(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 460 766 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.03.2019 Bulletin 2019/13

(51) Int Cl.:
G07D 7/01 *(2016.01)* *B42D 25/373* *(2014.01)*

(21) Application number: 18195209.4

(22) Date of filing: 18.09.2018

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: 22.09.2017 JP 2017181935

(71) Applicants:
- **Glory Ltd.**
  Hyogo 670-8567 (JP)
- **Toppan Printing Co., Ltd.**
  Taito-ku, Tokyo 110-0016 (JP)

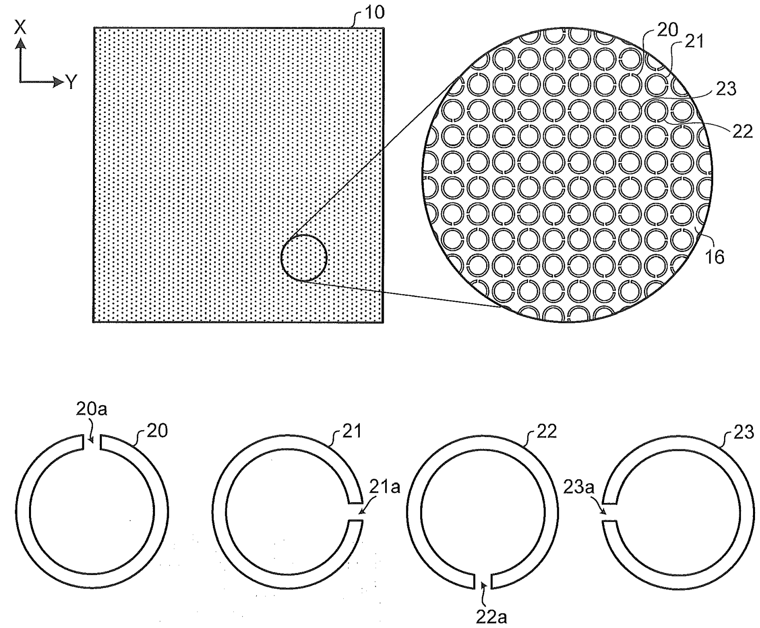
(72) Inventors:
- **MUTA, Keitaro**
  Hyogo, 670-8567 (JP)
- **GOCHO, Satoshi**
  Tokyo, 110-0016 (JP)

(74) Representative: **SSM Sandmair Patentanwälte Rechtsanwalt Partnerschaft mbB**
Joseph-Wild-Straße 20
81829 München (DE)

(54) COUNTERFEIT PREVENTION STRUCTURE AND COUNTERFEIT PREVENTION MEDIUM

(57) One object is to determine with a high accuracy authenticity of a counterfeit prevention medium having a counterfeit prevention structure. The counterfeit prevention structure provided on the medium to determine the authenticity of the medium includes a hybrid area in which a plurality of types of split ring resonators is formed in a mixed state in a predetermined ratio. Each split ring resonator includes an open part. The direction of the open part of each type of the split ring resonators is different from each other.
Most Illustrative Drawing: FIG. 1

FIG.1



Printed by Jouve, 75001 PARIS (FR)

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a counterfeit prevention structure capable of preventing counterfeiting and a counterfeit prevention medium including the counterfeit prevention structure.

2. Description of the Related Art

[0002] Conventionally, a counterfeit prevention structure that prevents counterfeiting is arranged in a sheet-like valuable medium such as a banknote (paper currency), a stock certificate, a bond, a check, a coupon, and the like. For example, Japanese Patent Application Laid-Open No. 2016-000498 discloses a technique of using a conductive layer, in which split ring resonators (SRRs) are formed, as the counterfeit prevention structure. The SRRs, each of which an outer diameter is around several hundred micrometers, have effect on terahertz electromagnetic waves. Metamaterial formed by the minute SRRs is used for counterfeit prevention.

[0003] Specifically, a conductive layer, in which SRRs of a predetermined shape are arranged in a matrix layout at regular intervals, is formed such that transmittance of a predetermined value is obtained when the SRRs are irradiated with terahertz electromagnetic waves of a specific frequency. Such a conductive layer is arranged inside or on a medium as the counterfeit prevention structure. The counterfeit prevention structure is irradiated with the terahertz electromagnetic waves, and the authenticity of the medium can be determined based on the obtained value of the transmittance.

[0004] The transmittance of the terahertz electromagnetic waves penetrating the conductive layer changes depending on the relation between a polarization direction of the terahertz electromagnetic waves and directions of open parts of the SRRs. The conductive layer is divided in a plurality of areas, and the open part directions of the SRRs in each area are different. By this structure, a counterfeit prevention structure in which the transmittance in each area is different can be obtained. The transmittance is measured while scanning each of the areas of the counterfeit prevention structure with the terahertz electromagnetic waves, and the authenticity of the medium is determined based on whether the change in the measured transmittance matches with a transmittance and a scan width of each of the areas.

[0005] In the conventional technique, however, the authenticity of a medium in which the counterfeit prevention structure is arranged may not be determined with a high accuracy. For example, positions of a transmitting unit that transmits the terahertz electromagnetic waves and a receiving unit that receives the terahertz electromagnetic waves are fixed in an apparatus, and when measuring the transmittance of the terahertz electromagnetic waves, the medium is transported such that the counterfeit prevention structure thereof passes between the transmitting unit and the receiving unit. As the medium is transported, when the counterfeit prevention structure made by the SRRs blocks the terahertz electromagnetic waves between the transmitting unit and the receiving unit, different transmittance is obtained depending on the directions of the open parts of the SRRs. At this time, if the transported medium inclines (skewed transport state), an angle between the polarization direction of the terahertz electromagnetic waves and the directions of the open parts changes, and the transmittance also changes. For example, in a certain counterfeit prevention structure that is designed such that the angle between the polarization direction of the terahertz electromagnetic waves and the directions of the open parts are 60 degrees, the value of the transmittance changes between 30% and 60% when the medium is inclined by between -15 degrees and 15 degrees. The authenticity is determined by comparing the value of the transmittance with a threshold value. However, if the threshold value is set so as to permit such a huge change in the transmittance, the authenticity cannot be determined with a high accuracy.

[0006] A range of variation of the transmittance due to the inclination of the medium varies according to the directions of the open parts of SRRs. In the conventional technique, the counterfeit prevention structure is divided in a plurality of areas, and the directions of the open parts in each of the areas are set in different directions. In this case, when the medium is inclined, the transmittance of each of the areas changes in a different range of variation depending on the directions of the open parts. Therefore, the change in the transmittance obtained by scanning the counterfeit prevention structure is different from the original change so that the authenticity may not be determined with a high accuracy.

SUMMARY OF THE INVENTION

[0007] The present invention has been made to solve the problems in the conventional technique. One object of the present invention is to provide a counterfeit prevention structure and a counterfeit prevention medium that allow highly accurate determination of the authenticity.

[0008] To solve the above problems and to achieve the above object, a counterfeit prevention structure according to one aspect of the present invention is provided on a medium to determine authenticity of the medium. The counterfeit prevention structure includes a hybrid area in which a plurality of types of split ring resonators is formed in a mixed state in a predetermined ratio. Each split ring resonator includes an open part. A direction of the open part of each type of the split ring resonators is different from each other.

[0009] A counterfeit prevention medium according to another aspect of the present invention is a counterfeit prevention medium including the above counterfeit prevention structure.

[0010] The above and other objects, features, advantages and technical and industrial significance of this invention will be better understood by reading the following detailed description of presently preferred embodiments of the invention, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0011]

FIG. 1 is a view indicating one embodiment of a counterfeit prevention structure.
FIG. 2 is a view for explaining a shape of a split ring resonator.
FIGS. 3A to 3C are views indicating examples of patterns formed by using a plurality of types of the split ring resonators.
FIG. 4 is a view indicating an example of frequency characteristics of transmittance obtained when an area in which the split ring resonators are arranged is irradiated with terahertz electromagnetic waves.
FIG. 5 is a view indicating an example of another pattern formed by using a plurality of types of the split ring resonators.
FIG. 6 is a view for explaining an example of the transmittance of the counterfeit prevention structure.
FIG. 7 is a view of an example of the counterfeit prevention structure in which a plurality of types of the patterns is combined.
FIG. 8 is a view indicating another pattern obtained by rotating one of the patterns shown in FIGS. 3A to 3C.
FIG. 9 is a view for explaining a change in the transmittance of the terahertz electromagnetic waves observed in a counterfeit prevention medium provided with the counterfeit prevention structure shown in FIG. 7.
FIG. 10 is a view for explaining change in the transmittance obtained when a secondary resonance frequency is used.
FIG. 11 is a schematic diagram indicating a schematic internal configuration of an authenticity determination apparatus seen from a side thereof.
FIGS. 12A and 12B are schematic diagrams of the configuration shown in FIG. 11 when seen from above.
FIG. 13 is a block diagram indicating a schematic functional configuration of the authenticity determination apparatus.
FIG. 14 is a schematic cross section indicating another structural example of the counterfeit prevention structure.
FIG. 15 is a view indicating an example of a counterfeit prevention structure having split ring resonators in which directions of open parts are different.
FIG. 16 is a view indicating another example of the counterfeit prevention structure that is divided in a plurality of areas.

EMBODIMENTS

[0012] Exemplary embodiments of a counterfeit prevention structure and a counterfeit prevention medium according to the present invention are explained below in detail by referring to the accompanying drawings. One feature of the present invention is that a plurality of types of split ring resonators (SRRs) is used to obtain a predetermined value of transmittance when terahertz electromagnetic waves penetrate a counterfeit prevention structure.

[0013] The SRR has a ring-like shape and has an open part (Split). For example, the shape of the SRR can be substantially like the English character C in which an open part is provided in a circular ring shape. Alternatively, the shape of the SRR can be rectangular in which an open part is provided in a rectangular ring shape. For example, SRRs each having an open part in a ring-like shape are formed with conductive material on a sheet of insulating material. When irradiating the SRRs with a terahertz electromagnetic wave, depending on the frequency and the polarization direction of the terahertz electromagnetic wave, the transmittance of the terahertz electromagnetic wave changes. Specifically, the transmittance of the terahertz electromagnetic wave that resonates with the SRRs is lower than the transmittance of the terahertz electromagnetic wave that does not resonate with the SRRs.

[0014] Alternatively, for example, an SRR can be formed by carving a sheet of conductive material into a ring-like shape having an open part. Particularly, an SRR formed by carving conductive material is called a complementary split ring resonator (CSRR). Even in a complementary split ring resonator, when irradiating the SRR with the terahertz electromagnetic wave, depending on the frequency and the polarization direction of the terahertz electromagnetic wave, the transmittance of the terahertz electromagnetic wave penetrating the sheet changes. Specifically, the transmittance of the terahertz electromagnetic wave that resonates with the SRR is higher than the transmittance of the terahertz electromagnetic wave that does not resonate with the SRR.

[0015] By arranging a large number of SRRs in an area, the transmittance of the terahertz electromagnetic wave of a specific frequency in this area can be controlled. For example, the large number of SRRs are arranged in a matrix layout in which the SRRs are arranged in a longitudinal direction and a lateral direction at regular intervals. Alternatively, the SRRs are arranged in a checkered pattern layout or in a honeycomb pattern layout.

[0016] One method of forming an area having a predetermined transmittance is to form the ring-like SRR by using conductive material on a sheet of insulating material. Another method is to form the SRR by carving a sheet of conductive material into a ring-like shape. An area, in which the transmittance of terahertz electromagnetic wave is a predetermined value, can be formed by using any of the above methods; however, a case of forming the SRR by carving a sheet of conductive material is explained as an example in the present embodiment.

[0017] The counterfeit prevention structure according to the present embodiment includes a conductive layer. When the prevention structure is irradiated with the terahertz electromagnetic wave that has a predetermined frequency and a predetermined polarization direction, the conductive layer shows a transmittance of a predetermined value. At least two types of the SRRs of which the directions of the open parts differing by 90 degrees are arranged in the conductive layer. Coordinate axes are shown in each of the drawings to facilitate understanding of the correspondence of the polarization direction of the terahertz electromagnetic waves used for measuring the transmittance, the direction of the open part of the SRR, and the like. The predetermined direction used in the context of the terahertz electromagnetic waves is a direction selected as the polarization direction of the terahertz electromagnetic waves used in the measurement of the transmittance. The predetermined frequency in the context of the terahertz electromagnetic waves is a frequency (resonance frequency) at which the terahertz electromagnetic waves resonate with the SRRs, and it is the frequency selected as the frequency of the terahertz electromagnetic waves used in the measurement of the transmittance. To detect a difference in the transmittance depending on the types of the SRRs, it is desirable that the predetermined frequency of the terahertz electromagnetic wave is the frequency at which the transmittance greatly changes when the direction of the open part of the SRR is changed with respect to the predetermined direction (polarization direction). Specifically, it is desirable that the terahertz electromagnetic wave has a frequency band including the central frequency corresponding with the peak frequency at which the transmittance has a peak value. If the peak frequency is stable in the counterfeit prevention structures, the terahertz electromagnetic wave having a single frequency can be also used. If it is possible to accommodate the variation in the transmittance, the terahertz electromagnetic wave can have the predetermined frequency that is not the peak frequency.

[0018] FIG. 1 is a view indicating one embodiment of a counterfeit prevention structure 10. A plan view of the counterfeit prevention structure 10 is shown in the upper left part of FIG. 1 and a partially enlarged view of a partial area of the counterfeit prevention structure 10 is shown in the upper right part of FIG. 1. Moreover, a plurality of types of SRRs 20 to 23 included in the counterfeit prevention structure 10 is shown in the bottom part of FIG. 1. This counterfeit prevention structure 10 is arranged in a counterfeit prevention medium (hereinafter, "medium") to prevent counterfeiting of the medium. The medium is, for example, a sheet valuable medium. Such a medium includes a banknote (paper currency), a stock certificate, a bond, a check, and a coupon.

