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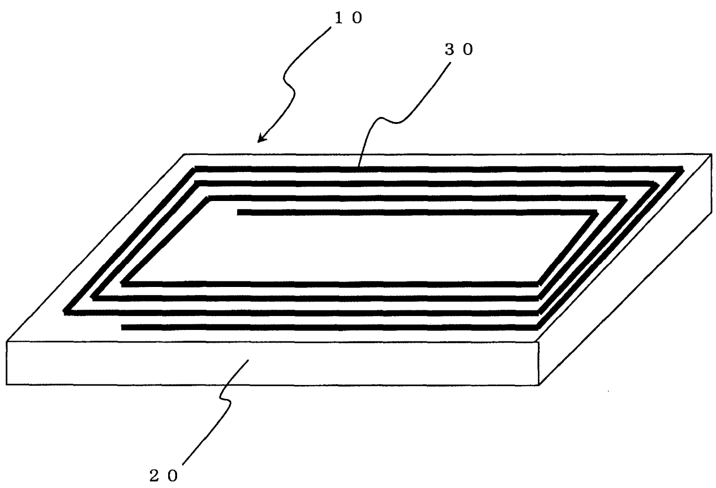
(54) **ANTENNA ELEMENT AND METHOD FOR MANUFACTURING SAME**

(57) There is provided a more easily manufactured antenna device used in a tag composing an RFID (Radio Frequency Identification) system. The antenna device (10) has (A) a laminar magnetic element formed of a magnetic composition containing a magnetic material and a polymer material, and (B) antenna wiring provided on one of the surfaces of the laminar magnetic element.

Fig. 1



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## Description

### Field of the Invention

**[0001]** The present invention relates to an antenna device, in particular an antenna device that may be used in an apparatus used in an RFID (Radio Frequency Identification) system, for example an antenna device that can be used in an IC tag or an antenna device used in a reader/writer. In addition, the present invention relates to an electronic apparatus, such as a wireless tag or an IC tag (which also may be a cell-phone), having such an antenna device, as well as a reader/writer used for transmission therewith.

### Background Art

**[0002]** RFID systems have been beginning to be used in various fields and their convenience has been demonstrated. As a result, it is expected that the RFID systems may be utilized in many other fields to take advantage of their convenience. On the other hand, various problems have been pointed out with respect to the technology related to the RFID systems and solutions therefor are desirable from now on.

**[0003]** One of such problems is a problem as to the antenna which tags, readers/writers or the like as units for forming the RFID systems include. The antenna is used in signal transmission and/or power supply by utilizing the electromagnetic induction effect.

**[0004]** Such an antenna is known to be greatly influenced by the environment in which it is placed. In particular, if a metallic article is present close to the antenna, an eddy current caused by the magnetic flux generated by the antenna flows on the metal surface in the reader/writer. As a result, carrier waves are significantly attenuated, and with respect to the tag, the intensity of the magnetic flux flowing through the antenna is attenuated, which may make communication impossible.

**[0005]** In order to suppress the effect generated by such a metallic article, combining a member formed of a magnetic material with the antenna has been proposed. For example, a non-contact type IC card reader/writer provided with a magnetic material in the form of a flexible sheet under the antenna has been proposed in order to prevent the adverse effects to the communication caused by the metallic article as well as to reduce occupied space (see Patent Reference 1 below). In this reader/writer, the antenna and the magnetic material in the form of the sheet are bonded with double-sided adhesive tape.

**[0006]** Further, a non-contact type data transmitter, having an antenna and an IC chip provided on one surface of a base substrate wherein a magnetic material layer is placed so as to cover at least one of the antenna and the IC chip, has been proposed (see Patent Reference 2 below). In the case of this data transmitter, it is stated that, by covering thus with the magnetic material layer, sufficient induced electromotive force may be generated even when in contact with an article containing a metal member.

**[0007]** This data transmitter is manufactured by pasting together a metal foil on a base material, after which the conductive foil is etched to form an antenna pattern, the IC chip is mounted, and finally the magnetic material is coated, and dried to be solidified.

[Patent Reference 1] Japanese Laid-open Patent Publication No. 2002-298095
[Patent Reference 2] Japanese Laid-open Patent Publication No. 2006-113750

### Disclosure of the Invention

### Problems to be Solved by the Invention

**[0008]** The RFID systems are expected to be more widely used in portable electronic apparatuses such as cell-phones. For the purpose of this, it is desirable that the antenna device contained in the tag, the reader/writer, or the like provided which forms the system is made more compact; it is also desirable that the antenna may be more easily manufactured.

