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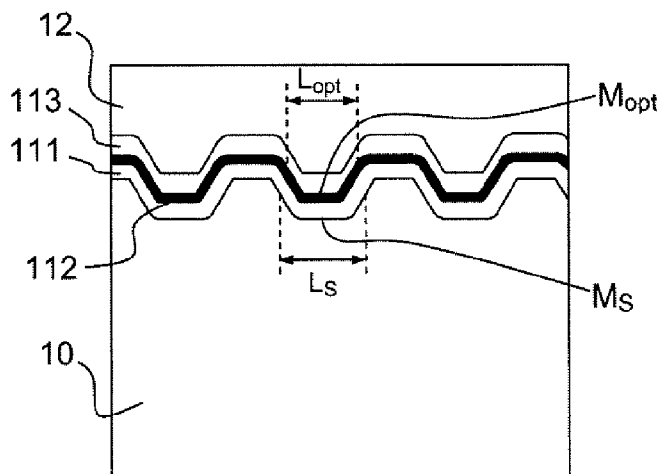
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Declarations under Rule 4.17:

[Continued on next page]

(54) Title: STRUCTURE FOR OPTICAL STORAGE OF INFORMATION AND METHOD OF OPTIMIZING PRODUCTION
OF THIS STRUCTURE**FIG. 4a**(57) Abstract: The invention relates to a high-
resolution optical storage structure possessing
an information storage capacity (C_{st}) and comprising:
a substrate (10) comprising physical
marks (M_s) whose geometric configuration
defines the item of information recorded, the
smallest physical marks ($2T$) exhibiting a
length on substrate (L_s) and a width on sub-
strate (l_s); a superposition of at least one first
layer (111) and of a second layer termed active
(112) on the surface of the said substrate com-
prising the physical marks, so as to create in-
formation marks (M_{opt}) ensuring the informa-
tion storage capacity at the level of the second
active layer, of optimal length (L_{opt}) and of so-
called optimal width (l_{opt}) characterized in that:
the length on substrate of the marks complies
with the following condition: $L_s = a L_{opt} + b$
the width on substrate of the marks complies
with the following condition: $l_s = c l_{opt} + d$
with a and c being between about 0.5 and 1 and b
and d being between about 30 and 80 nanometres
and L_{opt} and l_{opt} being between 0 and about 160
nanometres. The subject of the invention is
also a method of optimizing production of the
optical storage structure.



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- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- Published:**
- *with international search report (Art. 21(3))*

Structure for optical storage of information and method of optimizing production of this structure

The field of the invention is that of the field of data storage on optical
5 discs, and more particularly on optical discs of "high density" requiring the use of so-called Super-Resolution (SR) techniques in order to be read.

Generally, when seeking to increase the density of information recorded on an optical disc, one is limited by the performance of the device for reading the information. The basic principle is that only with great difficulty
10 is it possible to read physical information written into the disc if the dimension of the information is smaller than the limit of resolution of the optical system which is used to read this information.

Typically for reading with a red laser of wavelength 650 nm and a numerical aperture of 0.6, it is not possible to correctly read information of
15 dimension smaller than 0.4 micrometres.

This is why so-called super-resolution schemes have been developed for reading information whose physical dimension is smaller, or indeed even much smaller, than the wavelength. These schemes are based on the non-linear optical properties of certain materials used for the
20 manufacture of optical discs.

Typically, the optical properties of the material in which the information is recorded may vary in a non-linear manner as a function of the intensity of an optical reading beam. Thus, a reading laser may locally modify the optical properties of the material by thermal, optical, thermo-optical
25 and/or optoelectronic effects over smaller dimensions than the dimension of the reading spot; on account of the change of property, an item of optical information present in a very small volume may become detectable.