[0019] FIG. 1 shows an example of the counterfeit prevention structure 10 in which the plurality of types of the SRRs 20 to 23 are arranged in a matrix layout. The SRRs have open parts in different directions from each other. The plurality of types of the SRRs 20 to 23 is mixed in a predetermined ratio. In such a structure, transmittance of the terahertz electromagnetic wave of a specific frequency that penetrates the counterfeit prevention structure 10 can be maintained to a predetermined value.

[0020] The counterfeit prevention structure 10 includes a conductive layer 16 in which the plurality of types of the SRRs 20 to 23 are formed in the matrix layout at regular intervals. Each of the SRRs 20 to 23 has a shape substantially like the English character C in which a part of a circular ring is cut to form open part 20a to 23a. As shown in FIG. 1, when seen from a center of the ring part, the SRR 20 has the open part 20a in the positive X-axis direction. When seen from the center of the ring part, the SRR 21 has the open part 21a in the positive Y-axis direction. When seen from the center of the ring part, the SRR 22 has the open part 22a in the negative X-axis direction. When seen from the center of the ring part, the SRR 23 has the open part 23 a in the negative Y-axis direction. The shape of the SRR 20 matches with the shape of the SRR 21 when the SRR 20 is rotated clockwise by 90 degrees, the shape of the SRR 21 matches with the shape of the SRR 22 when the SRR 21 is rotated clockwise by 90 degrees, and the shape of the SRR 22 matches with the shape of the SRR 23 when the SRR 22 is rotated clockwise by 90 degrees. That is, the directions of the open parts of the SRRs 20 to 23 vary by 90 degrees from each other. The direction of the open part mentioned in the present embodiment is the direction when see from the center of the ring part of the SRR having the open part.

[0021] As shown in the partially enlarged view in the upper right part of FIG. 1, the four types of the SRRs 20 to 23 are arranged at regular intervals and form a predetermined pattern. Specifically, a basic pattern of a two-by-two matrix is formed by arranging the four SRRs 20 to 23 in two rows and two columns. In the basic pattern, the SRR 21 is arranged on the right side (in the positive Y-axis direction) of the SRR 20, the SRR 23 is arranged below (in the negative X-axis direction) the SRR 20, and the SRR 22 is arranged on the right side of the SRR 23. The four types of the SRRs 20 to 23 are arranged at regular intervals by repeating this basic pattern. The details about the basic pattern formed by using the four SRRs 20 to 23 will be explained later.

[0022] The SRRs 20 to 23 are formed by carving the conductive layer 16 made of conductive material into a shape substantially like the English character C. The four SRRs 20 to 23 have the same structure except that the directions (position in the ring part) of the open parts 20a to 23a thereof are different. The SRRs 21 to 23 can be obtained by rotating the SRR 20 and therefore the specific structure of the SRRs 20 to 23 will be explained below by using the SRR 20 as an example.

[0023] FIG. 2 is a view for explaining the shape of the SRR 20. A plan view of the SRR 20 is shown in the upper part of FIG. 2 and a cross-section along a line AA shown in the plan view is shown in the lower part of FIG. 2. The counterfeit prevention structure 10 includes a base member 17 made of insulating material and a thin conductive layer 16 formed on a surface of the base member 17. The base member 17 is made of insulating material, such as paper and resin, through which the terahertz electromagnetic waves can penetrate. On the other hand, the conductive layer 16 is made of conductive material, such as Al, Fe, Au, Cu, Ag, Mg, Zn, and Sn, that blocks the terahertz electromagnetic waves.

[0024] The SRR 20 is formed by carving from the conductive layer 16, which is formed on the base member 17, an area having the shape substantially like the English character C. Specifically, the SRR 20 is formed by carving the ring-shaped conductive layer 16 having a predetermined width in the diameter direction while leaving behind only the open part 20a. The area corresponding to the ring part having the shape substantially like the English character C is a groove and a surface of the base member 17 is exposed at the bottom of the groove. In an area other than the ring part, including the open part 20a, the surface of the base member 17 is covered with the conductive layer 16. Each of other SRRs 21 to 23 can be formed by changing the area that is left behind as the open part 21a to 23a when forming the groove having the shape substantially like the English character C. The machining method to form the SRR in the conductive layer, the functions of the SRR, and the like are disclosed, for example, in Japanese Patent Application Laid-Open No. 2016-000498.

[0025] A length and a width of the sheet-like counterfeit prevention structure 10 are, for example, 20 mm. An inner diameter d of the SRR 20, shown in the upper part of FIG. 2, is a few hundred μm and a width g of the open part 20a is a few ten μm. A width W of the SRR 20, shown in the lower part of FIG. 2, in a diameter direction thereof is a few ten μm. Other SRRs 21 to 23 are formed with the same size as that of the SRR 20. In the counterfeit prevention structure 10, the SRRs 20 to 23 are arranged vertically and horizontally at regular intervals and form the matrix layout. A distance between adjacent SRRs 20 to 23 is a few ten μm. For example, in 10 mm long, several tens of SRRs 20 to 23 is arranged at regular intervals. The shape of each SRRs 20 to 23 and the layout of the SRRs 20 to 23 are determined such that, resonance occurs when the SRRs 20 to 23 are irradiated with the terahertz electromagnetic wave of the predetermined frequency, and the terahertz electromagnetic wave penetrate the SRRs 20 to 23 at predetermined transmittance. The frequency of the terahertz electromagnetic wave is set, for example, between 0.1 THz and 1 THz. A dimension of an area of the conductive layer 16 irradiated with the terahertz electromagnetic wave is determined based on the SRRs 20 to 23 as the target for irradiation and is about 1 mm to about 5 mm in a diameter in a half-band width.

[0026] A minimal configuration of the counterfeit prevention structure 10 is shown in FIG. 2. As long as the properties of the conductive layer 16 with respect to the terahertz electromagnetic wave are not affected, another layer may be provided on the conductive layer 16 and/or below the base member 17. Moreover, another layer may be provided between the conductive layer 16 and the base member 17.

[0027] The thin counterfeit prevention structure 10 can be embedded in the medium, such as the coupon, that is the target of counterfeit prevention. Alternatively, the counterfeit prevention structure 10 can be affixed to the medium. For example, as the counterfeit prevention structure 10, both the conductive layer 16 and the base member 17 are newly arranged in the medium such as the coupon. For another example, the medium, such as the coupon, itself is used as the base member 17, and the conductive layer 16 is formed on the medium.

[0028] FIGS. 3A to 3C are views indicating examples of patterns formed by using the SRRs 20 to 23. A pattern that functions as a basic unit is shown in the left part of FIGS. 3A to 3C. A partial area of the counterfeit prevention structure 10 formed by repeatedly arranging these basic pattern in a matrix layout is shown in the right part of FIGS. 3A to 3C. Each pattern constitutes a hybrid area in which the plurality of types of the SRRs 20 to 23 are mixed in a predetermined ratio.

[0029] A first pattern 31 shown in FIG. 3A is a two-by-two matrix pattern. In the first pattern 31, the SRR 20 is arranged in the upper left corner, the two SRRs 22 are arranged on the right side of and below the SRR 20, and the other SRR 20 is arranged on the right side of the lower SRR 22. The first pattern 31 is the hybrid area in which two types of the SRRs, that is, the SRRs 20 and 22, are mixed in the predetermined ratio. The first pattern 31 is constituted by only the SRRs 20 and 22 that have the open parts 20a and 22a in the X-axis direction.

[0030] When the first pattern 31 is irradiated with the terahertz electromagnetic wave of the predetermined frequency (primary resonance frequency), which has the polarization direction in the X-axis direction, the transmittance of the SRRs 20 and 22, of which the open parts 20a and 22a are arranged in the X-axis direction that is the polarization direction, will be maximum. Therefore, when the counterfeit prevention structure 10 constituted by the first pattern 31 is irradiated with the terahertz electromagnetic wave having the polarization direction in the X-axis direction, the transmittance will be maximum.

[0031] About the order of the resonance frequency will be explained next. FIG. 4 is a view indicating an example of frequency characteristics of transmittance obtained when the area in which the SRRs are arranged is irradiated with the terahertz electromagnetic wave. The frequency characteristics shown in FIG. 4 is obtained when, as shown in FIGS. 3A to 3C, a large number of the SRRs having the open parts are arranged at regular intervals in a sufficiently wider area than the area irradiated with the terahertz electromagnetic wave.

[0032] When the polarization direction of the emitted terahertz electromagnetic wave and the directions of the open parts of the SRRs formed in the area irradiated with the terahertz electromagnetic wave match, that is, when both the directions are parallel, the frequency characteristics shown with a solid line in FIG. 4 is obtained. On the other hand, when the polarization direction of the emitted terahertz electromagnetic wave and the directions of the open parts of the SRRs formed in the area irradiated with the terahertz electromagnetic wave are orthogonal, the frequency characteristics shown with a dotted line in FIG. 4 is obtained. Specifically, for example, when the directions of the open parts of the SRRs are in the X-axis direction, the frequency characteristics as shown with the solid line will be obtained if the polarization direction of the terahertz electromagnetic wave matches with the X-axis direction, and the frequency characteristics shown with the dotted line will be obtained if the polarization direction of the terahertz electromagnetic wave matches with the Y-axis direction.

[0033] As shown with the solid line in FIG. 4, two peaks P1 and P2 are clearly observed when the directions of the open parts of the SRRs and the polarization direction of the terahertz electromagnetic wave match. On the other hand, as shown with the dotted line in FIG. 4, one peak V1 is clearly observed when the directions of the open parts of the SRRs and the polarization direction of the terahertz electromagnetic wave are orthogonal. The frequencies at which the peaks are obtained are referred to as P1, V1, and P2 sequentially from the low frequency side.

[0034] As has been mentioned above, it is desirable that the frequency (predetermined frequency) of the emitted terahertz electromagnetic wave is the resonance frequency at which the transmittance greatly changes when the directions of the open parts of the SRRs are changed with respect to the polarization direction (predetermined direction) of the emitted terahertz electromagnetic wave. When comparing a ratio of the dotted line showing transmittance with respect to Y-polarization to the solid line showing transmittance with respect to X-polarization at each peak P1, V1, and P2, the ratios at P1 and V1 are bigger than the ration at P2. To compare the difference in each of the transmittance obtained when the SRRs are irradiated with the terahertz electromagnetic waves having different polarization directions, it is preferable to adopt the peak P1 and the peak V1. Accordingly, the present embodiment is explained by taking the frequency of the peak P1 as a primary resonance frequency and by taking the frequency of the peak V1 as a secondary resonance frequency. As has been mentioned above, it is allowable to take the frequency band including the frequency of the peak P1 as the primary resonance frequency, and take the frequency band including the frequency of the peak V1 as the secondary resonance frequency.

[0035] A second pattern 32 shown in FIG. 3B is a two-by-two matrix pattern. In the second pattern 32, the SRR 20 is arranged in the upper left corner, the SRR 21 is arranged on the right side of the SRR 20, the SRR 22 is arranged below the SRR 20, and the other SRR 20 is arranged on the right side of the lower SRR 22. The second pattern 32 is obtained by replacing the upper right SRR 22 of the first pattern 31 with the SRR 21. The second pattern 32 is the hybrid area in which three types of the SRRs, that is, the SRRs 20 to 22, are mixed in the predetermined ratio. The second pattern 32 is constituted by three SRRs 20 and 22 having the open parts 20a and 22a in the X-axis direction and one SRR 21 having the open part 21a in the Y-axis direction. A ratio of the number of the SRRs 20 and 22 having the open parts 20a and 22a thereof parallel to the X-axis direction and the number of the SRR 21 having the direction of the open part 21a thereof orthogonal to the X-axis direction is 3:1. When four SRRs arranged in the two-by-two matrix pattern are selected from the area in which the SRRs of the second pattern 32 are arranged successively as shown in the right part of FIG. 3B, a ratio of the number of the SRRs having the open parts parallel to the X-axis direction and the number of the SRRs having the open parts orthogonal to the X-axis direction is 3:1. That is, when a desired area having the same shape as the second pattern 32 is selected, the ratio of the number of the SRRs 20 and 22 and the number of the SRRs 21 will always be the same.

[0036] When the SRRs are irradiated with the terahertz electromagnetic wave of the predetermined frequency (primary resonance frequency) having the polarization direction in the X-axis direction, the transmittance of the SRRs 20 and 22 having the open parts 20a and 22a parallel to the polarization direction (X-axis direction) will be maximum. On the other hand, the transmittance of the SRRs 21 and 23 having the open parts 21a and 23a orthogonal to the polarization direction (X-axis direction) will be minimum.

[0037] When the counterfeit prevention structure 10 having the plurality of types of the SRRs, of which the open parts have different directions, is irradiated with the terahertz electromagnetic wave, the transmittance will be a value between a transmittance Tx and Ty. The value Tx is a transmittance obtained when all the SRRs have the open parts in a direction parallel to the polarization direction of the terahertz electromagnetic wave. The value Ty is a transmittance obtained when all the SRRs have the open parts in a direction orthogonal to the polarization direction of the terahertz electromagnetic wave.

[0038] In the counterfeit prevention structure 10 according to the second pattern 32, a ratio of the number of the SRRs having the open parts parallel to the polarization direction (X-axis direction) and the number of the SRRs having the open parts orthogonal to the polarization direction (X-axis direction) is 3:1. Therefore, when the counterfeit prevention structure 10 of the second pattern 32 is irradiated with the terahertz electromagnetic wave of the predetermined frequency (primary resonance frequency) having the polarization direction in the X-axis direction, the transmittance will be a value near $(3\times Tx+Ty)/4$. The above-mentioned dimension of the area irradiated with the terahertz electromagnetic wave is determined so as to be at least larger than the area occupied by the SRRs arranged in the two-by-two matrix pattern.