### Means to Solve the Problems

**[0009]** After intensive studies as to the antenna device, it has been found that the above problems are solved by an antenna device comprising:

(A) a laminar magnetic element (for example in a plate form, a sheet form, or a film form) formed of a magnetic composition comprising a magnetic material(s) and a polymer material(s), and
(B) an antenna wiring provided on at least one of the surfaces of the laminar magnetic element.

**[0010]** The present invention provides a method of manufacturing an antenna device having a laminar magnetic element and antenna wiring provided thereon, the method comprising:

(1) a step to obtain a laminar magnetic element from a magnetic composition comprising a magnetic material(s) and a polymer material(s),
(2) a step to directly bond a metal foil on at least one of the surfaces of the laminar magnetic element, and
(3) a step to form the antenna wiring having a prescribed pattern through etching the metal foil.
By this manufacturing method, the antenna device according to the present invention which is described above and below is conveniently produced.

**[0011]** The present invention also provides an electronic apparatuses having an antenna device as described above and below, in particular an IC tag, a portable electronic apparatus having the IC tag (for example a cell-phone, a notebook PC, a PDA (Personal Digital Assistants), etc.), and a reader/writer used in transmission with the IC tag.

Effects of the Invention

**[0012]** The antenna device of the present invention has the antenna wiring attached directly to the laminar magnetic element. Therefore, there is nothing between the antenna wiring and the laminar magnetic element (for example, a double-sided adhesive tape or a resin layer derived from an adhesive), and further other elements such as a base substrate is not required, so that the antenna device may be formed to be thinner and therefore more compact.
**[0013]** Further, in the manufacturing method for the antenna device of the present invention, since the metal foil is bonded directly to the laminar magnetic element, after which the laminar magnetic element having the antenna wiring is obtained by etching, bonding of the metal foil to the laminar magnetic element is simplified. In addition, since no base substrate is required, the antenna device is manufactured more easily.

Brief Explanation of the Drawings

**[0014]**

[Figure 1] Figure 1 shows a schematic perspective view of an antenna device of the present invention.
[Figure 2] Figure 2 shows a flow sheet of the method of manufacturing an antenna device of the present invention.

Explanation of the Numerals

**[0015]**

10 - antenna device,
20 - laminar magnetic element,
30 - antenna wiring

Embodiments to Carry Out the Invention

**[0016]** The invention is described further in detail with reference to the drawings. Figure 1 shows the antenna device of the present invention in a schematic perspective view. Figure 2 shows a schematic flowchart of the manufacturing method of the antenna device according to the present invention.
**[0017]** The antenna device 10 of the present invention comprises a laminar magnetic element 20 formed of a magnetic composition containing a magnetic material(s) and a polymer material(s), and an antenna wiring 30 provided on one surface of the laminar magnetic element 20. The laminar magnetic element 20 may be of any appropriate form having a planar expanse, and may for example be in a plate form, a sheet form, a film form, or the like. Thus, the term "surface" in the present description is intended to mean a surface which defines such expanse, namely a main surface. The laminar magnetic element 30 has two surfaces on its both sides. Therefore, the antenna device according to the present invention includes an embodiment which has the antenna wiring on one side of the laminar magnetic element as well as an embodiment which has the antenna wirings on the both sides of the laminar magnetic element.
**[0018]** Various magnetic materials which have been proposed as being able to exhibit the antenna functions in the antenna device (in other words, the transmission function and/or the power supply function) may be used as the magnetic material which forms the laminar magnetic element. In particular, the use of materials having the ability to converge magnetic flux, in other words materials with superior magnetic permeability, is desirable. Examples of the magnetic materials preferably used are: iron-silicon alloys; magnetic materials referred to as ferrites, in particular Mn-Zn ferrites,

Ni-Zn ferrites; iron-nickel alloys, in particular permalloys, Sendust alloys; amorphous alloys, preferably magnetic materials referred to as iron-base amorphous alloys, in particular those having Fe as the main component with Si, B, Cu, and Nb added. More specifically, IRL (trade name of TDK Corporation) sold commercially by TDK Corporation as a composite electromagnetic shield material, Finemet commercially available from Hitachi Metals, Ltd. and the like may be used. Such magnetic materials may be in any appropriate form, and may for example be in granular form or flake form.