Indeed, the reading laser can be very strongly focused so as to exhibit a small cross section (of the order of the wavelength) with a Gaussian
30 power distribution that is very concentrated at its centre and very attenuated at the periphery. Thus by choosing a reading laser power such that the power density over a small part of the cross section significantly modifies at the centre of the beam an optical property of the material layer, whereas the power density outside of this small portion of cross section does not
35 significantly modify this optical property, it is thereby possible to render

readable an item of information which would not be readable without this modification.

The optical property can typically be the increasing of optical transmission in the case where the reading of a bit consisting of physical
5 marks on the optical disc requires transmission of the laser beam as far as the physical marks.

By resorting to non-linear optical properties of this type, it becomes notably possible to use a reading laser beam appearing to be focused over a much narrower diameter than is allowed by the wavelength of the said
10 reading beam.

Generally, the information written on discs is produced in layers of materials deposited on a pressed support containing convex areas and other concave areas, dubbed respectively "lands" and "pits".

The "pits" and "lands" of a disc do not correspond directly to 1s and
15 0s. The start and the end of a pit (that is to say its boundaries) each correspond to 1s, and all the other areas (both in the lands and the pits) correspond to 0s. The number of 0s between the boundaries of the pits is determined by a very precise time calculation.

If a single bit requires a time T to pass under the reading head, then
20 one speaks of "pits" of $2T$ for the smallest, knowing that "pits" ranging up to for example $8T$, as represented by way of indication in Figure 1, are also produced in a standard manner.

In the case of conventional (Read-Only Memory - ROM) prerecorded discs (DVD and Blu-Ray), a simple reflecting layer suffices to allow the
25 detection of the marks contained in the form of lands or pits in the substrate structured as represented in Figure 1, the dimension of these marks being larger than the limit of resolution of the optical head, defined by the product $\lambda/4.NA$, where λ is the wavelength of the writing laser and NA is the numerical aperture of the focusing objective.

30 In this case, as illustrated in Figure 2, the deposition of a simple thin metallic reflecting layer 11 whose thickness can vary between 10 and 40 nm on a substrate 10 is done in a compliant manner on the information bits premoulded in the plastic substrate. In a compliant manner signifies that the

thin layer hugs perfectly the geometry of the substrate on which it is deposited.

Typically, the length of the smaller marks (marks 2T) being 150 or 160 nm (corresponding respectively to a capacity of 23 or 25Gb), for a depth
5 of between 40 and 60 nm, the structured pattern on the substrate is reproduced perfectly after deposition, by the so-called PVD "Physical Vapour Deposition" technique, of the metallic layer, without distortion or modification of the initial geometric characteristics of the substrate, the whole assembly being covered with a protective layer 12. The marks can thus be read by a
10 reading laser beam F at the wavelength $\lambda = 0.85$ by virtue of a focusing optic FO, of numerical aperture NA = 0.85.

On the other hand, in the case of Super-Resolution ROM discs, the substrate contains shorter marks than the limit of resolution of the optical head. When the substrate is covered with a simple metallic layer similar to
15 that used in conventional ROM discs, the marks cannot be detected by the focused spot and no signal is detected at low reading power. However, a signal may be obtained originating from these small marks when an optical mask is introduced into the disc so as to disturb the process for reading the discs, based on the diffraction of the focused spot by the grating formed by
20 the marks.

In the case of SR optical discs (ROM, R and RW), this mask is produced by virtue of an "active" stack of thin layers, whose optical properties vary in a reversible manner under the influence of an intense optical excitation delivered by the continuous laser raised to high power as
25 explained in the introduction to the present patent application.

In the following patent applications No.0700938, 0702562, 0702561, the applicant has already described a particularly beneficial stack (represented in Figure 3) consisting of a layer of semi-conductor material 112 made of InSb (active layer having optical non-linear properties) encapsulated
30 between two layers 111 and 113 of dielectric material ZnS-SiO₂, able to deliver a signal of excellent quality (this may be considered to be the case when the bit "Error Rate", denoted bER, is less than or equal to $3 \cdot 10^{-4}$, a limit value allowing commercial use) originating from sequences comprising small marks of 80 nm as illustrated in Figure 3, thereby making it possible to
35 double the capacity of the discs (corresponding to a capacity of the order of

50Gb) with respect to the standard Blu-Ray format (capacity 23Gb) whose smallest marks measure 160 nm.