[0039] A third pattern 33 shown in FIG. 3C is a two-by-two matrix pattern. In the third pattern 33, the SRR 20 is arranged in the upper left corner, the SRR 21 is arranged on the right side of the SRR 20, the SRR 23 is arranged below the SRR 20, and the SRR 22 is arranged on the right side of the SRR 23. The third pattern 33 is obtained by replacing the lower left SRR 22 of the second pattern 32 with the SRR 23 and replacing the lower right SRR 20 of the second pattern 32 with the SRR 22. The third pattern 33 is the hybrid area in which four types of the SRRs, that is, the SRRs 20 to 23, are mixed in the predetermined ratio. The third pattern 33 is constituted by two SRRs 20 and 22 having the open parts 20a and 22a in the X-axis direction and two SRRs 21 and 23 having the open parts 21a and 23a in the Y-axis direction. A ratio of the number of the SRRs 20 and 22 having the open parts 20a and 22a parallel to the X-axis direction and the number of the SRRs 21 and 23 having the open parts 21a and 23a orthogonal to the X-axis direction is 1:1. When four SRRs arranged in the two-by-two matrix pattern are selected from the area in which the SRRs of the third pattern 33 are arranged successively as shown the right part of FIG. 3C, a ratio of the number of the SRRs having the open parts parallel to the X-axis direction and the number of the SRRs having the open parts orthogonal to the X-axis direction is 1:1. That is, when a desired area having the same shape as the third pattern 33 is selected, the ratio of the number of the SRRs 20 and 22 and the number of the SRRs 21 and 23 will always be the same. The third pattern 33 shown in FIG. 3C is used in the counterfeit prevention structure 10 shown in FIG. 1.

[0040] When the counterfeit prevention structure 10 of the third pattern 33 is irradiated with the terahertz electromagnetic wave of the predetermined frequency (primary resonance frequency) having the polarization direction in the X-axis direction, the transmittance will be a value between the transmittance Tx obtained when all the SRRs having the open parts in a direction parallel to the polarization direction (X-axis direction) and the transmittance Ty obtained when all the SRRs having the open parts in a direction orthogonal to the polarization direction (X-axis direction). In the third pattern 33, a ratio of the number of the SRRs having the open parts parallel to the polarization direction (X-axis direction) and the number of the SRRs having the open parts orthogonal to the polarization direction (X-axis direction) is 1:1. Therefore, the transmittance will be a value near

[0041] $(Tx+Ty)/2$. The above-mentioned dimension of the area irradiated with the terahertz electromagnetic wave is determined so as to be at least larger than the area occupied by the two-by-two matrix pattern SRRs.

[0042] The pattern formed with the four types of the SRRs 20 to 23 is not limited to the two-by-two matrix pattern. FIG. 5 is a view indicating an example of another pattern formed by the SRRs 20 to 23. FIG. 5 shows, in the left part, a fourth pattern 34 that functions as a basic unit. A partial area of the counterfeit prevention structure 10 formed by repeatedly arranging the fourth pattern 34 in the matrix layout is shown in the right part of FIG. 5.

[0043] In the fourth pattern 34 shown in FIG. 5, nine SRRs 20 to 23 are arranged in a three-by-three matrix pattern. The SRR 22 is arranged at the center, the two SRRs 20 arranged adjacent to the central SRR 22 in the diagonal direction are in the upper left and the lower left of the SRR 22, and the two SRRs 22 arranged adjacent to the central SRR 22 in the diagonal direction are in the upper right and the lower right of the SRR 22. The two SRRs 23 are arranged on the left side and the right side of the central SRR 22, and the two SRRs 21 are arranged above and below the central SRR 22. The fourth pattern 34 is the hybrid area in which four types of the SRRs, that is, the SRRs 20 to 23, are mixed in the predetermined ratio. The fourth pattern 34 is constituted by five SRRs 20 and 22 having the open parts 20a and 22a in the X-axis direction and the four SRRs 21 and 23 having the open parts 21a and 23a in the Y-axis direction. A ratio of the number of the SRRs 20 and 22 having the open parts 20a and 22a parallel to the X-axis direction and the number of the SRRs 21 and 23 having the open parts 21a and 23a orthogonal to the X-axis direction is 5:4. When SRRs forming a three-by-three matrix are selected from the area in which the SRRs of the fourth pattern 34 are arranged successively, a ratio of the number of the SRRs having the open parts parallel to the X-axis direction and the number of the SRRs having the open parts orthogonal to the X-axis direction is 5:4. That is, when a desired area having the same shape as the fourth pattern 34 is selected, the ratio of the number of the SRRs 20 and 22 and the number of the SRRs 21 and 23 will always be the same.

[0044] When the counterfeit prevention structure 10 of the fourth pattern 34 is irradiated with the terahertz electromagnetic wave of the predetermined frequency (primary resonance frequency) having the polarization direction in the X-axis direction, the transmittance will be a value between the transmittance Tx obtained when all the SRRs having the open parts in a direction parallel to the polarization direction (X-axis direction) and the transmittance Ty obtained when all the SRRs having the open parts in a direction orthogonal to the polarization direction (X-axis direction). In the fourth pattern 34, a ratio of the number of the SRRs having the open parts parallel to the polarization direction (X-axis direction) and the number of the SRRs having the open parts orthogonal to the polarization direction (X-axis direction) is 5:4. Therefore, the transmittance will be a value near $(5\times Tx+4\times Ty)/9$.

The above-mentioned dimension of the area irradiated with the terahertz electromagnetic wave is determined so as to be at least larger than the area occupied by the SRRs arranged in the three-by-three matrix pattern.

[0045] In this manner, a basic patter is formed by selecting the SRRs from the four types of the SRRs 20 to 23 having the open parts 20a to 23a parallel to or orthogonal to the X-axis direction. The transmittance of the terahertz electromagnetic wave can be changed by changing the type and the number of the SRRs. By using this technique, the first pattern 31 to the fourth pattern 34 are formed such that each gives a different transmittance. Moreover, the basic pattern set by using the SRRs 20 to 23 is successively arranged in a matrix layout thereby forming the counterfeit prevention structure 10. By this structure, the variation in the transmittance due to an inclination of the counterfeit prevention structure 10 can be suppressed.

[0046] FIG. 6 is a view for explaining an example of the transmittance of the counterfeit prevention structure 10. The frequency characteristics shown in the lower part of FIG. 6 is a schematic representation of the change in the transmittance when the counterfeit prevention structure 10 of the first pattern 31 to the fourth pattern 34 is irradiated with the terahertz electromagnetic wave having the polarization direction in the X-axis direction. The horizontal axis represents the frequency of the emitted terahertz electromagnetic wave and the vertical axis represents the transmittance value. As shown in the upper part of FIG. 6, an angle of an inclination of the counterfeit prevention structure 10 is taken as α. The frequency characteristics of the transmittance shown with a dotted line in the lower part of FIG. 6 is obtained when the counterfeit prevention structure 10 is not inclined (α=0 degree). On the other hand, the frequency characteristics of the transmittance shown with a solid line is obtained when the counterfeit prevention structure 10 is inclined by 15 degrees (α=15 degrees). A range of variation of the transmittance of the primary resonance frequency fl (THz) that can occur when the counterfeit prevention structure 10 is inclined is shown with "r" in FIG. 6. , Even when the counterfeit prevention structure 10 is inclined, the range r of variation of the transmittance is very small and it is only few percent of the absolute value of the transmittance.

[0047] Specifically, when the counterfeit prevention structure 10 that is not inclined (α=0 degree) is irradiated with the terahertz electromagnetic wave of the primary resonance frequency fl (THz) having the polarization direction in the X-axis direction, the transmittance of the counterfeit prevention structure 10 of the first pattern 31 is about 40%. Moreover, the transmittance of the counterfeit prevention structure 10 of the second pattern 32 is about 35%, the transmittance of the counterfeit prevention structure 10 of the third pattern 33 is about 30%, and the transmittance of the counterfeit prevention structure 10 of the fourth pattern 34 is about 30%. On the other hand, when a conventional counterfeit prevention structure, in which the angle between the polarization direction of the terahertz electromagnetic wave and the directions of the open parts of all the SRRs is 60 degrees, is similarly irradiated with the terahertz electromagnetic wave, the transmittance is about 30%.

[0048] When the counterfeit prevention structure 10 of the first pattern 31 inclines in a range of - 15 degrees to 15 degrees (-15 degrees $\leq \alpha \leq$ 15 degrees) while irradiating with the terahertz electromagnetic wave, the transmittance varies between about 40% and about 38%. The range of variation of the transmittance is about 2% in the counterfeit prevention structure 10 of the first pattern 31. Similarly, the range of variation of the transmittance is about 1% in the counterfeit prevention structure 10 of the second pattern 32, the range of variation of the transmittance is almost 0% in the counterfeit prevention structure 10 of the third pattern 33, and the range of variation of the transmittance is about 0.3% in the counterfeit prevention structure 10 of the fourth pattern 34. In a case where the conventional counterfeit prevention structure, in which the angle between the polarization direction of the terahertz electromagnetic wave and the directions of the open parts are 60 degrees, inclines in a range of -15 degrees to 15 degrees, the angle varies in a range of 45 degrees to 75 degrees and the range of variation of the transmittance is about 20%.

[0049] When the counterfeit prevention structure 10 is not inclined, the transmittance in the counterfeit prevention structure 10 of the third pattern 33, the counterfeit prevention structure 10 of the fourth pattern 34, and the conventional counterfeit prevention structure is almost the same and it is about 30%. On the other hand, when the counterfeit prevention structure is inclined in the range of -15 degrees to 15 degrees, while the range of variation of the transmittance of the conventional counterfeit prevention structure is about 20%, the range of variation of the transmittance of the counterfeit prevention structure 10 of the third pattern 33 and the counterfeit prevention structure 10 of the fourth pattern 34 remains less than 1%. This means that, in the counterfeit prevention structure 10 according to the present embodiment, the range of variation of the transmittance with respect to the inclination thereof can be suppressed in comparison with the conventional structure.

[0050] The reason why the range of variation of the transmittance is suppressed in the counterfeit prevention structure 10 of the first pattern 31 is because the range of variation arising from the inclination is less when the directions of the open parts of the SRRs are parallel to the polarization direction of the terahertz electromagnetic wave.

[0051] The reason why the range of variation of the transmittance is suppressed in the counterfeit prevention structure 10 of the second pattern 32 to the fourth pattern 34 is because of the use of a mixture of a plurality of types of the SRRs 20 to 23 in which the directions of the open parts differ by 90 degrees unit. Specifically, for example, if the SRRs are inclined while the terahertz electromagnetic wave of the primary resonance frequency is emitted, the transmittance of the SRRs having the open parts parallel to the polarization direction of the terahertz electromagnetic wave decreases, but the transmittance of the SRRs having the open parts orthogonal to the polarization direction increases. Therefore, the increase and the decrease in the transmittance are offset and the range of variation of the transmittance can be suppressed.

[0052] There is a mixture of the SRRs for which the transmittance increases and the SRRs for which the transmittance decreases when the counterfeit prevention structure 10 is inclined with respect to the polarization direction of the terahertz electromagnetic wave, an effect of suppressing the range of variation of the transmittance due to the inclination can be achieved. The types of the SRRs used to make the counterfeit prevention structure 10 are not limited to the SRRs in which the directions of the open parts are different by 90 degrees. However, by using the SRRs in which the directions of the open parts are different by 90 degrees, irrespective of the polarization direction of the terahertz electromagnetic wave, there will be a mixture of the SRRs for which the transmittance increases and the SRRs for which the transmittance decreases when the counterfeit prevention structure 10 is inclined. Accordingly, an effect of suppressing the range of variation of the transmittance due to the inclination of the counterfeit prevention structure 10 can be achieved irrespective of the polarization direction of the terahertz electromagnetic wave.

[0053] In FIGS. 3A, 3B, 3C, and 5 is shown an example of the counterfeit prevention structure 10 formed by successively arranging in a matrix layout one pattern of the SRRs selected from the four types of the SRRs 20 to 23; however, the counterfeit prevention structure can be obtained by combining a plurality of types of the patterns.

[0054] FIG. 7 is a view of an example of a counterfeit prevention structure 50 in which a plurality of types of the patterns is combined. In the left part of FIG. 7 is shown a plan view of the counterfeit prevention structure 50 including a first area 11 (11a and 11b), a second area 12, and a third area 13 (13a and 13b), and in the right part is shown an enlarged view of a partial area 15 containing these three areas 11 to 13. The first area 11 has the shape substantially like the English character L. The third area 13 has a shape obtained by rotating the first area 11 by 180 degrees. An area surrounded by the first area 11 and the third area 13 is the second area 12. The sheet-like counterfeit prevention structure 50 is, for example, a square of a length and a width 20 mm. The second area 12 arranged at the center of the counterfeit prevention structure 50 is a square of a length and a width 10 mm.

[0055] As shown in the partially enlarged view in the right part of FIG. 7, the first pattern 31 shown in FIG. 3A is successively arranged into a matrix layout in the first area 11. In the third area 13, the third pattern 33 shown in FIG. 3C is successively arranged into a matrix layout.

[0056] The second area 12 is constituted by a fifth pattern 35 obtained by rotating the first pattern 31 in the counterclockwise direction by 90 degrees. FIG. 8 indicates a configuration of the fifth pattern 35. The fifth pattern 35 that functions as a basic unit is shown in the left part of FIG. 8. A part of the second area 12 formed by repeatedly arranging the fifth pattern 35 in a matrix layout is shown in the right part of FIG. 8. The fifth pattern 35 is a two-by-two matrix pattern in which the SRR 21 is arranged in the upper left corner, the SRRs 23 are arranged on the right side of and below the SRR 21, and the SRR 21 is arranged on the right side of the lower SRR 23. The fifth pattern 35 is constituted by only the SRRs 21 and 23 that have the open parts 21a and 23a in the Y-axis direction.

[0057] FIG. 9 is a view for explaining a change in the transmittance of the terahertz electromagnetic wave observed in a medium 100 on which the counterfeit prevention structure 50 shown in FIG. 7 is provided. A plan view of the medium 100 having the counterfeit prevention structure 50 is shown in the upper part of FIG. 9. The counterfeit prevention structure 50 of the square shape is arranged such that each edge thereof is parallel to the corresponding edge of the rectangular medium 100. A scanning position and a scanning direction when the counterfeit prevention structure 50 is scanned with the terahertz electromagnetic wave are shown with an arrow 200 in the central part of FIG. 9. A waveform of the transmittance of the terahertz electromagnetic wave obtained at the scanning position is shown in the lower part of FIG. 9. This transmittance waveform is a schematic representation of the change in the transmittance of the counterfeit prevention structure 50 when scanned with the terahertz electromagnetic wave of the primary resonance frequency.