**[0019]** Various polymer materials which has been proposed as being able to improve, in combination with the magnetic materials, the antenna functions in the antenna device (in other words, the transmission function and/or the power supply function) may be used as the polymer material forming the laminar magnetic element. In particular, the use of polymer materials that will not adversely affect, or will favorably affect the magnetic materials having the ability to converge the magnetic flux is desirable. Specifically, the polymer materials preferably used may be either crystalline polymers or non-crystalline polymers, for example, thermoplastic polymers such as a polyethylene (PE), a polyethylene chloride, a polyphenylene sulfide (PPS), a polypropylene, polyvinyl chloride, a polyvinylidene fluoride, a polystyrene, a polyoxymethylene, an ethylene-vinyl acetate copolymer (EVA), an ethylene-butyl acrylate copolymer (EBA), a polyethylene terephthalate (PET), a Nylon, an acrylonitrile-butadiene-styrene terpolymer (ABS) and the like. Thermoplastic elastomers may also be used as the polymer material.

**[0020]** The magnetic composition comprising the magnetic materials and polymer materials described above may comprise these materials in any appropriate ratio as long as the antenna device of the present invention is able to exhibit the antenna functions. For example, the magnetic composition comprises 60-95 parts by mass of the magnetic material and 40-5 parts by mass of the polymer materials, more preferably 75-92 parts by mass of the magnetic material and 25-8 parts by mass of the polymer material. The magnetic composition may, as required, contain additional components (for example, a plasticizer for the polymer material (for example, a paraffin chloride, an epoxidized soybean oil, an olefin-based wax), organic/inorganic flame retardant, etc.).

**[0021]** In the antenna device of the present invention, the antenna wiring 30 is provided on, for example, one surface of the laminar magnetic element 20 as shown in the drawing. In the other embodiment described below, the antenna wirings may be provided on the both sides of the laminar magnetic element. In either embodiment, the antenna wiring (s) 30 is bonded directly to the laminar magnetic element 20. The term "on the surface" means that the antenna wiring protrudes from the surface of the laminar magnetic element. Further, the term "directly" means that the antenna wiring and the laminar magnetic element are connected while they are in mutual contact, in other words connected directly. The antenna wiring may be of any appropriate shape, for example a spiral shape (a rectangular spiral shape) as illustrated. The other shape such as a loop shape, a helical shape, a monopole shape, a dipole shape, a patch shape, a slot shape or the like may be possible.

**[0022]** The antenna device of the present invention may, in addition to the antenna wiring, have a required electronic component (an IC chip, a capacitor, a chip resistor and the like) and any other wiring required to connect therewith electrically. Such an electronic component and other wiring may be provided on any of the surfaces of the laminar magnetic element as required. In one embodiment, these electronic component(s) and other wiring(s) are present on the surface of the laminar magnetic element on which surface the antenna wiring is present. In other embodiment, at least some of the electronic component(s) and other wiring(s) may be present on the opposite surface of the laminar magnetic element, in which case a through hole(s) may be provided through the laminar magnetic element with an electrically conductive element(s) (such as an electrically conductive resin, a resin solder, or the like) embedded therein or with an electrically conductive plated metal layer formed on the inside of the through hole(s) so as to ensure the electrical connection between the antenna wirings on the both surfaces of the laminar magnetic element and the electronic component(s) and other wiring(s).

**[0023]** The structure described above wherein the antenna wiring is protruded from the surface of the laminar magnetic element is intrinsically obtained by manufacturing in accordance with the antenna device manufacturing method of the present invention as described above and below. In other words, by pasting the metal foil, as the precursor of the antenna wiring, on the laminar magnetic element, and then etching the metal foil so that only portions corresponding to the antenna wiring remain, such a structure is obtained as a result.

**[0024]** Thus, the manufacturing method of the antenna device according to the present invention comprises the step of bonding (for example, thermally pressing) a metal foil directly on the laminar magnetic element so as to produce an antenna element precursor (the step (2) in Fig. 2) and the step of etching the metal foil to form the antenna wiring having a prescribed pattern (the step (3) in Fig. 2).

**[0025]** The laminar magnetic element may be obtained by forming the above magnetic composition into a layer form. In one preferred embodiment, the laminar magnetic element may be obtained in sheet form by press molding or compression molding. For example, the laminar element having a prescribed thickness may be obtained by filling a cavity corresponding to the prescribed thickness of the laminar element with the magnetic composition and pressing/heating this. In another preferred embodiment, the laminar magnetic element may be obtained by extruding the magnetic component under heat. In this case, an elongated (or continuous) laminar magnetic element is obtained. In either embodiment, the heated laminar magnetic element may be cooled as required.

