50 \mu\text{m}$. The thickness of the interconnects between the power source and the display is preferably within the range from approximately 1 to $30 \mu\text{m}$.

[0045] Methods for the production of a security document of the present invention are obvious to the skilled person. The substrate means is preferably provided with the thermoelectric power generator means and the electronic security means, wherein all components, including the electronic security means, may be provided simultaneously onto a common substrate. Alternatively, for substrates that are not compatible with the manufacturing techniques required for the electronic security means, the thermoelectric power generator means and the interconnects may be provided onto the substrate before or after, preferably before the display assembly is attached to the substrate. In this latter case, electrical connection will be made by ensuring that exposed printed contact pads on the substrate align with contact pads on the electronic security means.

[0046] The semiconductor materials may be deposited by a variety of methods including sol-gel, spray pyrolysis, hot wall pyrolysis, flash evaporation, vacuum sputtering, chemical vapour deposition and electrochemical deposition. The deposition technique that is considered to be most suitable for the intended application is electrodeposition. In this technique a specially formulated catalytic ink is printed onto the substrate in a desired pattern. The substrate is then immersed in a chemical solution containing ions of the metal to be deposited. Over time, electroless deposition of the metal onto the substrate areas printed with catalytic ink occurs. This technique is advantageous compared to other methods for producing the desired electrically conducting tracks and the thermoelectric power generator means, such as printing of metal-loaded inks, since the technique produces deposited material with a density that is very close to that of the bulk material. Furthermore, this technique is advantageous over standard printing of loaded inks in that the adhesion of the deposited material to the substrate is superior.

[0047] The aforementioned electroless deposition technique is described in detail in Patent Application WO 02/099163 and is suitable for a range of substrates (such as polyester, polypropylene, synthetic paper, fine-weave cloths and polycarbonate) and a range of deposited metals (including copper, nickel, cobalt, iron, tin and a variety of magnetic and non-magnetic alloys). However, the present invention does not preclude other methods of deposition.

[0048] In one especially preferred embodiment of the present invention at least one thermoelectric power generator means and at least one electronic security means is provided on the front of the security document and at least one thermoelectric power generator means and preferably at least one electronic security means is provided on the back of the security document, preferably in close proximity one to another to allow the simultaneous application of a temperature gradient via a warm clamp, such as the thumb and the index finger of a human hand.

[0049] For checking authenticity of the security document of the present invention a temperature gradient is applied to the thermoelectric power generator means and a status change of said electronic security means is observed. Thereby the temperature gradient is preferably at least 1 K, very preferably at least 5 K, and most preferably at least 10 K. The electronic security means is activated by the application of the temperature gradient to the security document. In this invention only a very low temperature gradient is required, since for electrophoretic-type displays, such as microencapsulated electrophoretic inks or electrophoretic liquid crystal-type displays, only a very low level of electrical current is required for operation of the display.

[0050] In fact, it has been discovered that at room temperature (25°C) or below the body heat from the application of pressing a human body skin, preferably at least one finger, very preferably the thumb or the index finger, across the thermoelectric power generator means is sufficient to meet the required temperature gradient for operation of electronic security means, in particular of electrophoretic displays.

[0051] The temperature gradient that will always be available is that of body heat compared to ambient temperature. When inactive, basal heat production of the human body is typically around 90 W. Typical skin surface area is around 2 m^2 , and whilst, proportionally more heat is lost from exposed skin surfaces than from clothed areas of the body, only

a very small amount of heat could be harnessed over the area of a thumb, namely something of the order of tens of milliwatts.

[0052] The efficiency at which this energy can be recovered is limited by the Carnot cycle. It is possible to calculate the maximum theoretical conversion efficiency at various ambient temperatures, using the following relationship:

$$\text{Efficiency} = \frac{T_{\text{body}} - T_{\text{ambient}}}{T_{\text{body}}} \times 100\% \quad (1)$$

In this equation T_{body} and T_{ambient} are the absolute temperatures (K) for the body surface and ambient conditions, and it is assumed that $T_{\text{body}} > T_{\text{ambient}}$. Taking the typical skin temperature to be 34°C, at an ambient temperature of 20°C, the Carnot efficiency is 4.56%, whilst at 25°C ambient this falls further to 2.93%.