[0058] A substantially central part in the X-axis direction of the counterfeit prevention structure 50 is scanned in the direction shown with the arrow 200 with the terahertz electromagnetic wave of the predetermined frequency having the polarization direction in the X-axis direction. The medium 100 is scanned in a where that the medium 100 namely the counterfeit prevention structure 50 is not inclined. The transmittance in the first area 11 constituted by the first pattern 31, the transmittance in the second area 12 constituted by the fifth pattern 35, and the transmittance in the third area 13 constituted by the third pattern 33 show different values corresponding to the respective pattern.

[0059] For example, for the primary resonance frequency, the transmittance in the first area 11 shows a high value (about 40%), and the transmittance in the second area 12 shows a very low value (about 2%). The transmittance in the third area 13 shows a value (about 20%) between the transmittance in the first area 11 and the transmittance in the second area 12. Therefore, as shown in the lower part of FIG. 9, after a waveform 71 indicating a substantially constant and high transmittance is obtained in the first area 11 on the right side of FIG. 9, the transmittance decreases in the central second area 12. After a waveform 72 indicating a substantially constant transmittance is obtained in the second area 12, the transmittance increases again in the third area 13 on the left side of FIG. 9. A waveform 73 indicating a substantially constant transmittance lower than the waveform 71 is obtained in the third area 13. In this manner, if the counterfeit prevention structure 50 is constituted by a plurality of areas each of which indicates a different transmittance when irradiated with the predetermined terahertz electromagnetic wave, a characteristic waveform in which the transmittance changes while scanning the counterfeit prevention structure 50 can be obtained. The authenticity of the medium 100 can be determined based on the feature of the obtained transmittance waveform.

[0060] Even when the counterfeit prevention structure 50 is inclined by 15 degrees, the range of variation of the transmittance of the first area 11 constituted by the first pattern 31 and the range of variation of the transmittance of the second area 12 remain as low as 2%. Moreover, the transmittance of the third area 13 constituted by the third pattern 33 almost does not vary. Therefore, even when the counterfeit prevention structure 50 is inclined, as shown in the lower part of FIG. 9, a stepped waveform in which the transmittance decreases from the waveform 71 to the waveform 72 and the transmittance increases from the waveform 72 to the waveform 73 is obtained. Moreover, the relation of the magnitudes of the waveform 71, the waveform 72, and the waveform 73 does not change even when the counterfeit prevention structure 50 is inclined. Therefore, even when the inclined medium 100 namely the inclined counterfeiting prevention structure 50 is scanned for measuring the transmittance, a characteristic waveform in which the transmittance changes in three phases can be obtained. The authenticity of the medium 100 can be determined based on the feature of the obtained transmittance waveform.

[0061] A case of irradiating the counterfeit prevention structures 10 and 50 with the terahertz electromagnetic wave of the primary resonance frequency (PI of FIG. 4) having the polarization direction in the X-axis direction is mainly explained above; however, different transmission characteristics will be obtained with the secondary resonance frequency (V1 of FIG. 4). FIG. 10 is a view for explaining a change in the transmittance obtained when the secondary resonance frequency is used. A plan view of the medium 100, which is the same as that shown in FIG. 9, having the counterfeit prevention structure 50 is shown in the upper part of FIG. 10, and a scanning position and a scanning direction when the counterfeit prevention structure 50 is scanned with the terahertz electromagnetic wave are shown with the arrow 200 in the central part. A transmittance waveform obtained when the counterfeit prevention structure 50 is scanned with the terahertz electromagnetic wave of the secondary resonance frequency at the scanning position is shown in the lower part of FIG. 10.

[0062] A substantially central part in the X-axis direction of the counterfeit prevention structure 50 is scanned in the direction shown with the arrow 200 with the terahertz electromagnetic wave of the predetermined frequency having the polarization direction in the X-axis direction. The medium 100 is scanned in a state where the medium 100 namely the counterfeit prevention structure 50 shown in FIG. 7 is not inclined. The transmittance waveform shown in the lower part of FIG. 9 is obtained when the scanning is performed by using the terahertz electromagnetic wave of the primary resonance frequency, and the transmittance waveform shown in the lower part of FIG. 10 is obtained when the scanning is performed by using the terahertz electromagnetic wave of the secondary resonance frequency. The relation between the polarization direction of the terahertz electromagnetic wave, the directions of the open parts of the SRRs 20 to 23 and the transmittance value varies depending on a resonance mode. For the primary resonance frequency, the transmittance becomes maximum when the directions of the open parts of the SRRs are parallel to the polarization direction of the terahertz electromagnetic wave. On the other hand, for the secondary resonance frequency, the transmittance becomes maximum when the directions of the open parts of the SRRs are orthogonal to the polarization direction of the terahertz electromagnetic wave.

[0063] Even for the secondary resonance frequency, different transmittance can be obtained in each of the first area 11 to the third area 13; however, the transmittance in the first area 11 shows a very low value of a few percent and the transmittance in the second area 12 shows a high value. The transmittance in the third area 13 shows a value between the transmittance in the second area 12 and the transmittance in the first area 11. Therefore, as shown in the lower part of FIG. 10, after a waveform 81 indicating a substantially constant and low transmittance is obtained in the first area 11 on the right side of FIG. 10, the transmittance increases in the central second area 12. After a waveform 82 indicating a substantially constant transmittance is obtained in the second area 12, the transmittance decreases again in the third area 13 on the left side of FIG. 10. A waveform 83 indicating a substantially constant transmittance higher than the waveform 81 is obtained in the third area 13. The authenticity of the medium 100 can be determined based on the feature of the obtained transmittance waveform.

[0064] Even when the counterfeit prevention structure 50 is inclined by 15 degrees, like in the case of the primary resonance frequency, each of the range of variation of the transmittance of the first area 11, the range of variation of the transmittance of the second area 12, and the range of variation of the transmittance of the third area 13 remains as low as 4%. Therefore, even when the counterfeit prevention structure 50 is inclined, a stepped waveform in which the transmittance increases from the waveform 81 to the waveform 82 is obtained as shown in the lower part of FIG. 10. There is a difference of about

15% between the transmittance of the second area 12 shown with the waveform 82 and the transmittance of the third area 13 shown with the waveform 83. Even when the counterfeit prevention structure 50 is inclined by 15 degrees, the range of variation of the transmittance of the second area 12 remains as low as about 4%, and the transmittance of the third area 13 almost does not vary. Therefore, even when the counterfeit prevention structure 50 is inclined, a stepped waveform in which the transmittance decreases from the waveform 82 to the waveform 83 is obtained as shown in the lower part of FIG. 10. Moreover, the relation of the magnitudes of the waveform 81, the waveform 82, and the waveform 83 does not change even when the counterfeit prevention structure 50 is inclined. Even when measuring the transmittance by scanning the inclined medium 100 namely the inclined counterfeit prevention structure 50, a characteristic waveform in which the transmittance changes in three phases can be obtained. The authenticity of the medium 100 can be determined based on the feature of the obtained transmittance waveform.

[0065] As explained by referring FIGS. 9 and 10, the counterfeit prevention structure 50 provided in the medium 100 is scanned with the terahertz electromagnetic wave. Such a scanning can be implemented by an authenticity determination apparatus. In the authenticity determination apparatus, a position from which the terahertz electromagnetic wave is emitted and a position at which the emitted terahertz electromagnetic wave is received are fixed. The medium 100 is scanned by being transported inside the authenticity determination apparatus. Such an authenticity determination apparatus is explained below by taking the measurements corresponding to FIG. 9 as an example.

[0066] FIG. 11 is a schematic diagram indicating a schematic internal configuration of the authenticity determination apparatus seen from a side thereof. A transport unit 63 transports the medium 100 in a direction shown with an arrow 201. A terahertz electromagnetic wave transmitting unit 61 is arranged above the transport unit 63. A terahertz electromagnetic wave receiving unit 62 is arranged below the transport unit 63. The terahertz electromagnetic wave transmitting unit 61 transmits the terahertz electromagnetic wave of the predetermined frequency having the polarization direction in the X-axis direction in a lower direction as shown with an arrow 202. The counterfeit prevention structure 50 provided on the medium 100 being transported by the transport unit 63 is irradiated with the terahertz electromagnetic wave. The terahertz electromagnetic wave receiving unit 62 receives the terahertz electromagnetic wave that penetrates the counterfeit prevention structure 50. A position from which the terahertz electromagnetic wave is emitted and a position at which the terahertz electromagnetic wave is received are fixed. The terahertz electromagnetic wave receiving unit 62 detects intensity of the received terahertz electromagnetic wave, and obtains a transmittance from the detected intensity. The transmittance is a ratio of the detected intensity to intensity of the terahertz electromagnetic wave that is detected in a state where there is no medium 100 being transported by the transport unit 63. As shown in FIG. 11, the medium 100 is transported by the transport unit 63 in the direction shown with the arrow 201. The medium 100 passes through the position at which the terahertz electromagnetic wave is emitted and received. While the medium 100 passes through the position, the counterfeit prevention structure 50 is scanned in the direction shown with the arrow 200 and the waveform of the transmittance is obtained as shown in FIG. 9. Instead of calculating the transmittance in the terahertz electromagnetic wave receiving unit 62, the transmittance can be calculated by a control unit 64. In this case, the terahertz electromagnetic wave receiving unit 62 outputs the intensity of the received terahertz electromagnetic wave to the control unit 64, and the control unit 64 calculates the transmittance.

[0067] FIGS. 12A and 12B are schematic diagrams of the configuration shown in FIG. 11 when seen from above. FIG. 12A shows a case in which the medium 100 is transported without inclining. FIG. 12B shows a case in which the medium 100 is transported while the medium 100 is inclined by an angle α. The transmittance of the terahertz electromagnetic wave penetrating the counterfeit prevention structure 50 is different for the state shown in FIG. 12A and the state shown in FIG. 12B, however, the range of variation of the transmittance is small. Therefore, the authenticity of the medium 100 can be determined with a high accuracy based on the value of the transmittance, the waveforms of the transmittance obtained by scanning the counterfeit prevention structure 50, and the like.

[0068] FIG. 13 is a block diagram indicating a schematic functional configuration of an authenticity determination apparatus 1. The authenticity determination apparatus 1 includes the control unit 64 and a memory 65 in addition to the configuration shown in FIG. 11. The memory 65 is a nonvolatile storage device constituted by a semiconductor memory and the like. In the memory 65, reference data is previously prepared. The reference data includes the values of the transmittance, the waveforms of the transmittance, the characteristic features of the waveforms, and the like to be obtained by irradiating the counterfeit prevention structure 50 with the predetermined terahertz electromagnetic wave.

[0069] The control unit 64 controls the transport of the medium 100 by the transport unit 63, the transmission of the terahertz electromagnetic wave by the terahertz electromagnetic wave transmitting unit 61, the receiving of the terahertz electromagnetic wave by the terahertz electromagnetic wave receiving unit 62, and the like. Moreover, the control unit 64 acquires the values of the transmittance of the terahertz electromagnetic wave that penetrates the counterfeit prevention structure 50, the waveforms of the transmittance, and the like. The control unit 64 determines the authenticity of the medium 100 by comparing with the reference data prepared previously in the memory 65 at least one among the values of transmittance, the waveforms of the transmittance, the characteristic features of the waveforms, and the like. The control unit 64 outputs the determination result of the authenticity to a not-shown external apparatus. For example, the determination result of the authenticity is output to a display apparatus to be displayed and alarmed.

[0070] The present embodiment explained an example in which the counterfeit prevention structures 10 and 50 includes the base member 17 and the conductive layer 16 in which the SRRs 20 to 23 are formed; however, the structure of the counterfeit prevention structures 10 and 50 is not limited to this. FIG. 14 is a schematic cross section indicating another structural example of the counterfeit prevention structures 10 and 50. In the counterfeit prevention structures 10 and 50 shown in FIG. 14, the conductive layer 16 shown in FIGS. 1 and 7 is adhered to a surface of the medium 100 via an adhesive layer 41. A hologram layer 42 is arranged on the conductive layer 16, and a release layer 43 is arranged on the hologram layer 42. For example, after the release layer 43, the hologram layer 42, the conductive layer 16, and the adhesive 41 are sequentially formed on a predetermined base material, the layers above and including the release layer 43 are separated from the base material, the top and bottom of the separated structure is reversed, and the configuration shown in FIG. 14 is obtained by sticking the released structure to the medium 100 via the adhesive 41. The release layer 43 is made of material such as transparent resin. Under the visible light, when the counterfeit prevention structures 10 and 50 shown in FIG. 14 is seen from above, a three-dimensional image recorded in the hologram layer 42 can be seen. The SRRs 20 to 23 each having the shape substantially like the English character C are minute structures formed in the thin conductive layer 16 having a thickness of few μm and therefore, it is difficult to see with the naked eyes. Moreover, because the predetermined design recorded in the hologram layer and the like arranged on the conductive layer 16 is seen, it becomes more difficult to notice the SRRs 20 to 23 whereby the effect of the counterfeit prevention is enhanced.

[0071] The present embodiment explained an example in which the directions of the open parts of the SRRs are either parallel or orthogonal to the polarization direction of the terahertz electromagnetic wave; however, the direction of open part is not limited to this. FIG. 15 is a view indicating an example of the counterfeit prevention structure 10 having SRRs 120 to 123 of which the open parts are in different directions. The SRRs 120 to 123 shown in FIG. 15 have a shape obtained by rotating each of the SRRs 20 to 23 shown in FIG. 1 in the clockwise direction by 45 degrees. The directions of open parts 120a to 123a of the SRRs 120 to 123 make an angle of 45 degrees to the X-axis direction and the Y-axis direction. Even when the SRRs 20 to 23 constituting the first pattern 31 to the fifth pattern 35 are replaced with the SRRs 120 to 123 shown in FIG. 15, respectively, an area in which the transmittance of the terahertz electromagnetic wave shows a predetermined value can be realized as explained above.