It should be noted that in the case of these super-resolution structures, on the one hand the stack of thin layers deposited on the substrate is several tens of nanometres, corresponding to a much greater
5 total thickness than the fine metallic layer of the standard ROM Blu-Ray disc, and on the other hand the length of the marks is below the limit of resolution of the optical system (less than 120nm).

The combination of these two conditions raises the problem of the making and reproduction, without distortion, of the basic geometric pattern premoulded on the substrate after the deposition of all the layers of the
10 super-resolution stack.

Indeed, whatever stack of layers is necessary within the framework of the super-resolution technique, it is still necessary to succeed in obtaining the expected information capacity, by virtue of satisfactory dimensions of
15 marks.

Typically it will be sought to produce a mark 2T of 80 nm, with a depth of about 40nm (for a capacity of about 50 Gb) after deposition of the various thin layers whatever distortion effects are induced by the deposition
20 technique.

For example, the active layer of active material (which may typically be of the order of 20 nm of material InSb), deposited on a dielectric material layer, typically 50 nm thick, must carry the information and have the expected capacity.
25

This is why and within this context, the subject of the present invention is a novel type of optical storage structure affording a solution to the technical problem raised in respect of high density optical discs which requires the use of Super-Resolution techniques in order to be read, and
30 therefore the use of an active stack of thin layers.

More precisely, the invention relates to a high-resolution optical storage structure possessing an information storage capacity and comprising:

- a substrate comprising physical marks whose geometric configuration defines the item of information recorded, the smallest physical marks exhibiting a length on substrate L_s and a width on substrate l_s ;

- a superposition of at least one first layer and of a second layer
 5 termed active on the surface of the said substrate comprising the physical marks, so as to create information marks ensuring the information storage capacity at the level of the second active layer, of optimal length L_{opt} and of so-called optimal width l_{opt} characterized in that:

- the length on substrate of the marks complies with the following
 10 condition:

$$L_s = a L_{opt} + b$$

- the width on substrate of the marks complies with the following condition:

$$l_s = c l_{opt} + d$$

15 with a and c being between about 0.5 and 1

b and d being between about 30 and 80 nanometres

and L_{opt} and l_{opt} being between 0 and about 160 nanometres.

According to a variant of the invention, the coefficient a is of the order of 0.8, the parameter b is of the order of 40, the optimal length L_{opt} being of
 20 the order of 80 nanometres.

According to a variant of the invention, the coefficient c is of the order of 0.6, the parameter d is of the order of 60, the optimal width being of the order of 80 nanometres.

According to a variant of the invention, the depth of the marks on
 25 substrate is of the order 50 nm.

According to a variant of the invention, the superposition of layers comprises an active layer based on phase change material possibly being of the AgInSbTe or GeSbTe compound type.

According to a variant of the invention, the superposition of layers
 30 comprises an active layer based on doped or undoped semiconductor material of type InSb, GaSb, ZnO.

According to a variant of the invention, the optical storage structure furthermore comprises a third layer made of dielectric material.

According to a variant of the invention, the first and third layers made
 35 of dielectric material are made of ZnS-SiO₂.

According to a variant of the invention, the first and third layers made of dielectric material are made of oxide, nitride or carbide of one of the following elements: Zr, Si, Al, Hf, Ti, Ta.

According to a variant of the invention, the thicknesses of the first
5 and third layers are of the order of some fifty or so nanometres, the thickness of the second layer being of the order of 20 nm.

According to a variant of the invention, the optical storage structure is intended to be read with a head by a reading beam at a wavelength $\lambda = 405$ nm and exhibiting a limit of resolution of 120 nm, with a numerical aperture
10 NA of 0.85, the optical storage capacity of the structure being about 50 Gb.