[0053] Although larger temperature gradients may be considered (perhaps by blowing across one element to cool it, or by making use of cold surfaces such as windows) the following considerations are limited to the freely available case described above. Hence, using body heat as the heat source, and before the efficiency of conversion of the thermoelectric device is taken into account, the maximum available thermal power would be of the order of 1mW or less. The proportion of this heat that is converted into useable power depends on the efficiency of the thermoelectric cell, which is dependent on the thermoelectric 'figure of merit'. The overall efficiency, ϕ_{max} , of a thermoelectric cell in converting heat to electrical power can be estimated using the expression:

$$\phi_{\text{max}} = \gamma \eta \quad (2)$$

where

$$\gamma = \frac{T_{\text{hot}} - T_{\text{cold}}}{T_{\text{hot}}} \quad (3)$$

where T_{hot} is the temperature of the heated top surface of the generator and T_{cold} is the temperature of the bottom surface of the generator,

and

$$\eta = \frac{(1 + ZT)^{1/2} - 1}{(1 + ZT)^{1/2} + T_{\text{cold}}/T_{\text{hot}}} \quad (4)$$

and

$$Z = \frac{\alpha^2 \sigma}{\lambda} \quad (5)$$

where α is the Seebeck coefficient (V K^{-1}) of the thermoelectric material used in the generator, σ is the electrical conductivity of the thermoelectric material used in the generator ($\Omega^{-1} \text{ m}^{-1}$), and λ is the thermal conductivity of the thermoelectric material used in the generator ($\text{W m}^{-1} \text{ K}^{-1}$).

and

$$T = \frac{T_{\text{hot}} - T_{\text{cold}}}{2} \quad (6)$$

For a reasonable figure of merit, Z , for semiconductor thermoelectric materials of around $2 \times 10^{-3} \text{ K}^{-1}$, and for a temperature gradient of 10K with the cold side of the cell maintained at room temperature, can be estimated at $<0.5\%$. Therefore the maximum power extracted from a thumbprint area is of the order of tens of microwatts.

[0054] Alternative sources of heat for operation of the feature, e.g. blowing of warm air and the use of 'behind-the-counter' hot plates, can also be considered. In this case, higher temperature gradients are possible leading to higher power outputs from the thermoelectric device. The power produced by the thermoelectric device may be sufficient for operation of display devices that require higher powers such as semi-conductor LEDs, electrochromic displays, thermochromic displays and electroluminescent displays. These possible variations are contemplated as falling within the scope of the present invention.

[0055] Referring now to the figures, several preferred embodiments of the invention will be discussed. Fig. 1 is a plan view of a first particular preferred embodiment of the present invention. The security document comprises a thin flexible substrate 1 and a thin flexible thermoelectric generator patch 2 deposited or printed onto said substrate 1. The thermoelectric generator patch 2 is electrically connected, via flexible electrically conducting tracks 3 and 4, which may be printed or deposited on the substrate 1, to a thin and flexible low power display 5. The display 5 may be printed or deposited onto the substrate or adhered to the substrate before or after the printing and/or deposition of the other components of the feature. In any case, electrical connectivity is made between the display 5 and the thermoelectric generator 2. The thermoelectric generator 2 is designed such that application of modest heat, such as that provided by body heat in the form of a thumb 6 pressed upon the generator, generates sufficient electric voltage and current to operate the display.

[0056] Fig. 2 is a perspective view of a preferred embodiment of the thermoelectric power generator means used in the present invention wherein the thicknesses of the elements are greatly exaggerated for clarity. The thermoelectric power generator means comprise an array of metallic thermocouple elements 7. Each of the thermocouple elements 7 comprises two dissimilar metals 8 and 9, which are in contact with each other. When connected in series using electrically conducting tracks 10 as shown the voltage generated by each of these thermocouples under the application of heat will sum to provide an overall higher voltage. It is estimated that, if using a thermocouple with the p-type metal as an alloy of 90% nickel and 10% chromium and with the n-type metal as the alloy constantan, then about 2000 thermocouples in series will produce a potential voltage of about 1.2 volts under the application of a temperature gradient of 10 degrees centigrade. The initial potential voltage, and associated low electrical currents, that is generated by the application of the heat source (such as body heat from the application of pressing a thumb across the array) will be sufficient for operation of electronic security means, e.g. electrophoretic displays.