[0072] In the example explained with reference to FIGS. 9 and 10, the medium 100 provided with the counterfeit prevention structure 50 is rectangle, and the directions of the open parts of the SRRs and the orientations of the edges of the medium 100 are parallel or orthogonal; however, the angle between the directions of the open parts and the edges of the medium 100 can be 45 degrees. Specifically, for example, the medium 100 shown in FIG. 9 can be kept as it is and only the counterfeit prevention structure 50 can be rotated in the clockwise direction by 45 degrees. Alternatively, for example, the SRRs of the counterfeit prevention structure 50 can be replaced with the SRRs 120 to 123 shown in FIG. 15. Even in this case, a waveform having different transmittance of the terahertz electromagnetic wave can be obtained in the first area 11 to the third area 13 as explained above.

[0073] Moreover, a structure different from that shown in FIG. 7 can be adopted as the structure in which the transmittance changes in various areas while scanning the counterfeit prevention structure 50 of the medium 100 being transported. FIG. 16 is a view indicating another example of a counterfeit prevention structure 150 that is divided in a plurality of areas. The counterfeit prevention structure 150 having a square shape shown in FIG. 16 is divided into eight areas at regular intervals in the diagonal direction. These eight areas make an angle of 45 degrees to the edges of the counterfeit prevention structure 150. The areas are constituted by two types of areas, a first area 111 and a second area 112, and the two types of areas are arranged alternately. For example, a desired one of the first pattern 31 to the fifth pattern 35 can be selected for each of the first area 111 and the second area 112 thereby obtaining areas having different patterns. Moreover, for example, the first area 111 can be an area made of insulating material through which the terahertz electromagnetic wave can penetrate or can be made of conductive material that blocks the terahertz electromagnetic wave, and that does not include the SRRs. In this example, the second area 112 can be an area constituted by a pattern selected among the first pattern 31 to the fifth pattern 35, and that includes the SRRs. With this configuration, when a substantially central in the X-axis direction of the counterfeit prevention structure 150 is scanned in the Y-axis direction with the predetermined terahertz electromagnetic wave, the transmittance changes in the first area 111 and the second area 112. The authenticity determination can be performed based on the transmission characteristics of the counterfeit prevention structure 150.

[0074] The present embodiment explained an example in which each area of the counterfeit prevention structure 50 shown in FIG. 7 is constituted by one of the first pattern 31 and the third pattern 33 shown in FIGS. 3A and 3C and the fifth pattern 35 shown in FIG. 8; however, the patterns used to form the areas are not particularly limited. For example, the second pattern 32 and the fourth pattern 34 can be used. Moreover, the counterfeit prevention structure 50 can be divided in two areas or can be divided in four or more areas. Moreover, it is explained to use the fifth pattern 35 obtained by rotating the first pattern 31 by 90 degrees as the basic pattern; however, it is allowable to use a pattern obtained by rotating the second pattern 32, the third pattern 33, and the fourth pattern 34 by 90 degrees.

[0075] The present embodiment explained an example in which the first pattern 31 to the fifth pattern 35 are taken as the basic pattern; however, the basic patterns are not limited to this. The shape of the basic pattern, and the type, the number, the layout, and the like of the SRRs that constitute the basic pattern are not particularly limited as long as, in an area which has the same shape as the basic pattern and is selected from a desired position of an area in which the basic patterns are repeatedly arranged in a matrix layout, the ratio of the number of the SRRs having the open parts parallel to the polarization direction of the terahertz electromagnetic wave to the number of the SRRs having the open parts orthogonal to the polarization direction of the terahertz electromagnetic wave is the same as that of the basic pattern. Specifically, for example, regarding the layout of the SRRs in the basic pattern, other than the matrix layout, in which the SRRs are arranged repeatedly vertically and horizontally, the SRRs can be arranged in the checkered pattern layout or in the honeycomb pattern layout. Regarding the layout of the basic patterns in each area, other than arranging the basic patterns in the matrix layout, a block pattern layout, a honeycomb pattern layout, or a layout in which the basic patterns are repeated as desired can be used. The shape of the SRRs is also not limited as long as the desired transmittance can be obtained when the terahertz electromagnetic wave of predetermined frequency is emitted. For example, the ring part can have a rectangle shape. Moreover, as long as the resonance frequency is the same, it is not necessary that all of the types of the SRRs are of the same shape. It is allowable that the SRRs having different shapes, such as the rectangle shape, the circular shape, are mixed.

[0076] The present embodiment explained an example in which the polarization direction of the terahertz electromagnetic wave used for the authenticity determination is mainly along the X-axis direction; however, the terahertz electromagnetic wave having the polarization direction in the Y-axis direction can be used. The transmittance in each of the basic patterns changes when the polarization direction of the terahertz electromagnetic wave changes, however the authenticity determination can be performed as explained above by previously acquiring the transmittance corresponding to the polarization direction.

[0077] The present embodiment explained an example in which the transmittance of the terahertz electromagnetic wave is used for the authenticity determination of the counterfeit prevention structure; however, it is allowable to use reflectivity of the terahertz electromagnetic wave. The transmittance and the reflectivity of terahertz electromagnetic wave have such a relation that when one of them increases the other decreases. For example, the terahertz electromagnetic wave transmitting unit 61 and the terahertz electromagnetic wave receiving unit 62 are arranged across the transported medium 100 in FIG. 11; however, these two units can be arranged on the same side of the medium 100. The reflectivity can be measured by receiving the terahertz electromagnetic wave, which is emitted by the terahertz electromagnetic wave transmitting unit 61 and reflected from the medium 100, in the terahertz electromagnetic wave receiving unit 62. Accordingly, the characteristics of the counterfeit prevention structure can be obtained based on the reflectivity of the terahertz electromagnetic wave and the authenticity determination of the counterfeit prevention structure can be performed by using the transmittance in the same manner as explained above.

[0078] As explained above, when the authenticity determination apparatus according to the present embodiment is used, it is possible to irradiate the counterfeit prevention medium, such as the banknote or the coupon, provided with the counterfeit prevention structure with the terahertz electromagnetic wave and determine the authenticity of the counterfeit prevention medium based on the transmission characteristics, such as the frequency and the transmittance, of the emitted terahertz electromagnetic wave.

[0079] To allow determination of the authenticity, the plurality of types of the split ring resonators that constitute the counterfeit prevention structure include, for example, the open parts in the direction that is parallel or orthogonal to the polarization direction of the emitted terahertz electromagnetic wave. By adjusting the ratio of the number of the split ring resonators having the open parts parallel to and the number of the split ring resonators having the open parts orthogonal to the polarization direction, the counterfeit prevention structure through which the terahertz electromagnetic wave of the predetermined frequency penetrates at the predetermined transmittance can be realized. Moreover, by using the split ring resonators having the open parts parallel and orthogonal to the polarization direction of the terahertz electromagnetic wave, the variation in the transmittance of the counterfeit prevention structure when the counterfeit prevention structure is inclined with respect to the polarization direction of the terahertz electromagnetic wave can be suppressed. Therefore, the authenticity determination can be performed with a high accuracy by using the counterfeit prevention structure.

[0080] The counterfeit prevention structure according to one aspect of the present invention is a counterfeit prevention structure provided on a medium to determine authenticity of the medium. The counterfeit prevention structure includes a hybrid area in which a plurality of types of split ring resonators is formed in a mixed state in a predetermined ratio. Each split ring resonator includes an open part. A direction of an open part of each type of the split ring resonators is different from each other.

[0081] In the above counterfeit prevention structure, the plurality of types of the split ring resonators resonates with a terahertz electromagnetic wave having the same frequency.

[0082] In the above counterfeit prevention structure, the hybrid area is formed by repeatedly arranging a basic pattern that includes at least two types of the split ring resonators.

[0083] In the above counterfeit prevention structure, when the counterfeit prevention structure is irradiated with a terahertz electromagnetic wave of a predetermined frequency having a polarization direction in a predetermined direction, a transmittance of the terahertz electromagnetic wave in the hybrid area indicates a value depending on a ratio of mixed types of the split ring resonators.

[0084] In the above counterfeit prevention structure, the plurality of types of the split ring resonators includes at least two types of the split ring resonators having the open parts of which respective opening directions are different by 90 degrees.

[0085] The above counterfeit prevention structure includes a plurality of types of areas each of which indicates a different transmittance when irradiated with a terahertz electromagnetic wave of a predetermined frequency having a polarization direction in a predetermined direction. At least one of the plurality of types of the areas is the hybrid area.

[0086] In the above counterfeit prevention structure, the plurality of types of the areas includes a plurality of types of the hybrid areas. Each of the plurality of types of the hybrid areas has a different mixed ratio of the plurality of types of the split ring resonators and a different transmittance.

[0087] The above counterfeit prevention structure includes a hologram layer operable to generate a predetermined design under visible light.

[0088] The above counterfeit prevention structure is formed on a banknote.

[0089] A counterfeit prevention medium according to another aspect of the present invention is a counterfeit prevention medium including the above counterfeit prevention structure.

[0090] In the counterfeit prevention structure according to the present invention, the range of variation of the transmittance due to the inclination thereof can be suppressed and the authenticity determination can be performed with a high accuracy in comparison with the counterfeit prevention structure in which all the sprit ring resonators have the same directions of the open parts.

[0091] As explained above, the counterfeit prevention structure and the counterfeit prevention medium according to the present invention are useful in determining the authenticity of the counterfeit prevention medium provided with the counterfeit prevention structure with a high accuracy.

[0092] Although the invention has been explained with respect to specific embodiments for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art that fairly fall within the basic teaching of the claims.

Claims

1. A counterfeit prevention structure provided on a medium to determine authenticity of the medium, the counterfeit prevention structure comprising:

    a hybrid area in which a plurality of types of split ring resonators is formed in a mixed state in a predetermined ratio,
    wherein
    each split ring resonator includes an open part, and
    a direction of the open part of each type of the split ring resonators is different from each other.

2. The counterfeit prevention structure as claimed in claim 1, wherein the plurality of types of the split ring resonators resonates with a terahertz electromagnetic wave having a same frequency.

3. The counterfeit prevention structure as claimed in claim 1 or 2, wherein the hybrid area is formed by repeatedly arranging a basic pattern that includes at least two types of the split ring resonators.

4. The counterfeit prevention structure as claimed in any one of claims 1 to 3, wherein when the counterfeit prevention structure is irradiated with a terahertz electromagnetic wave of a predetermined frequency having a polarization direction in a predetermined direction, a transmittance of the terahertz electromagnetic wave in the hybrid area indicates a value depending on a ratio of mixed types of the split ring resonators.

5. The counterfeit prevention structure as claimed in any one of claims 1 to 4, wherein the plurality of types of the split ring resonators includes at least two types of the split ring resonators having the open parts of which respective opening directions are different by 90 degrees.

6. The counterfeit prevention structure as claimed in any one of claims 1 to 5, wherein
the counterfeit prevention structure includes a plurality of types of areas each of which indicates a different transmittance when irradiated with a terahertz electromagnetic wave of a predetermined frequency

having a polarization direction in a predetermined direction, and
at least one of the plurality of types of the areas is the hybrid area.

7. The counterfeit prevention structure as claimed in claim 6, wherein
the plurality of types of the areas includes a plurality of types of the hybrid areas, and
each of the plurality of types of the hybrid areas has a different mixed ratio of the plurality of types of split ring resonators and indicates a different transmittance.

8. The counterfeit prevention structure as claimed in any one of claims 1 to 7, further comprising a hologram layer operable to generate a predetermined design under visible light.

9. The counterfeit prevention structure as claimed in any one of claims 1 to 8, wherein the counterfeit prevention structure is formed on a banknote.

10. A counterfeit prevention medium comprising the counterfeit prevention structure as claimed in any one of claims 1 to 8.