The subject of the invention is also a method of optimizing production of an optical storage structure making it possible to improve the performance thereof, and more particularly to improve the quality of the signal delivered
15 during reading.

More precisely, the subject of the invention is further a method of optimizing production of an optical storage structure according to the invention, characterized in that it comprises the following steps:

- the production of physical marks in the substrate exhibiting so-called
20 substrate lengths and widths;
- the production of a stack of layers comprising an active layer;
- the carrying out of test measurements making it possible to determine the lengths, widths of the information marks ensuring the information storage capacity at the level of the second active layer;
- 25 - the determination of laws of correspondences between the substrate lengths, widths and the lengths, widths of the marks in the active layer.

According to a variant of the invention, the test measurements are performed with an atomic force microscope.

30 The invention will be better understood and other advantages will become apparent on reading the nonlimiting description which follows and by virtue of the appended figures among which:

- Figure 1 illustrates the correspondence between etching marks and information of "0" and of "1";

- 5 - Figure 2 illustrates a schematic representation of a conventional ROM Blu-Ray optical disc, comprising a simple reflecting layer sufficient to allow the detection of the marks which are longer (160 nm for the smallest) than the limit of resolution of the optical head (120 nm);
- Figure 3 illustrates a schematic representation of an SR ROM Blu-Ray optical disc, comprising a standard active stack ZnS-SiO₂/InSb/ZnS-SiO₂ allowing the detection of shorter marks (80 nm for the smallest) than the limit of resolution of the optical head;
- 10 - Figures 4a and 4b illustrate the optical storage structure of the invention with the dimensions of the marks etched in the substrate and those at the level of the sensitive layer;
- Figures 5a, 5b and 5c illustrate an exemplary optical storage structure seen from above and comprising marks 2T of 100 nm. The marks are represented respectively at the level of the substrate, of the first dielectric layer and of the active layer, as are the associated observations carried out by atomic force microscopy;
- 15 - Figure 6 illustrates the evolution of the length of marks at the substrate level as a function of the length of the marks written into the active layer;
- 20 - Figure 7 illustrates the evolution of the width of marks at the substrate level as a function of the width of the marks written into the active layer and in correspondence with given lengths of marks.
- 25

In general, the thin layers of materials constituting the optical discs are made by so-called PVD (Physical Vapour Deposition) methods, whatever the nature of the materials (dielectrics, semi-conductors, phase change materials, etc.) constituting these layers. This deposition technique is particularly beneficial since it makes it possible to carry out depositions of thin layers at low temperature, compatible with the use of polymer substrate.

According to the invention and as illustrated in Figure 4a, the optical storage structure is intended to be able to be read with a super-resolution technique, this is why the said structure comprises an active stack on the

surface of a support 10 comprising the marks M_s of dimensions defined in the plane by a length L_s and a width l_s as represented in Figure 4b, the said stack consisting:

- of an active layer 112, that is to say one exhibiting optical non-linear properties,
- of two dielectric layers 111 and 113 situated either side of the active layer, which play both an optical role (adjustment of the optical properties of the disc) and a thermal role (thermal insulation of the active layer).

The active layer of the discs making it possible to deal with the problem raised, must exhibit optical non-linear properties at the working wavelength. It can in particular consist of phase change materials possibly being of the AgInSbTe, GeSbTe compounds type, inter alia), of doped or undoped semi-conductor materials (such as InSb, GaSb, ZnO) and in which it is thus possible to define optimized marks M_{opt} of dimensions defined in the plane by an optimal length L_{opt} and an optimal width l_{opt} .

The transparent layers of dielectric materials of the active stack, which play both an optical role to ensure the adjustment of the optical properties of the disc and a thermal role allowing thermal insulation of the active layer, can preferably be of the type: ZrO_2 , Si_3N_4 , AlN, HfO_2 , TiO_2 , SiO_2 , etc.