[0057] As will be obvious to any person skilled in the art, many different geometrical designs of array of thermocouples are possible.

[0058] It is considered that the components 8 and 9 of the thermoelectric generator described above, including electrical interconnects 10 may be most easily deposited onto the substrate using an electroless deposition technique. In the example structure shown in Figure 2 it is envisaged that the electrical interconnects 10 would be deposited first followed by the thermocouple elements 8 and 9. Alternatively, the components may be electroplated on top of an initial electrically conducting patterned layer, which itself is either printed (using solid-loaded ink), or deposited using the aforementioned electroless deposition technique. A number of other techniques for depositing the thermoelectric materials can be considered and include, chemical vapour deposition, vacuum sputtering, sol-gel deposition, spray pyrolysis, hot wall pyrolysis and flash evaporation.

[0059] The size (area) of the thermocouple elements 7 described above may be typically 100 micrometres square (in plan view). For 2000 elements the overall area of the thermoelectric generator is therefore about 80 square millimetres. The minimum area of the elements and the spacing between them is only limited by the resolution of the deposition or printing technique. The thickness of the thermocouple elements can be typically about 5 to 50 micrometres. The thickness of the electrical interconnecting tracks can be typically 1 to 30 micrometres.

[0060] Fig. 3 is a perspective view of another preferred embodiment of the thermoelectric power generator means used in the present invention wherein the thicknesses of the elements are greatly exaggerated for clarity. The thermoelectric power generator means comprise an array of thermocouple elements 11. Each thermocouple 11 consists of a p-type semiconducting material 12 and an n-type semiconducting material 13. Electrical interconnects 10 connect together the p-type and n-type semiconducting thermoelements. Semiconductor materials have the advantage of having higher Seebeck coefficients than metallic thermocouple pairs and of having a lower thermal conductivity such that they can support a larger continuous temperature gradient across the device.

Claims

1. Security document comprising substrate means (1) and at least one electronic security means (5), wherein said security document is a banknote, **characterized in that** said security document also comprises at least one ther-

thermoelectric power generator means (2) electrically connected to said electronic security means (5), wherein said security feature of the banknote can be activated by a user by touching the thermoelectric power generator means, and wherein the thickness of said security document is smaller than 100 μm .

2. Security document according to claim 1, **characterized in that** said security document comprises at least two thermoelectric power generator means (2) electrically connected in series.
3. Security document according to at least one of the preceding claims, **characterized in that** said security document comprises at least two thermoelectric power generator means (2) electrically connected in parallel.
4. Security document according to at least one of the preceding claims, **characterized in that** said thermoelectric power generator means (2) comprises at least two dissimilar metals, metal alloys or semiconductors which are in contact with each other (8, 9).
5. Security document according to claim 4, **characterized in that** said thermoelectric power generator means (2) comprises at least one n-type material and at least one p-type material.
6. Security document according to claim 5, **characterized in that** said n-type material is $\text{Bi}_2\text{Te}_{3-x}\text{Se}_x$, wherein x is a number in the range of 0 to 3, SiGe, InP or Ge doped with Sb.
7. Security document according to claim 5 or 6, **characterized in that** p-type material is $\text{Bi}_{2-y}\text{Sb}_y\text{Te}_3$, herein y is a number in the range of 0 to 2, Sb_2Te_3 , SiGe or Ge doped with B.
8. Security document according to at least one of the preceding claims, **characterized in that** said thermoelectric power generator means (2) is coated with a protective layer.
9. Security document according to at least one of the preceding claims, **characterized in that** said security document comprises electrically conducting tracks (10) electrically connecting said thermoelectric power generator means (2) to said electronic security means (5).
10. Security document according to at least one of the preceding claims, **characterized in that** said electronic security means (5) is an overt security feature.
11. Security document according to at least one of the preceding claims, **characterized in that** said electronic security means (5) is a low power display means.
12. Security document according to claim 11, **characterized in that** the power needed by said lower power display is 1 mW or less.
13. Security document according to claim 11 or 12, **characterized in that** said low power display means are electrophoretic ink display means, liquid crystal display means and/or polymer light emitting diodes.
14. Security document according to at least one of the preceding claims, **characterized in that** said substrate means (1) comprises paper, plastic, polymer, elemental metallic foils, metallic alloy foils and/or synthetic paper.
15. Method for the production of a security document according to at least one of the preceding claims, wherein thermoelectric power generator means (2) and electronic security means (5) are provided on substrate means (1).
16. Method according to claim 15, **characterized in that** said thermoelectric power generator means (2) are provided onto said substrate means (1) by the use of electroless deposition technique, electroplating, chemical vapour deposition, vacuum sputtering, sol-gel deposition, spray pyrolysis, hot wall pyrolysis and/or flash evaporation.
17. Method according to claim 15 or 16, **characterized in that** electrical interconnections (10) are provided on said substrate means (1) and said thermoelectric power generator means (2) and said electronic security means (5) are provided onto said electrical interconnections (10).
18. Method according to at least one of the claims 15 to 17, **characterized in that** said electronic security means (5) is provided before or after the provision of said thermoelectric power generator means (2).