FIG.1

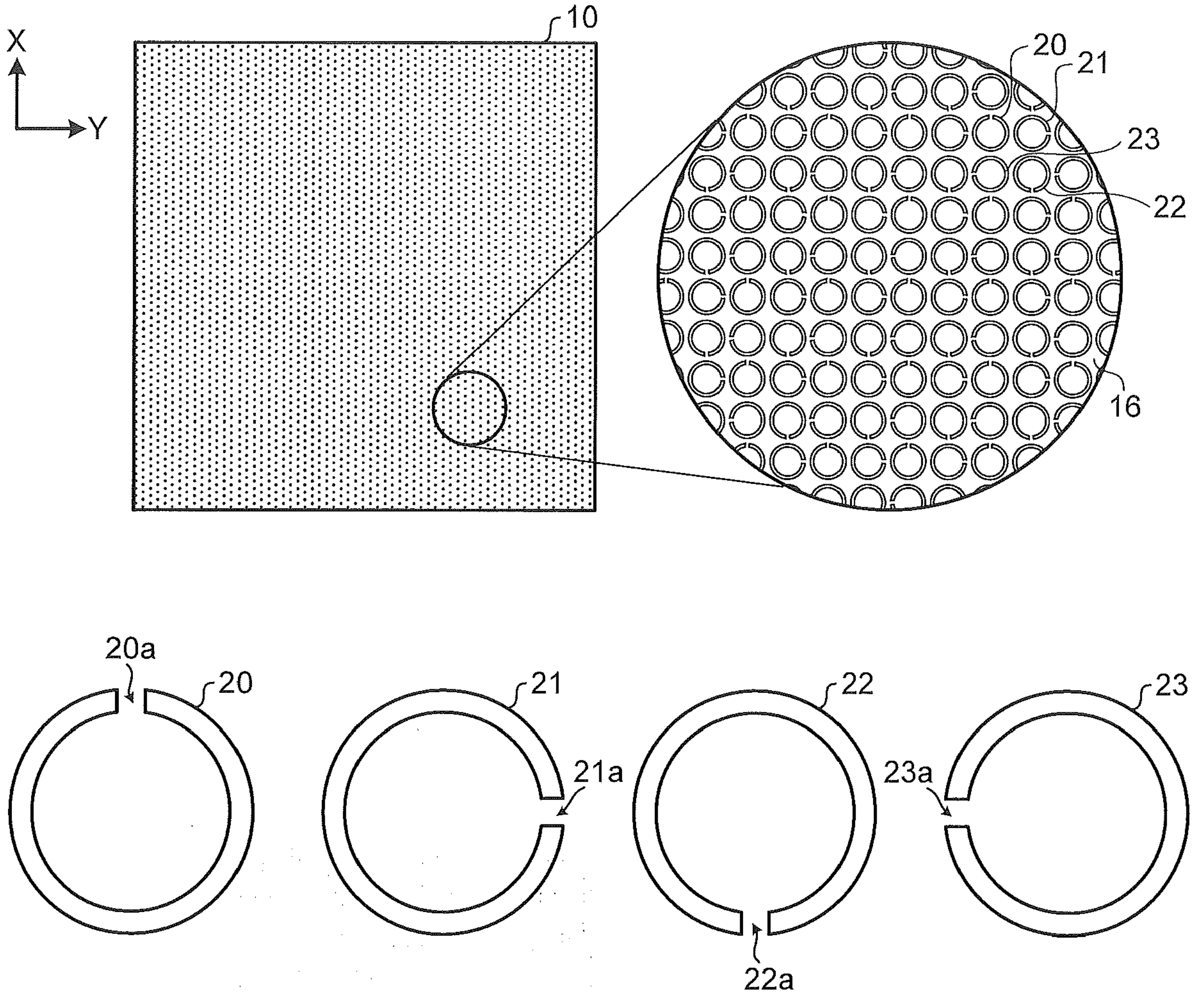


FIG.2

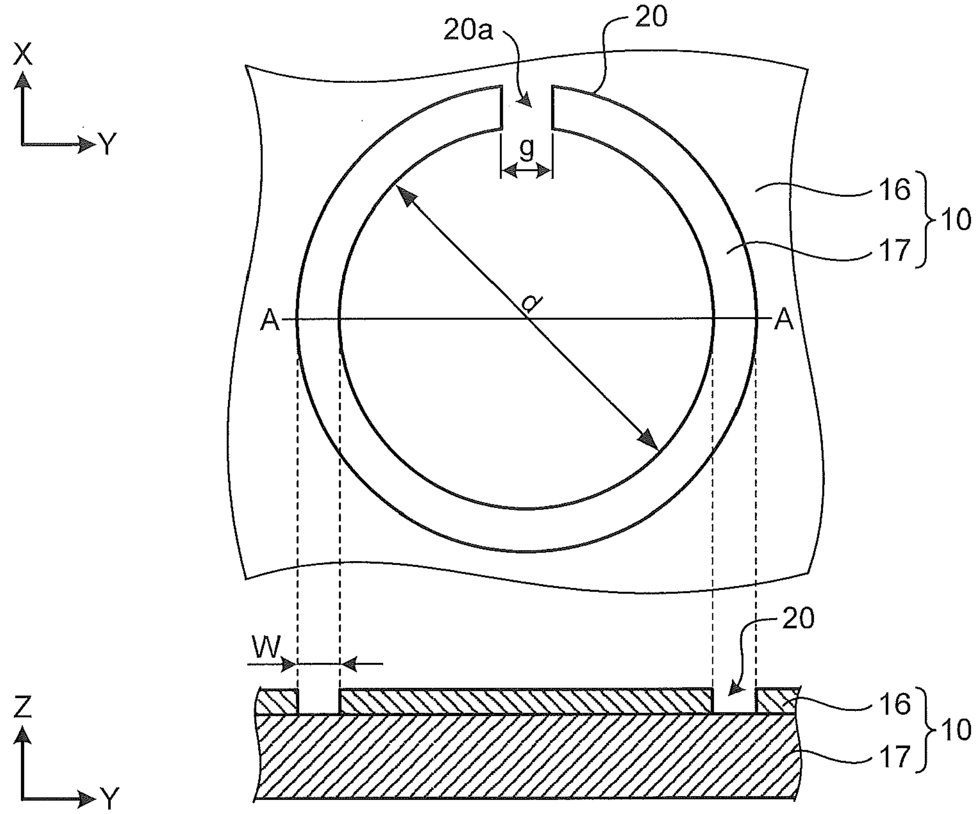


FIG.3A

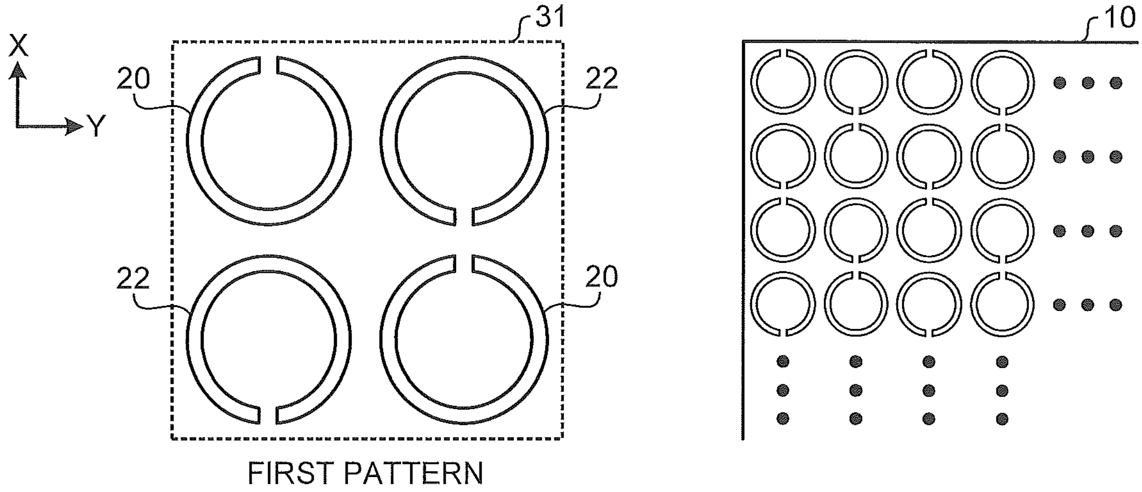


FIG.3B

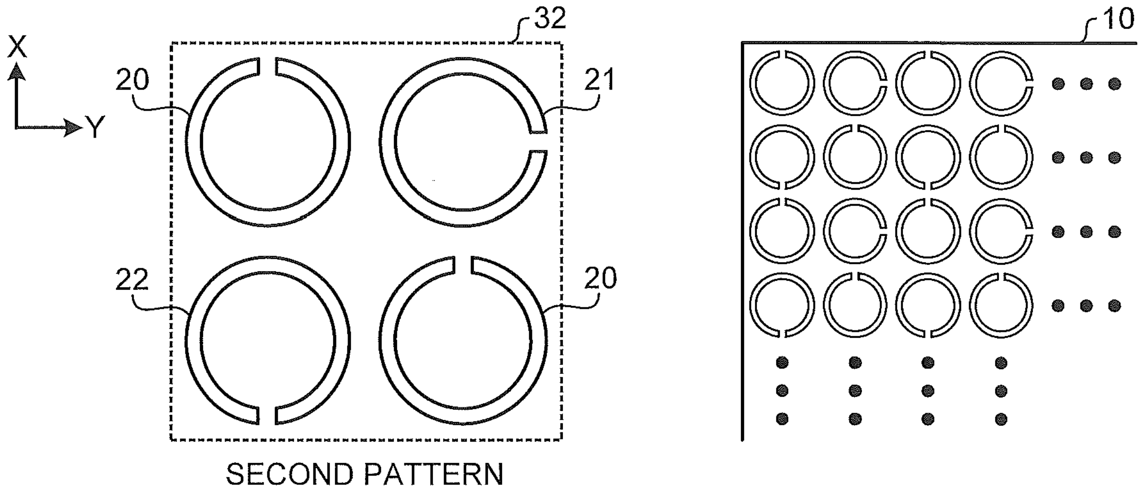


FIG.3C

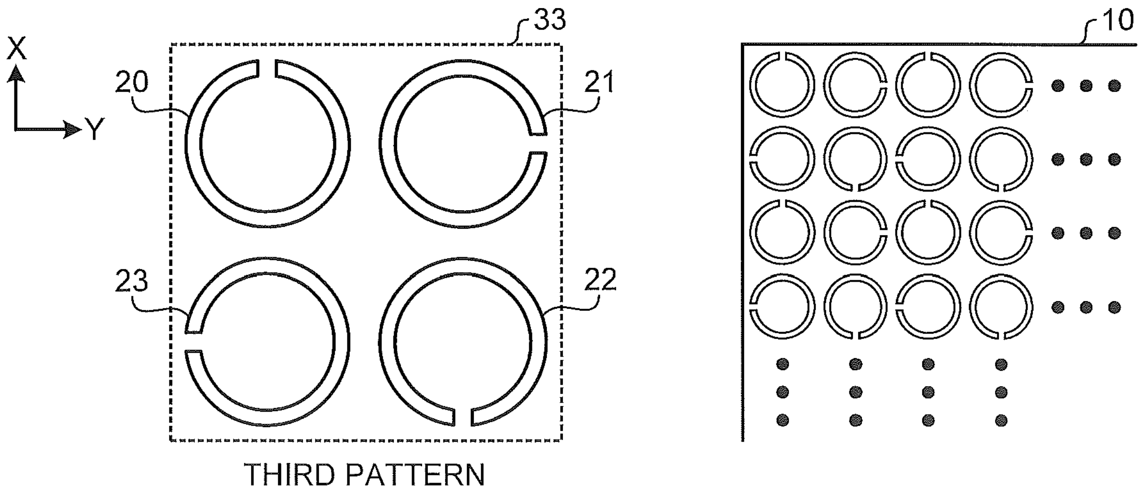


FIG.4

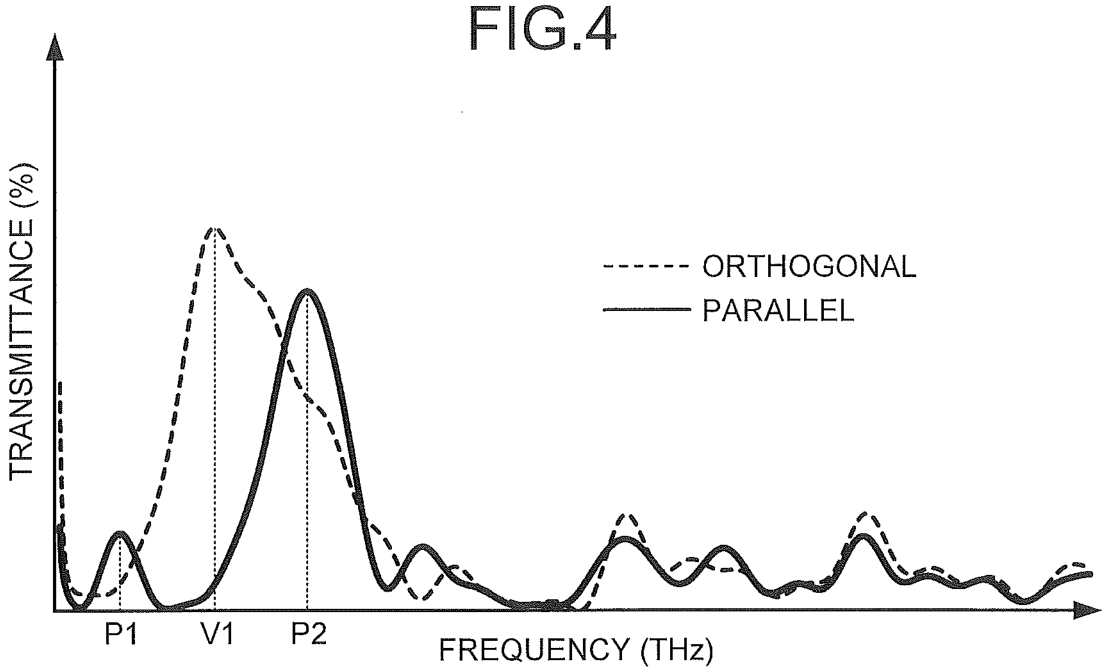


FIG.5

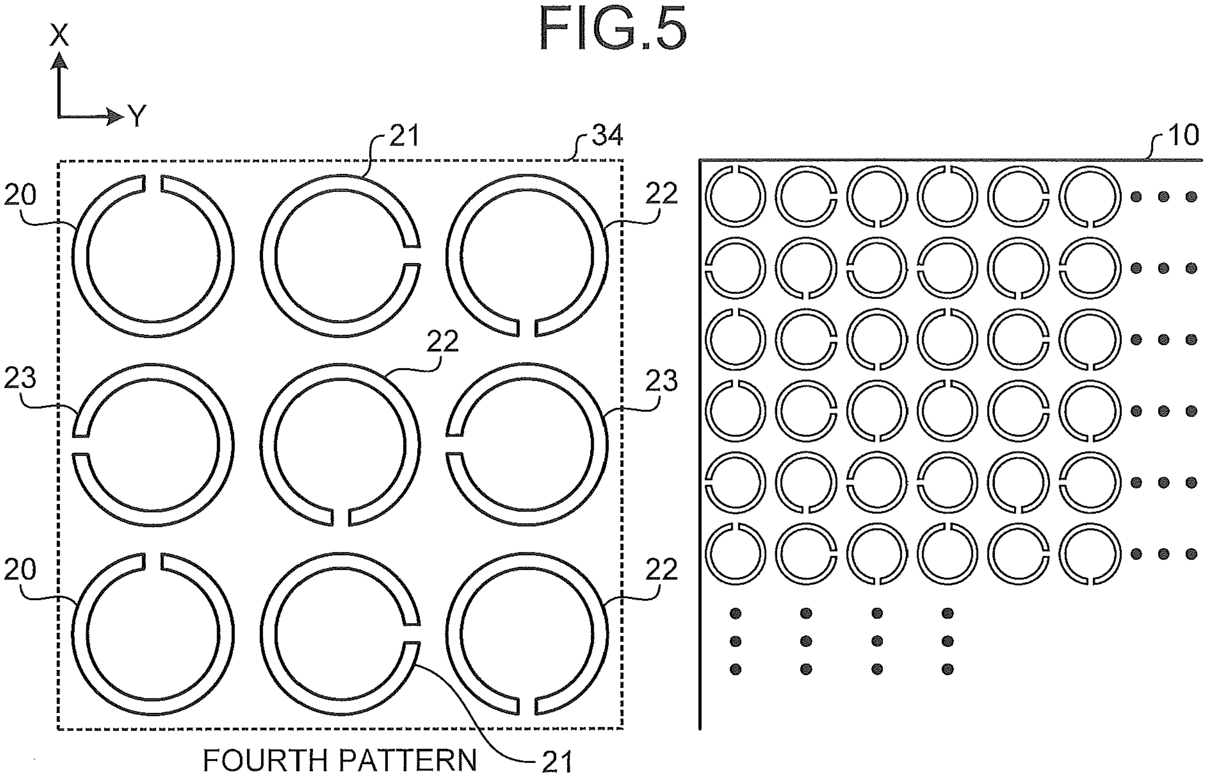


FIG.6