The substrates used in the discs making it possible to deal with the problem raised consist of polymer materials and are structured by pressing.

According to the invention, it is proposed to optimize the substrate by modifying in a relevant manner the geometries of the premoulded patterns in such a way that the effects of the successive depositions of the thin layers lead to the obtaining of the appropriate geometry, i.e. the expected dimension of the marks and therefore the capacity desired at the level of the so-called active layer carrying the information.

Exemplary embodiment:

According to this example, the optical storage structure corresponds to a prerecorded SR disc intended to be read with a "Blu-Ray" optical head

by a reading beam at a wavelength $\lambda = 405$ nm, with a numerical aperture NA of 0.85 and exhibiting a resolution limit of 120 nm.

The optical storage structure comprises a structured substrate containing sequences coded according to a standard (1,7) RLL algorithm of the Blu-Ray format, so that the informational content is manifested by the succession of marks and spaces of length varying between 2T and 9T.

In the case of the conventional Blu-Ray format (23 Gb version), the marks 2T measure 160 nm.

The SR discs presented in this example contain sequences of marks and spaces that are shorter than those of the Blu-Ray standard. The small marks 2T have a length of 100 nm or of 80 nm depending on the capacity sought, less than the limit of resolution of the optical head equal to 120 nm, and therefore require a Super-Resolution effect in order to be detected.

A stack of a first layer, of a second active layer and of a third layer is produced on the substrate in which the physical marks have been produced.

The active layer is a layer of semiconductor material made of InSb encapsulated between the first and third layers of dielectric material made of ZnS-SiO₂.

A configuration offering very good performance in terms of signal quality is obtained when the active layer InSb has a thickness of 20 nm, and the dielectric layers ZnS-SiO₂ a thickness of 50 nm each.

Figures 5a, 5b and 5c show observations carried out by atomic force microscopy (AFM) which make it possible to view very small dimensions, typically of the order of a nanometre. These figures relate respectively to the initial marks produced at the level of the substrate, of those apparent at the level of the first ZnS-SiO₂ dielectric material layer 50 nm thick and of those apparent at the level of the InSb sensitive layer 20 nm thick.

The applicant has noted that for dimensions of marks of the order of 150 nm, no particular precaution need be envisaged in respect of the initial geometry of the substrate since the geometry of the marks in terms of length and depth is hardly modified after deposition of the InSb layer carrying the information.

On the other hand, when the dimension of the marks decreases and becomes less than 120 nm, the applicant has noted an effect of filling of the smaller marks, with notably a decrease in the length after the successive

depositions of dielectric ZnS-SiO₂ (50 nm) and of sensitive layer of non-linear material of InSb (20 nm). A decrease in the length of the marks of 15% is apparent after depositions with respect to the bare substrate in the case of marks 100 nm in diameter on the substrate. This "filling" effect is still more
 5 marked for the pits of 80 nm. A decrease in the length of the marks from 20 to 30% after depositions with respect to the bare substrate is noted.

These effects of the conditions of deposition on the geometry of the marks must therefore be taken into account in order to define the optimized substrate. To obtain a post-deposition geometry compatible with the densities
 10 sought, it is necessary to mould for example, pits 2T having a length of 95-105 nm (80nm+20-30%) to obtain after deposition of the information carrying layer (InSb), the right length of marks 2T of 80nm.

A method of optimization has thus been formulated by the applicant who has established laws of correspondences between the lengths, widths of
 15 the marks in the substrate and the lengths, widths of the marks in the sensitive layer.

Figure 6 illustrates in this regard the evolution of the length of marks at the substrate level as a function of the length of the marks written into the
 20 active layer, expressed in nanometres. The straight line f_6 relates to the ideal case of depositing a stack of layers without any distortion introduced by the successive deposition operations. The function $L_s = a L_{opt} + b$ is that obtained on the basis of experimental measurements performed by AFM measurement and represented by the curve C_6 .