**[0026]** Thus, in one embodiment, the method of manufacturing the antenna device of the present invention comprises:

(1) a step to obtain an extruded element by extruding a magnetic composition containing a magnetic material(s) and a polymer material(s) into a laminar form,
(2) a step to directly bond a metal foil on the extruded element, and
(3) a step to etch the metal foil to form an antenna wiring having a prescribed pattern.

**[0027]** Figure 2 shows a flow sheet of the manufacturing method of the present invention as described above. In Figure 2, the step to obtain the magnetic composition is also shown. In this step, the magnetic material and the polymer material are mixed using appropriate mixing/kneading means (such as Banbury Mixer, a twin screw kneader, or the like) to obtain a composition wherein these are homogeneously mixed. The composition is formed (for example extruded) into the laminar magnetic element

**[0028]** The bonding of the metal foil to the laminar magnetic element is preferably performed by placing the metal foil on the laminar magnetic element and thermally pressing using, for example, a thermal press. In this case, when the metal foil is bonded to a previously manufactured laminar magnetic element, the laminar magnetic element is heated. At least the surface on which the metal foil is placed is heated to at least the softening temperature of the polymer material, and preferably to the melting temperature thereof. As to the heating of the laminar magnetic element, it may be heated alone or together with the metal foil placed thereon. The metal foil may also be heated, when required.

**[0029]** When the laminar magnetic element is obtained by the extrusion, the metal foil is thermally compressed immediately after obtaining the laminar magnetic element by extrusion, while the laminar magnetic element is still at a relatively high temperature. Thus, the metal foil is preferably thermally pressed immediately after the extrusion. In this case, it is particularly preferred that the extrusion and the thermal pressing are performed as a continuous process. In this case, the laminar magnetic element, in particular the surface thereof, may be heated as required. Heating rollers for example may be used for this purpose.

**[0030]** The metal foil to be used preferably has, on the surface that is to be in contact with the laminar magnetic element, nodular or bumpy protrusions, which ensure adequate bond strength with the laminar magnetic element. For such a metal foil, the use of a metal foil of which surface has irregularities formed by electrodepositing metal bumps and which is commercially available as an electrolytic metal foil (for example, an electrolytic copper foil) is preferred. In this case, the metal foil is preferably placed so that the uneven surface is in contact with the laminar magnetic element. By using such a surface having the irregularities, the adhesion between the metal foil and the laminar magnetic element is improved through the anchoring effect of the bumps.

**[0031]** In the method of manufacturing the antenna device according to the present invention, when bonding the metal foil and forming the antenna wiring pattern by etching, the metal foil has a sufficient area to be able to form a plurality of the antenna wirings. Thus, a plurality of the antenna wirings are formed by etching. In this case, this may be divided after etching into the laminar magnetic elements each having an individual antenna wiring to obtain separate antenna devices.

**[0032]** As described above, the antenna device of the present invention may have a required electronic component (s) (for example, an IC chip, a capacitors or the like) in addition to the antenna wiring, and may have other wiring(s) to connect in a prescribed manner such an electronic component(s) with the antenna wiring. Such wiring is also preferably formed, as required, simultaneously during etching to form the antenna wiring.

**[0033]** It is noted that the electronic component(s) is preferably mounted after the antenna wiring and other required wiring are formed by etching. When forming a plurality of the antenna wirings by etching, mounting is preferably performed before dividing into the separate antenna devices.

**[0034]** In the above description with reference to the drawings, the antenna wiring is present on one of the surfaces of the laminar magnetic element. In other embodiment of the antenna device according to the present invention, the antenna wirings are present on the both sides of the laminar magnetic element. As seen from the above description as to the manufacturing method of the antenna device, such antenna device can be manufactured by directly bonding the metal foils to the both sides of the laminar magnetic element, and then etching the metal foils.

**[0035]** When the metal foil is bonded to one surface of the laminar magnetic element, the thermally pressing is preferably used. Upon thermally pressing, the laminar magnetic element and the metal foil are both heated, and then they are cooled. Since thermal expansion coefficient (particularly, linear expansion coefficient) of them are different, the composite of the metal foil and the laminar magnetic element having been thermally pressed together includes an inner stress due to the thermal expansion coefficient difference even though the composite apparently looks flat. When a part of the metal foil is removed by etching the metal foil thereafter, such inner stress appears so that the composite shows warpage.