19. Method according to at least one of the claims 15 to 18, **characterized in that** said electronic security means (5) and said thermoelectric power generator means (2) are provided on both sides of said security document.
20. Use of a security document according to at least one of the claims 1 to 14 for checking its authenticity, wherein a temperature gradient is applied to said thermoelectric power generator means (2) and a status change of said electronic security means (5) is observed.
21. Use according to claim 20, **characterized in that** said temperature gradient is at least 1 K.
22. Use according to claim 21, **characterized in that** said temperature gradient is generated by contacting the thermoelectric power generator means with human body skin.

Patentansprüche

1. Sicherheitsdokument mit Substratmitteln (1) und wenigstens einem elektronischen Sicherheitsmittel (5), wobei das Sicherheitsdokument eine Banknote ist, **dadurch gekennzeichnet, dass** das Sicherheitsdokument auch wenigstens ein thermoelektrisches Stromerzeugermittel (2) umfasst, das mit dem elektronischen Sicherheitsmittel (5) elektrisch verbunden ist, wobei das Sicherheitsmerkmal der Banknote von einem Benutzer durch Berühren des thermoelektrischen Stromerzeugermittels aktiviert werden kann und wobei die Dicke des Sicherheitsdokuments kleiner als 100 µm ist.
2. Sicherheitsdokument nach Anspruch 1, **dadurch gekennzeichnet, dass** das Sicherheitsdokument wenigstens zwei thermoelektrische Stromerzeugermittel (2) umfasst, die elektrisch in Reihe geschaltet sind.
3. Sicherheitsdokument nach wenigstens einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Sicherheitsdokument wenigstens zwei thermoelektrische Stromerzeugermittel (2) umfasst, die elektrisch parallelgeschaltet sind.
4. Sicherheitsdokument nach wenigstens einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das thermoelektrische Stromerzeugermittel (2) wenigstens zwei unterschiedliche Metalle, Metalllegierungen oder Halbleiter umfasst, die miteinander (8, 9) in Kontakt sind.
5. Sicherheitsdokument nach Anspruch 4, **dadurch gekennzeichnet, dass** das thermoelektrische Stromerzeugermittel (2) wenigstens ein n-leitendes Material und wenigstens ein p-leitendes Material umfasst.
6. Sicherheitsdokument nach Anspruch 5, **dadurch gekennzeichnet, dass** das n-leitende Material $\text{Bi}_2\text{Te}_{3-x}\text{Se}_x$ ist, wobei x eine Zahl im Bereich von 0 bis 3, SiGe, InP oder mit Sb dotiertes Ge ist.
7. Sicherheitsdokument nach Anspruch 5 oder 6, **dadurch gekennzeichnet, dass** das p-leitende Material $\text{Bi}_{2-y}\text{Sb}_y\text{Te}_3$ ist, worin y eine Zahl im Bereich von 0 bis 2, Sb_2Te_3 , SiGe oder mit B dotiertes Ge ist.
8. Sicherheitsdokument nach wenigstens einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das thermoelektrische Stromerzeugermittel (2) mit einer Schutzschicht beschichtet ist.
9. Sicherheitsdokument nach wenigstens einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Sicherheitsdokument elektrisch leitende Bahnen (10) umfasst, die das thermoelektrische Stromerzeugermittel (2) elektrisch mit dem elektronischen Sicherheitsmittel (5) verbinden.
10. Sicherheitsdokument nach wenigstens einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das elektronische Sicherheitsmittel (5) ein offenes Sicherheitsmerkmal ist.
11. Sicherheitsdokument nach wenigstens einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das elektronische Sicherheitsmittel (5) ein Kleinleistungsanzeigemittel ist.
12. Sicherheitsdokument nach Anspruch 11, **dadurch gekennzeichnet, dass** der von der Anzeige mit kleinerer Leistung benötigte Strom 1 mW oder weniger beträgt.