Figure 7 illustrates the evolution of the width of marks at the substrate level as a function of the width of marks written into the active layer, expressed in nanometres. The straight line f_7 relates to the ideal case
 25 of depositing a stack of layers without any distortion introduced by the successive deposition operations. The function $l_s = c l_{opt} + d$ is that obtained on the basis of experimental measurements performed by AFM measurement and represented by the curve C_7 , for given mark lengths.
 30

Typically this yields information marks that may exhibit the following value pairs:

$L_{opt} = 80 \text{ nm}, l_{opt} = 80 \text{ nm}$
 35 $L_{opt} = 100 \text{ nm}, l_{opt} = 90 \text{ nm}$

$$L_{\text{opt}} = 160 \text{ nm}, l_{\text{opt}} = 115 \text{ nm}$$

By establishing these laws, an optimized structuring of the geometry of the marks is thus obtained, in addition to the appropriate stack of thin
5 layers which makes it possible to obtain a signal of very good quality when the disc is read at 2.65m/s (capacity of the disc 46GB) since after processing by an advanced signal processing algorithm of the PRML type, an error rate (bit Error Rate-bER) of 10^{-5} is obtained.

CLAIMS

1. High-resolution optical storage structure possessing an information storage capacity (C_{st}) and comprising:

- 5 - a substrate (10) comprising physical marks (M_s) whose geometric configuration defines the item of information recorded, the smallest physical marks exhibiting a length on substrate (L_s) and a width on substrate (l_s);
- a superposition of at least one first layer (111) and of a second layer termed active (112) on the surface of the said substrate comprising the
- 10 physical marks, so as to create information marks (M_{opt}) ensuring the information storage capacity at the level of the second active layer, of optimal length (L_{opt}) and of optimal width (l_{opt}) characterized in that:
- the length on substrate of the marks complies with the following condition:

$$L_s = a L_{opt} + b$$

- the width on substrate of the marks complies with the following condition:

$$I_s = c I_{opt} + d$$

with a and c being between about 0.5 and 1

- 20 b and d being between about 30 and 80 nanometres
and L_{opt} and l_{opt} being between 0 and about 160 nanometres.

2. Optical storage structure according to Claim 1, characterized in that the coefficient a is of the order of 0.8, the parameter b is of the order of 40, the optimal length (L_{opt}) being of the order of 80 nanometres.

3. Optical storage structure according to one of Claims 1 or 2, characterized in that the coefficient c is of the order of 0.6, the parameter d is of the order of 60, the optimal width being of the order of 80 nanometres.

4. Optical storage structure for information according to one of Claims 1 to 3, characterized in that the depth on substrate of the marks is of the order of 50 nanometres.

5. Optical storage structure according to one of Claims 1 to 4, characterized in that the superposition of layers comprises an active layer based on phase change material possibly being of the AgInSbTe or GeSbTe compound type.

5

6. Optical storage structure according to one of Claims 1 to 5, characterized in that the superposition of layers comprises an active layer based on doped or undoped semiconductor material of type InSb, GaSb, ZnO.

10

7. Optical storage structure according to one of Claims 1 to 6, characterized in that the superposition furthermore comprises a third layer, the first and third layers being made of dielectric material.

15

8. Optical storage structure according to Claim 7, characterized in that the first and/or third layers made of dielectric material are made of ZnS-SiO₂.

9. Optical storage structure according to Claim 7, characterized in that the first and/or third layers made of dielectric material are made of oxide, nitride or carbide of one of the following elements: Zr, Si, Al, Hf, Ti, Ta.

10. Optical storage structure according to one of Claims 1 to 8, characterized in that the thicknesses of the first and third layers are of the order of some fifty or so nanometres, the thickness of the second layer being of the order of 20 nanometres.

11. Optical storage structure according to one of Claims 1 to 10, and intended to be read with a head by a reading beam at a wavelength $\lambda = 405$ nm, with a numerical aperture NA of 0.85 and exhibiting a limit of resolution of 120 nanometres, characterized in that the storage capacity is about 50 Gb.