**[0036]** However, when the metal foils are bonded to the both surfaces of the magnetic element as in the above mentioned embodiment, the inner stress is substantially still potential even with the difference in the thermal expansion coefficients because the metal foils are present on the both sides of the laminar magnetic element, so that improved flatness is achieved. In this sense, it is preferable for the antenna device according to the present invention that the antenna wirings are present on the both sides of the laminar magnetic element. In this case, it is preferable that the antenna wirings are formed so as to oppose to each other through the laminar magnetic element. That is, it is preferable that one antenna wiring is overlapped with the other antenna wiring through the laminar magnetic element. For example, one antenna wiring is at least partly overlapped with the other antenna wiring, and one antenna wiring is preferably substantially just overlapped with the other antenna wiring.

**[0037]** It is noted that when the antenna wirings are present on the both sides of the laminar magnetic element, a through hole is formed through the laminar magnetic element at an end of one antenna wiring, and the through hole is filled with an electrically conductive element or a plating layer is formed on the inside of the through hole so as to surely achieve the electric conductivity between the both antenna wirings.

**[0038]** The presence of the antenna wirings on the both sides of the laminar magnetic element allows the absolute length of the antenna wiring to be longer than the presence of the antenna wiring on one side of the laminar magnetic element when the both elements are of the same size. This means the size of the antenna device can be smaller. Since the absolute length of the antenna wiring becomes longer, it is able to give a more margin to the inductance/capacitance adjustment, and also a more freedom to the antenna wiring design, so that it becomes possible that the geometric limitations upon the formation of the antenna wiring becomes more relaxed compared with the formation of the single antenna wiring on one side of the laminar magnetic element.

[Examples]

**[0039]** Manufacture of laminar magnetic element The following magnetic material and polymer material were used:

- magnetic material
  Finemet (registered trademark) FP-FT-5M (manufactured by Hitachi Metal K.K., planular magnetic filler, average particle size: 30-41 μm, apparent density; 0.5-0.7 g/cm3, tap density: 1.0-1.4 g/cm3)
- polymer material
  Daisolac (registered trademark) C-130 (chlorinated polyethylene, manufactured by Daiso Co. Ltd., true density 1.11 g/cm3)

**[0040]** These magnetic material and polymer material were weighed on an electronic scale to obtain ratios as shown in Table 1 below, and then mixed for 1 minute in a sample container using a plastic spatula to obtain a mixed powder.

**[0041]**

Table 1

| | Example 1 | Example 2 |
|---|---|---|
| Magnetic material | 88.0 % by mass | 80.0 % by mass |
| Polymer material | 12.0 % by mass | 20.0 % by mass |

**[0042]** After this, 45 cc of the mixed powder was put in a powder kneader (manufactured by Toyo Seiki Seisakusho, Labo Plastomill: Model 50C150, blade R60B) and kneaded for 15 minutes at a set temperature of 100 °C and a blade rotation of 60 rotations per minute (rpm) to obtain a kneaded lump.

**[0043]** The kneaded lump obtained as described above was made into a sandwich construction of iron plate/Teflon sheet/thickness adjusting spacer (SUS, thickness 0.5mm) + kneaded lump/Teflon sheet/iron plate, and pre-pressed form 3 minutes using a thermal pressure pressing machine (manufactured by Toho Press Seisakusho, hydraulic molding machine: Model T-1) at a set temperature of 100 °C and a set pressure of 1 MPa, after which actual pressing was performed at 15 MPa for 4 minutes. After this, cold pressing was performed at 1 MPa for 4 minutes using a cold pressing machine (manufactured by Toho Press Seisakusho, hydraulic molding machine: Model T-1) with circulation of water set at a temperature of 22 °C by a chiller, thereby obtaining a 12 cm x 12 cm magnetic sheet (thickness: 0.4-0.6 mm) as the laminar magnetic element.

**[0044]** Evaluation of magnetic properties of the laminar magnetic element:

Test samples (15 mm x 5 mm) were cut out from the laminar magnetic element obtained as described above, and the magnetic permeability and the saturation magnetic flux density were measured using the following equipments:

Magnetic permeability measurement: ultra-high frequency band permeameter PMF-3000 (manufactured by Ryowa Electronics Co., Ltd.)

Saturation magnetic flux density measurement: vibrating sample magnetometer (VSM) BHV-50H (manufactured by Riken Electronics Co., Ltd.) Table 2 below shows the results of the magnetic permeability (unit: H/m) at 14 MHz bandwidth and the saturation magnetic flux density (unit: G) of the test samples.