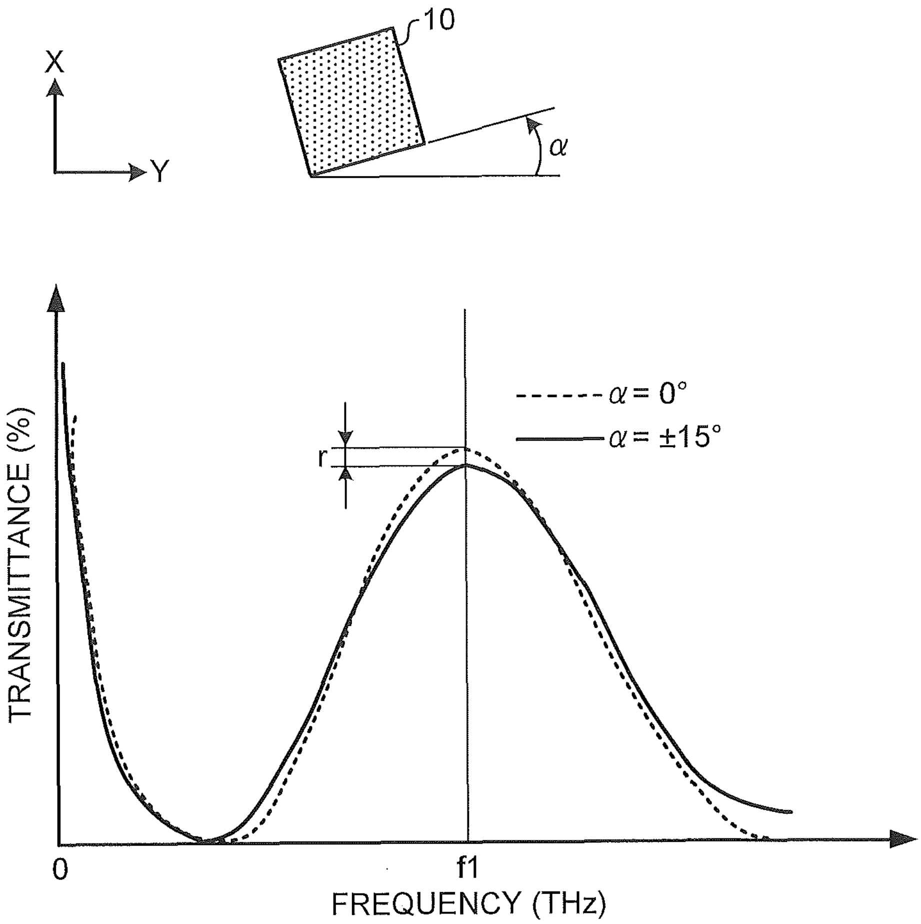


FIG.7

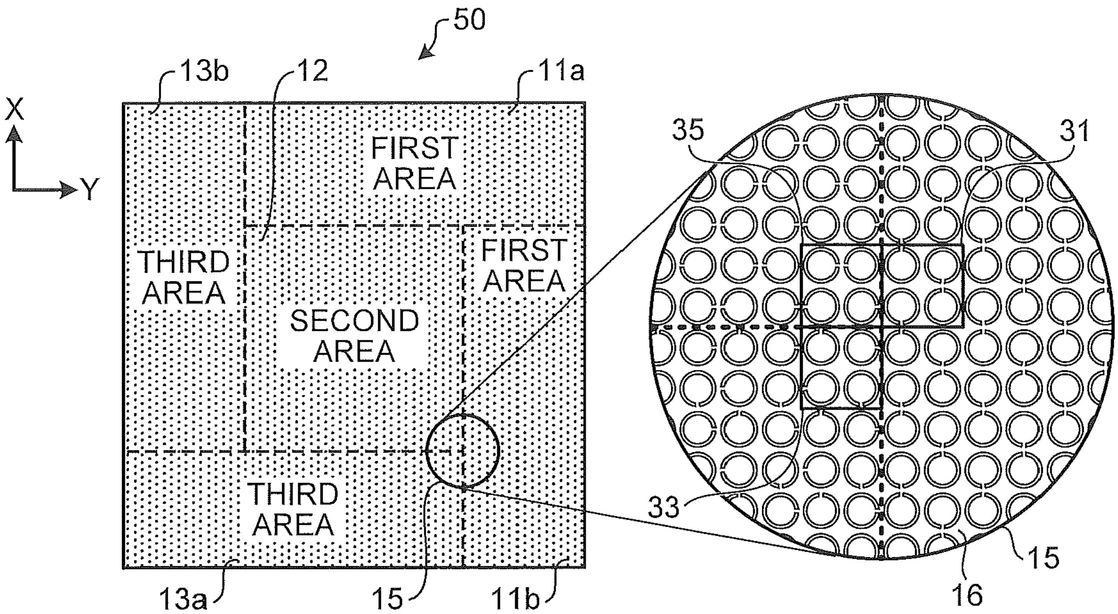

50
13b
12
11a
X
Y
FIRST AREA
THIRD AREA
FIRST AREA
SECOND AREA
THIRD AREA
13a
15
11b
35
31
33
15
16

FIG.8

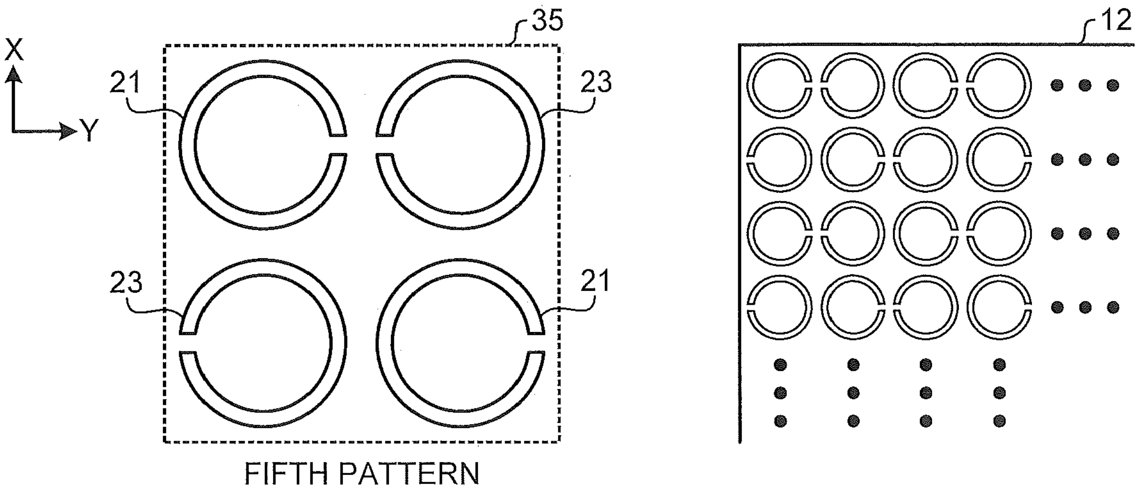

35
X
Y
21
23
23
21
FIFTH PATTERN
12

FIG.9

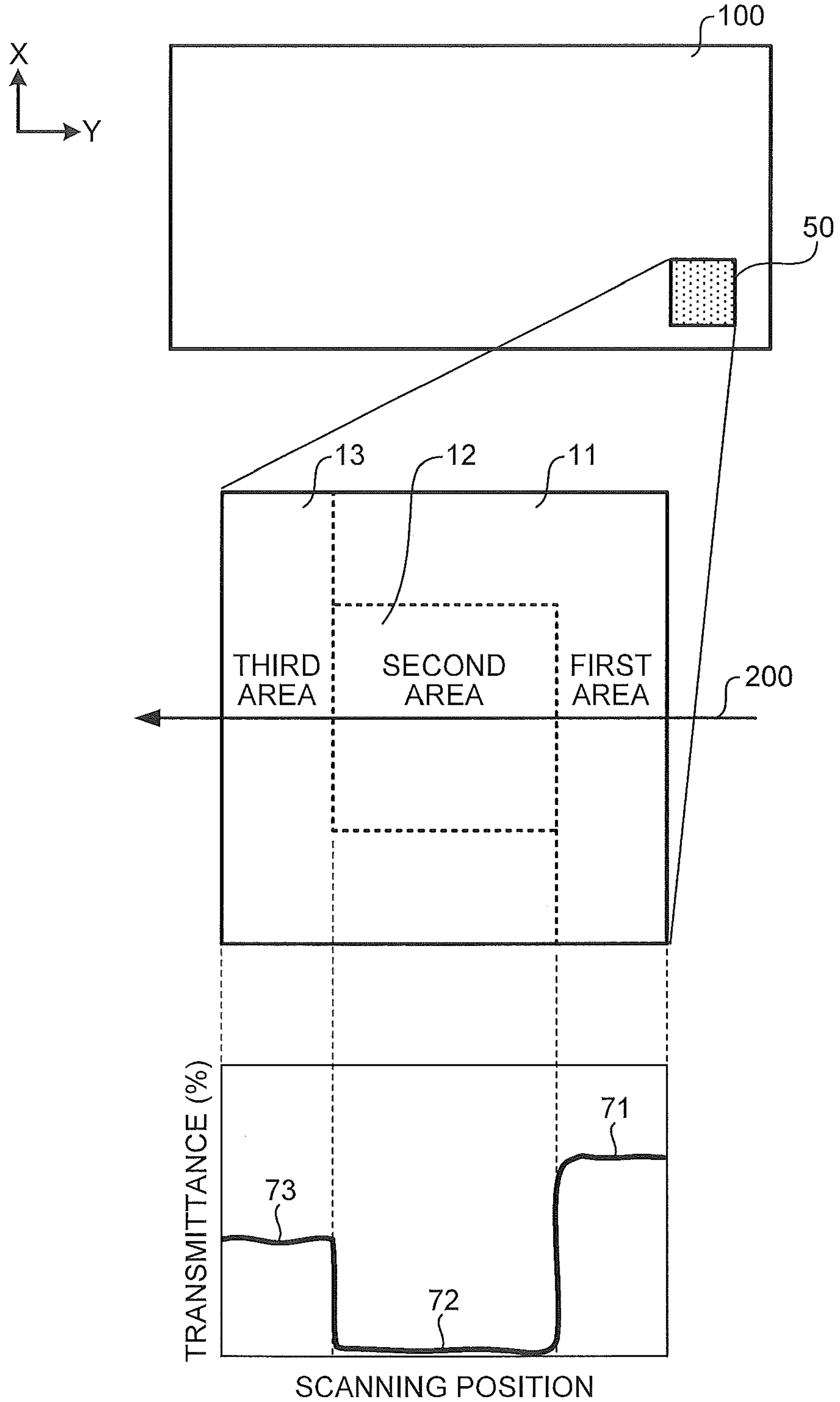
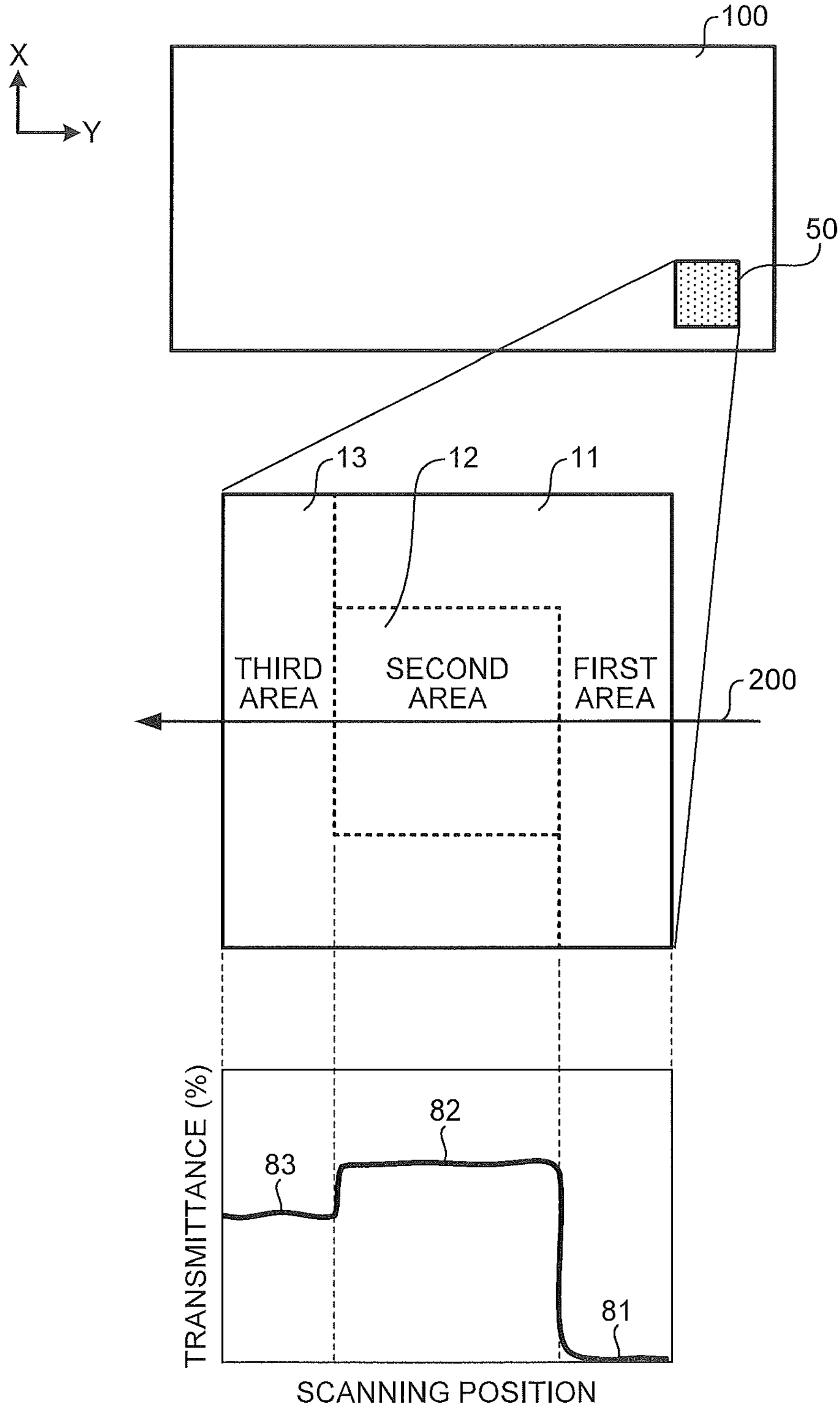