13. Sicherheitsdokument nach Anspruch 11 oder 12, **dadurch gekennzeichnet, dass** die Kleinleistungsanzeigemittel Anzeigemittel mit elektrophoretischer Farbe, Flüssigkristallanzeigemittel und/oder Polymer-Leuchtdioden sind.
- 5 14. Sicherheitsdokument nach wenigstens einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** das Substratmittel (1) Papier, Kunststoff, Polymer, elementare metallische Folien, Metalllegierungsfolien und/oder synthetisches Papier umfasst.
- 10 15. Verfahren zur Herstellung eines Sicherheitsdokuments nach wenigstens einem der vorhergehenden Ansprüche, bei dem thermoelektrische Stromerzeugermittel (2) und elektronische Sicherheitsmittel (5) auf Substratmitteln (1) vorgesehen sind.
- 15 16. Verfahren nach Anspruch 15, **dadurch gekennzeichnet, dass** die thermoelektrischen Stromerzeugermittel (2) durch die Verwendung von stromloser Abscheidetechnik, Galvanisierung, chemischer Gasphasenabscheidung, Vakuumzerstäubung, Sol-Gel-Abscheidung, Sprühpyrolyse, Heißwandpyrolyse und/oder Entspannungsverdampfung auf den Substratmitteln (1) vorgesehen werden.
- 20 17. Verfahren nach Anspruch 15 oder 16, **dadurch gekennzeichnet, dass** elektrische Verbindungsleitungen (10) auf den Substratmitteln (1) vorgesehen sind und die thermoelektrischen Stromerzeugermittel (2) und die elektronischen Sicherheitsmittel (5) auf den elektrischen Verbindungsleitungen (10) vorgesehen werden.
- 25 18. Verfahren nach wenigstens einem der Ansprüche 15 bis 17, **dadurch gekennzeichnet, dass** das elektronische Sicherheitsmittel (5) vor oder nach der Bereitstellung der thermoelektrischen Stromerzeugermittel (2) vorgesehen wird.
- 30 19. Verfahren nach wenigstens einem der Ansprüche 15 bis 18, **dadurch gekennzeichnet, dass** die elektronischen Sicherheitsmittel (5) und die thermoelektrischen Stromerzeugermittel (2) auf beiden Seiten des Sicherheitsdokuments vorgesehen werden.
- 35 20. Verwendung eines Sicherheitsdokuments nach wenigstens einem der Ansprüche 1 bis 14 zur Überprüfung seiner Echtheit, wobei an die thermoelektrischen Stromerzeugermittel (2) ein Temperaturgradient angelegt wird und eine Zustandsänderung der elektronischen Sicherheitsmittel (5) beobachtet wird.
21. Verwendung nach Anspruch 20, **dadurch gekennzeichnet, dass** der Temperaturgradient wenigstens 1 K beträgt.
22. Verwendung nach Anspruch 21, **dadurch gekennzeichnet, dass** der Temperaturgradient erzeugt wird, indem die thermoelektrischen Stromerzeugermittel mit Haut des menschlichen Körpers in Kontakt gebracht werden.

Revendications

1. Document de sécurité, comportant des moyens de substrat (1) et au moins un moyen de sécurité (5) électronique, le document de sécurité étant un billet de banque, **caractérisé en ce que** le document de sécurité comporte aussi au moins un moyen (2) de génération de puissance thermoélectrique qui est relié électriquement au moyen de sécurité (5) électronique, la caractéristique de sécurité du billet de banque étant apte à être activée par un utilisateur en touchant le moyen de génération de puissance thermoélectrique, et l'épaisseur du document de sécurité étant inférieure à 100 μm .
2. Document de sécurité selon la revendication 1, **caractérisé en ce que** le document de sécurité comporte au moins deux moyens (2) de génération de puissance thermoélectriques couplés électriquement en série.
3. Document de sécurité selon au moins l'une des revendications précédentes, **caractérisé en ce que** le document de sécurité comporte au moins deux moyens (2) de génération de puissance thermoélectriques couplés électriquement en parallèle.
4. Document de sécurité selon au moins l'une des revendications précédentes, **caractérisé en ce que** le moyen (2) de génération de puissance thermoélectrique comporte au moins deux métaux, alliages métalliques ou semiconducteurs différents qui sont en contact l'un avec l'autre (8, 9).