**[0045]**

Table 2

| | Example 1 | Example 2 |
|---|---|---|
| Magnetic permeability (@14 MHz) | 30.70 | 43.00 |
| Saturation magnetic flux density (G) | 2986 | 2674 |

**[0046]** Next, using a thermal pressure pressing machine, an electrolytic copper foil(manufactured by Fukuda Metal Foil/Powder Industry, CF-T8GD-STD-35, thickness 35 μm), one of which sides was roughened and was treated with a nickel-based compound, was thermally pressed on one surface of each magnetic sheet of Examples 1 and 2.

**[0047]** As the pressing conditions, a sandwich construction consisting of iron plate/silicone rubber/Teflon sheet/thickness adjusting spacer (SUS, thickness 0.5 mm) + magnetic sheet + electrolytic copper foil/Teflon sheet/silicone rubber/iron plate was pressed for 4 minutes with a thermal pressure pressing machine (manufactured by Toho Press Seisakusho, hydraulic molding machine: Model T-1) at 120 °C and 4 MPa. It is noted that the nodule surface (roughened surface having irregularities) of the electrolytic copper foil was placed adjacent to the magnetic sheet.

**[0048]** After this, cold pressing was performed at 1 MPa for 4 minutes using a cool pressing machine (manufactured by Toho Press Seisakusho, hydraulic molding machine: Model T-1) with circulation of water set at a temperature of 22 °C by a chiller, thereby preparing a 10 cm x 10 cm magnetic sheets with the copper foil.

**[0049]** With respect to the magnetic sheet with the copper foil obtained as described above, test samples were measured in the same way as before in the above, for the magnetic permeability and the saturation magnetic flux density. Table 3 below shows the results of the measurements.

**[0050]**

Table 3

| | Example 1 | Example 2 |
|---|---|---|
| Magnetic permeability (@14 MHz) | 36.80 | 51.30 |
| Saturation magnetic flux density (G) | 3495 | 3265 |

**[0051]** As is evident when Table 2 and Table 3 are compared, it can be seen that the magnetic permeability and the saturation magnetic flux density are both improved by bonding the copper foil.

**[0052]** Each magnetic sheet with the copper foil, obtained as described above, was given an etching treatment, and a spiral antenna pattern as shown in Figure 1 was formed on the magnetic sheet to obtain the antenna devices of the present invention. After this, using an LCR Meter 4263A (manufactured by Hewlett Packard), measuring probes were placed on both ends of the antenna and the inductance L and Q values were measured at 10 kHz. The results are shown in Table 4 below.

**[0053]**

Table 4

| | Example 1 | Example 2 |
|---|---|---|
| L | 86.83 H | 14.9 H |
| Q | 8.7 | 4.9 |

**[0054]** From the measurement results in Table 4, it can be seen that the antenna device of the present invention, having the spiral antenna pattern, shows sufficient inductance L and Q values, and thus performs the functions as an antenna device.

Industrial Applicability

**[0055]** The present invention provides the antenna device which can be manufactured more conveniently as well as the method for manufacturing such device.

## Claims

1. An antenna device comprising:

   (A) a laminar magnetic element formed of a magnetic composition containing a magnetic material(s) and a polymer material(s), and
   (B) an antenna wiring provided on at least one of the surfaces of the laminar magnetic element.

2. The antenna device according to Claim 1, **characterized by** the antenna wiring protruding from the surface of the laminar magnetic element.

3. The antenna device according to Claim 1 or 2, wherein the magnetic material is at least one of selected from the group consisting of an iron-silicon alloy, a ferrite, an iron-nickel alloy, a Sendust alloy, and an amorphous alloy.

4. The antenna device according to any one of Claims 1-3, wherein the polymer material is at least one selected from a polyethylene, a polypropylene, a polyethylene chloride, a polyvinyl chloride, a polyvinylidene fluoride, a polystyrene, a polyoxymethylene, an ethylene-vinyl acetate copolymer, an ethylene-butyl acrylate copolymer, a polyethylene terephthalate, a Nylon, an acrylonitrile-butadiene-styrene terpolymer, and a polyphenylene sulfide.

5. The antenna device according to any one of Claims 1-4, **characterized by** the antenna wiring being formed of an electrolytic metal foil whose uneven surface is in contact with the laminar magnetic element.