X
Y
100
50
13
12
11
THIRD AREA
SECOND AREA
FIRST AREA
200
TRANSMITTANCE (%)
71
73
72
SCANNING POSITION

FIG.10



100
X
Y
50
13
12
11
THIRD AREA
SECOND AREA
FIRST AREA
200
TRANSMITTANCE (%)
82
83
81
SCANNING POSITION

FIG.11

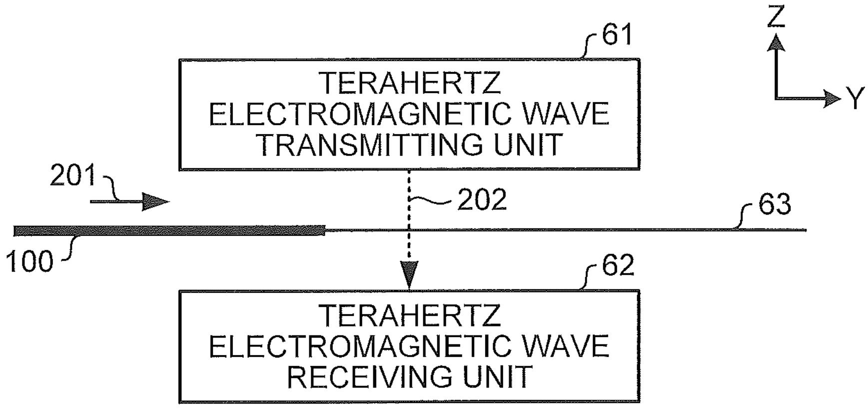


FIG.12A

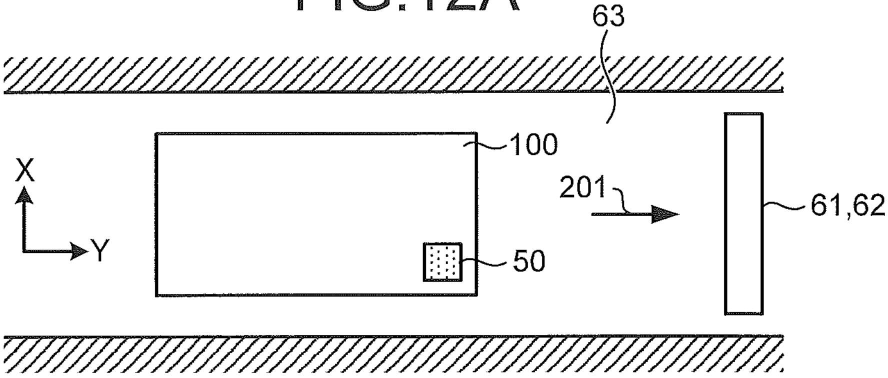


FIG.12B

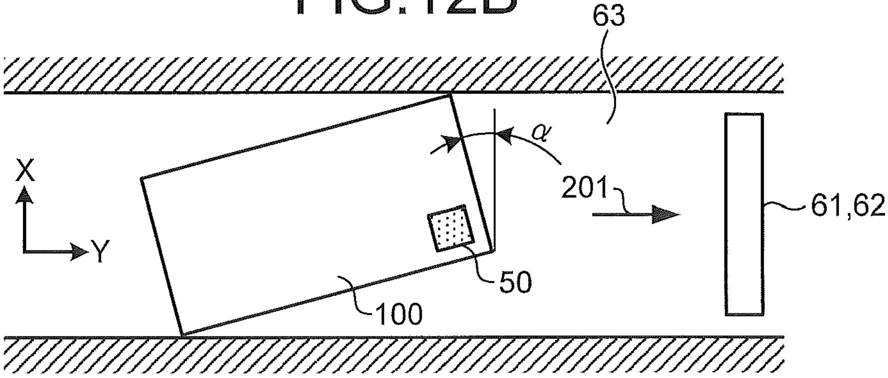


FIG.13

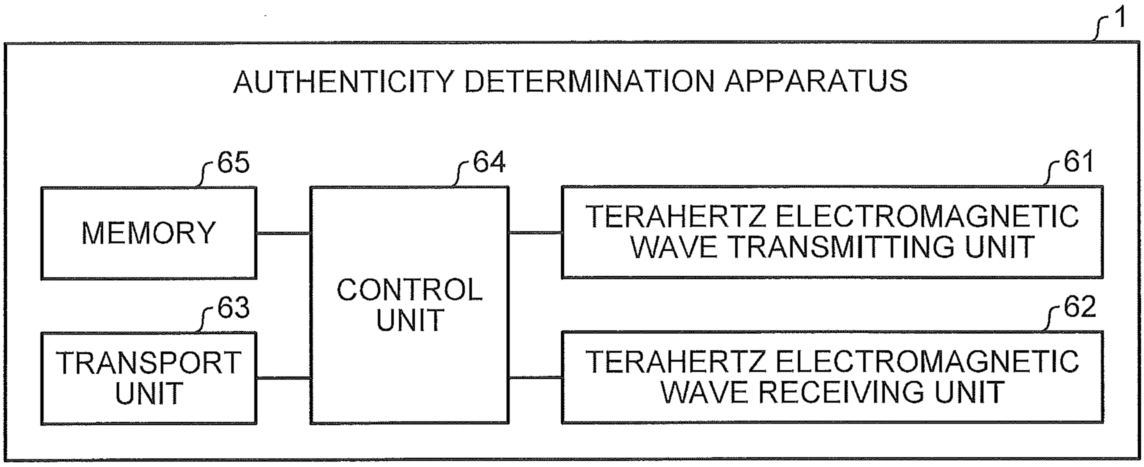

1
AUTHENTICITY DETERMINATION APPARATUS
65
MEMORY
64
CONTROL UNIT
61
TERAHERTZ ELECTROMAGNETIC WAVE TRANSMITTING UNIT
63
TRANSPORT UNIT
62
TERAHERTZ ELECTROMAGNETIC WAVE RECEIVING UNIT

FIG.14

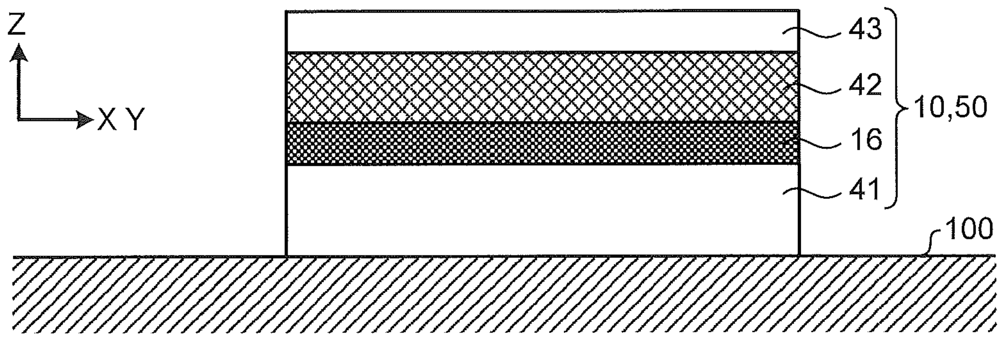

Z
X Y
43
42
16
41
10,50
100

FIG.15

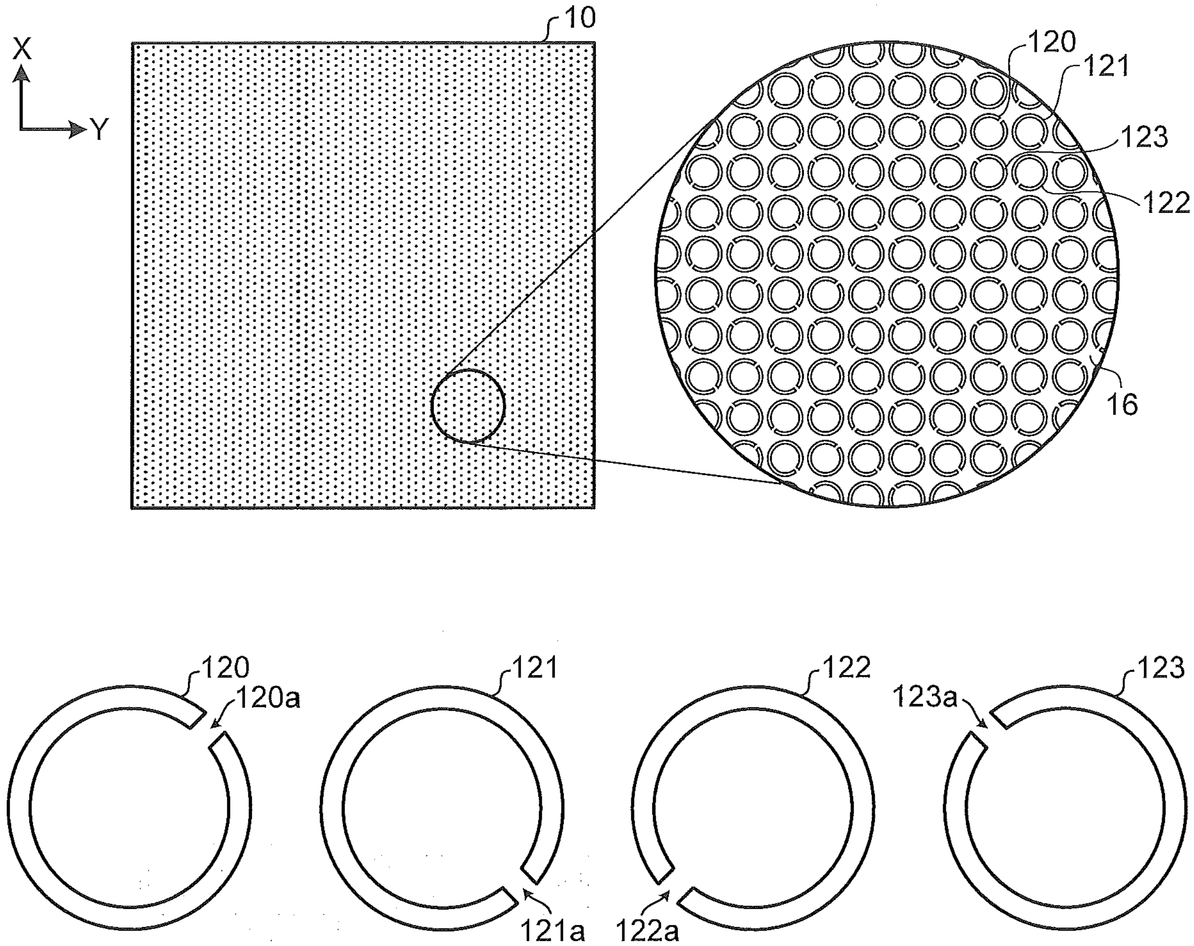
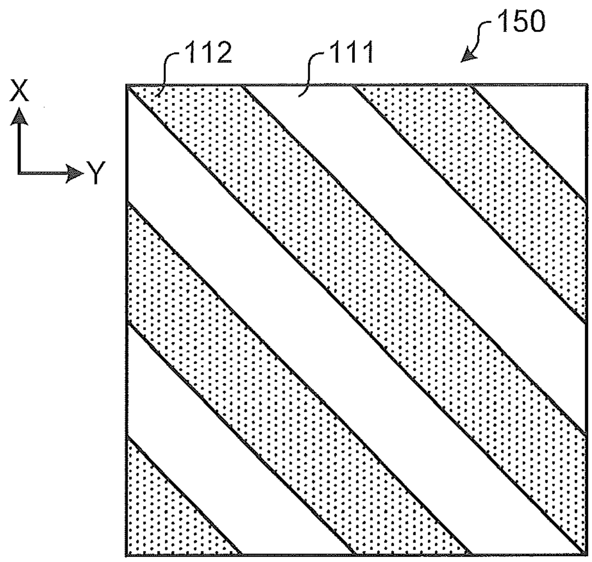


FIG.16



Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 18 19 5209

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,D	JP 2016 000498 A (TOPPAN PRINTING CO LTD; GLORY KOGYO KK; UNIV OSAKA) 7 January 2016 (2016-01-07) * paragraph [0001] * * paragraph [0016] - paragraph [0019] * * paragraph [0035] - paragraph [0040] * * paragraph [0047] - paragraph [0051] * * paragraph [0058] - paragraph [0060] * * figures 1,10-13 * -----	1-10	INV. G07D7/01 B42D25/373
X	JP 2016 141065 A (TOPPAN PRINTING CO LTD; GLORY KOGYO KK) 8 August 2016 (2016-08-08) * paragraphs [0024], [0041] * * paragraph [0057] - paragraph [0063] * * figures 1,5,6,8-10 * -----	1-10	

TECHNICAL FIELDS SEARCHED (IPC)

G07D
B42F
B42D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	11 February 2019	Bauer, Sebastian

2

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 19 5209

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-02-2019

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2016000498 A	07-01-2016	JP 6418592 B2	07-11-2018
		JP 2016000498 A	07-01-2016
JP 2016141065 A	08-08-2016	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2016000498 A **[0002] [0024]**