5. Document de sécurité selon la revendication 4, **caractérisé en ce que** le moyen (2) de génération de puissance thermoélectrique comporte au moins un matériau de type n et au moins un matériau de type p.
- 5 6. Document de sécurité selon la revendication 5, **caractérisé en ce que** le matériau de type n est du $\text{Bi}_2\text{Te}_{3-x}\text{Se}_x$, x étant un nombre compris entre 0 et 3, du SiGe, du InP ou du Ge dopé avec du Sb.
7. Document de sécurité selon la revendication 5 ou 6, **caractérisé en ce que** le matériau de type p est du $\text{Bi}_{2-y}\text{Sb}_y\text{Te}_3$, y étant un nombre compris entre 0 et 2, du Sb_2Te_3 , du SiGe ou du Ge dopé avec du B.
- 10 8. Document de sécurité selon au moins l'une des revendications précédentes, **caractérisé en ce que** le moyen (2) de génération de puissance thermoélectrique est revêtu d'une couche protectrice.
9. Document de sécurité selon au moins l'une des revendications précédentes, **caractérisé en ce que** le document de sécurité comporte des pistes (10) électriquement conductrices reliant le moyen (2) de génération de puissance thermoélectrique de manière électrique au moyen de sécurité (5) électronique.
- 15 10. Document de sécurité selon au moins l'une des revendications précédentes, **caractérisé en ce que** le moyen de sécurité (5) électronique est une caractéristique de sécurité évidente.
- 20 11. Document de sécurité selon au moins l'une des revendications précédentes, **caractérisé en ce que** le moyen de sécurité (5) électronique est un moyen d'affichage de basse puissance.
12. Document de sécurité selon la revendication 11, **caractérisé en ce que** la puissance dont le dispositif d'affichage de plus basse puissance a besoin est de 1 mW ou moins.
- 25 13. Document de sécurité selon la revendication 11 ou 12, **caractérisé en ce que** les moyens d'affichage de basse puissance sont des moyens d'affichage à encre électrophorétique, des moyens d'affichage à cristaux liquides et/ou des diodes électroluminescentes polymères.
- 30 14. Document de sécurité selon au moins l'une des revendications précédentes, **caractérisé en ce que** le moyen de substrat (1) comprend du papier, du plastique, un polymère, des feuilles métalliques élémentaires, des feuilles d'alliages métalliques et/ou du papier synthétique.
- 35 15. Procédé de fabrication d'un document de sécurité selon au moins l'une des revendications précédentes, dans lequel des moyens (2) de génération de puissance thermoélectriques et des moyens de sécurité (5) électroniques sont prévus sur des moyens de substrat (1).
- 40 16. Procédé selon la revendication 15, **caractérisé en ce que** les moyens (2) de génération de puissance thermoélectriques sont prévus sur les moyens de substrat (1) en employant une technique de dépôt sans courant, la galvanoplastie, le dépôt chimique en phase vapeur, la pulvérisation sous vide, le dépôt sol-gel, la pyrolyse par pulvérisation, la pyrolyse à paroi chaude et/ou la vaporisation éclair.
- 45 17. Procédé selon la revendication 15 ou 16, **caractérisé en ce que** des lignes de connexion électriques (10) sont prévues sur les moyens de substrat (1) et **en ce que** les moyens (2) de génération de puissance thermoélectriques et le moyen de sécurité (5) électronique sont prévus sur les lignes de connexion électriques (10).
- 50 18. Procédé selon au moins l'une des revendications 15 à 17, **caractérisé en ce que** le moyen de sécurité (5) électronique est prévu avant ou après avoir prévu les moyens (2) de génération de puissance thermoélectriques.
- 55 19. Procédé selon au moins l'une des revendications 15 à 18, **caractérisé en ce que** le moyen de sécurité (5) électronique et les moyens (2) de génération de puissance sont prévus des deux côtés du document de sécurité.
20. Utilisation d'un document de sécurité selon au moins l'une des revendications 1 à 14 pour la vérification de son authenticité, un gradient thermique étant appliqué aux moyens (2) de génération de puissance thermoélectriques et un changement d'état du moyen de sécurité (5) électronique étant observé.
21. Utilisation selon la revendication 20, **caractérisée en ce que** le gradient thermique est d'au moins 1 K.