6. The antenna device according to any one of Claims 1-5, **characterized by** the antenna wiring being provided on the surface of the laminar magnetic element by thermal pressing.

7. The antenna device according to any one of Claims 1-6, **characterized by** the magnetic composition containing 60-95 parts by mass of the magnetic material and 40-5 parts by mass of the polymer material.

8. The antenna device according to any one of Claims 1-7, **characterized by** further comprising an IC chip connected to the antenna wiring.

9. A method of manufacturing an antenna device having a laminar magnetic element and an antenna wiring provided thereon, the method comprising:

   (1) a step to obtain the laminar magnetic element from a magnetic composition containing a magnetic material (s) and a polymer material(s),
   (2) a step to directly bond a metal foil on at least one of surfaces of the laminar magnetic element, and
   (3) a step to etch the metal foil to form the antenna wiring having a prescribed pattern.

10. The method of manufacturing the antenna device according to Claim 9, **characterized by** step (1) and step (2) being performed continuously by thermally pressing the metal foil immediately after obtaining the laminar magnetic element by extrusion.

11. The method of manufacturing the antenna device according to Claim 9 or 10, **characterized by** the step (2) being performed by placing the metal foil over the extruded material, and then thermally pressing.

12. The method of manufacturing the antenna device according to any one of Claims 9-11, **characterized by** a plurality of the antenna wiring being formed in the step (3).

13. The method of manufacturing the antenna device according to any one of Claims 9-12, **characterized by** mounting a prescribed IC chip associated with each antenna wiring by placing the IC chip on the laminar magnetic element, and electrically connecting each IC chip to each antenna wiring in a prescribed manner.

**14.** The method of manufacturing the antenna device according to any one of Claims 9-13, **characterized by** further comprising, when a plurality of the antenna wirings are formed, a step, after mounting, of dividing into separate antenna devices each having a single antenna wiring.

**15.** An IC tag for an RFID system comprising the antenna device according to any one of Claims 1-8.

**16.** A reader/writer for an RFID system comprising the antenna device according to any one of Claims 1-8.

**17.** A portable electronic apparatus comprising the antenna device according to any one of Claims 1-8.

Fig. 1

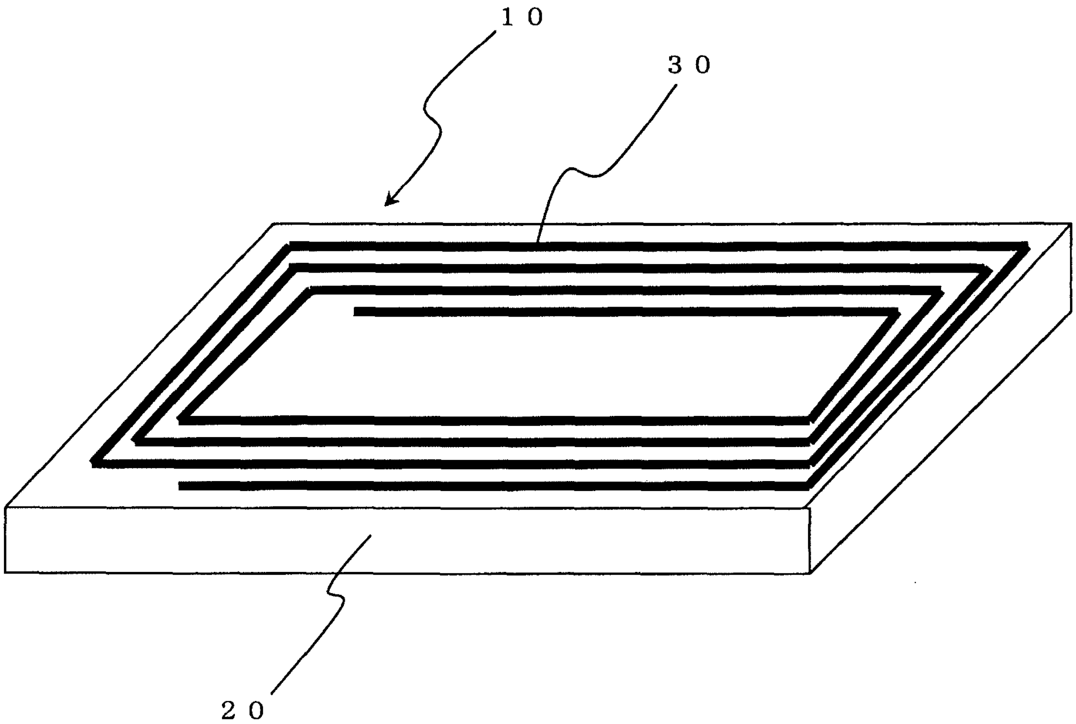
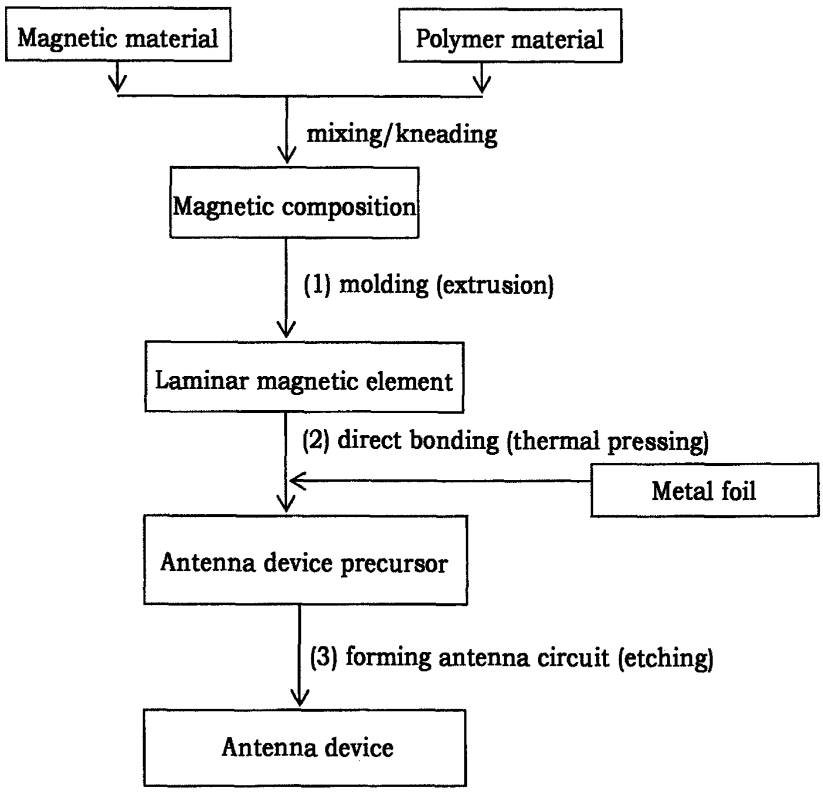

1 0
3 0
2 0

Fig. 2


Magnetic material
Polymer material
mixing/kneading
Magnetic composition
(1) molding (extrusion)
Laminar magnetic element
(2) direct bonding (thermal pressing)
Metal foil
Antenna device precursor
(3) forming antenna circuit (etching)
Antenna device

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2007/065732

A. CLASSIFICATION OF SUBJECT MATTER
*H01Q7/06*(2006.01)i, *H01P11/00*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01Q7/06, H01P11/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

| | | | |
|---|---|---|---|
| Jitsuyo Shinan Koho | 1922-1996 | Jitsuyo Shinan Toroku Koho | 1996-2007 |
| Kokai Jitsuyo Shinan Koho | 1971-2007 | Toroku Jitsuyo Shinan Koho | 1994-2007 |

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | JP 2005-317674 A (NEC Tokin Corp.), 10 November, 2005 (10.11.05), Full text; all drawings & EP 1592085 A1 & US 2005/237254 A1 | 1-4,7,8, 15-17 |
| X<br>Y | JP 3491670 B2 (Mitsubishi Materials Corp.), 14 November, 2003 (14.11.03), Full text; all drawings (Family: none) | 1-4,7,8, 15-17<br>6,11-14 |
| X<br>Y | JP 2005-309811 A (Mitsubishi Materials Corp.), 04 November, 2005 (04.11.05), Full text; Fig. 2 (Family: none) | 1-5,7-10, 15-17<br>6,11-14 |

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 05 September, 2007 (05.09.07) | 18 September, 2007 (18.09.07) |
| Name and mailing address of the ISA/ Japanese Patent Office | Authorized officer |
| Facsimile No. | Telephone No. |

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**INTERNATIONAL SEARCH REPORT**

International application No.
PCT/JP2007/065732

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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| X<br><br>Y | JP 2005-286997 A (TDK Corp.),<br>13 October, 2005 (13.10.05),<br>Full text; all drawings<br>(Family: none) | 1-5,7-10,<br>15-17<br>6,11-14 |
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## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


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