22. Utilisation selon la revendication 21, **caractérisée en ce que** le gradient thermique est généré en mettant les moyens de génération de puissance thermoélectriques en contact avec la peau d'un corps humain.

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Fig. 1

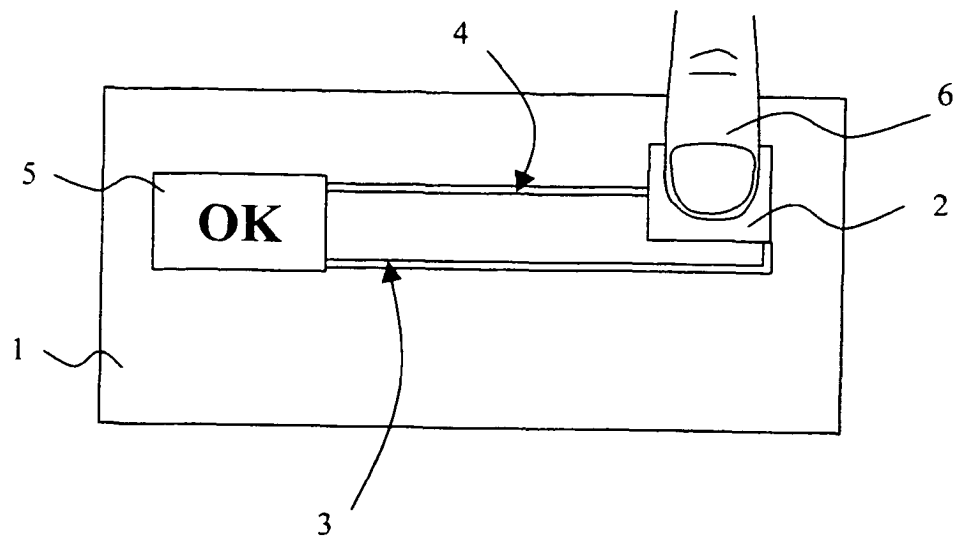


Fig. 2

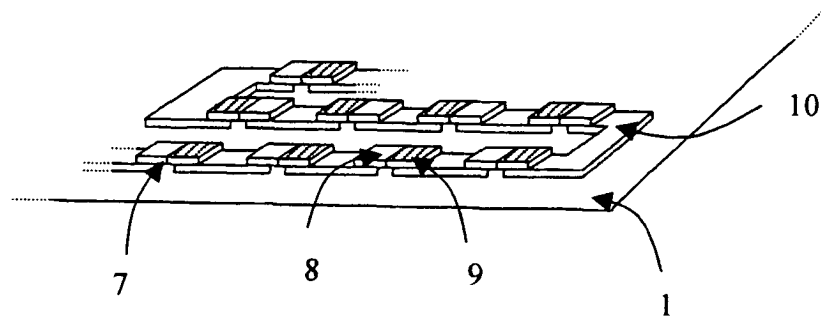
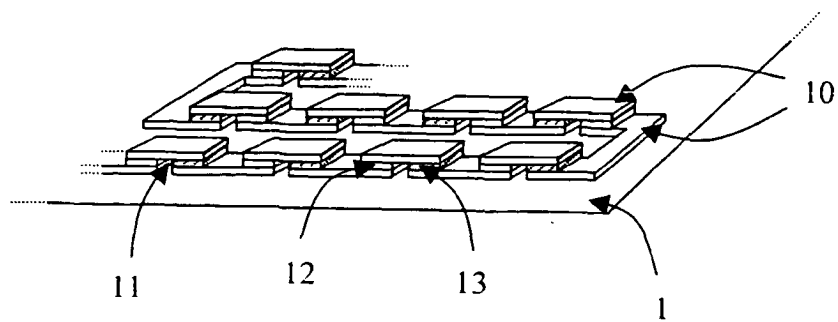


Fig. 3



REFERENCES CITED IN THE DESCRIPTION

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