12. Method of optimizing production of an optical structure according to one of Claims 1 to 10, characterized in that it comprises the following steps:

35

- the production of physical marks in the substrate exhibiting so-called substrate lengths and widths;
- the production of a stack of layers comprising an active layer;
- the carrying out of test measurements making it possible to determine
5 the lengths and the widths of the information marks ensuring the information storage capacity at the level of the second active layer;
- the determination of laws of correspondences between the substrate lengths and widths and the lengths and widths of the marks in the active layer.

10

13. Method of optimizing production according to Claim 10, characterized in that the test measurements are performed by atomic force microscopy.

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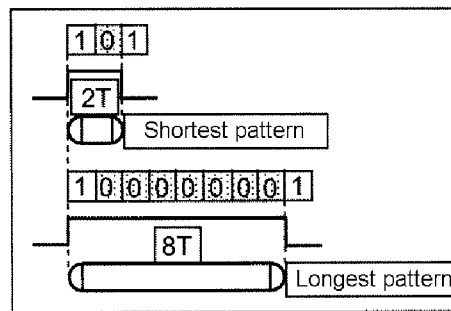


FIG.1

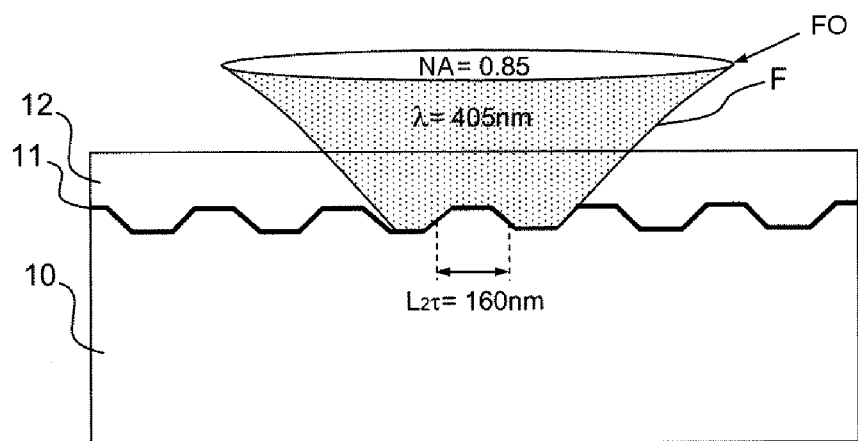


FIG.2

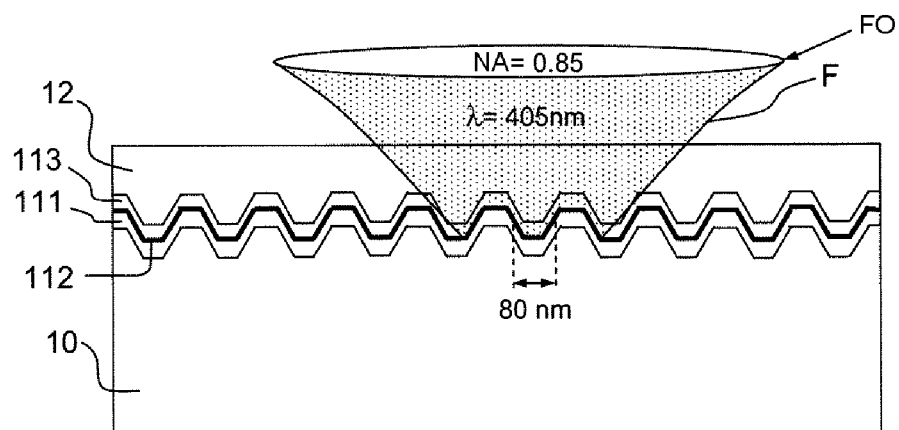


FIG.3

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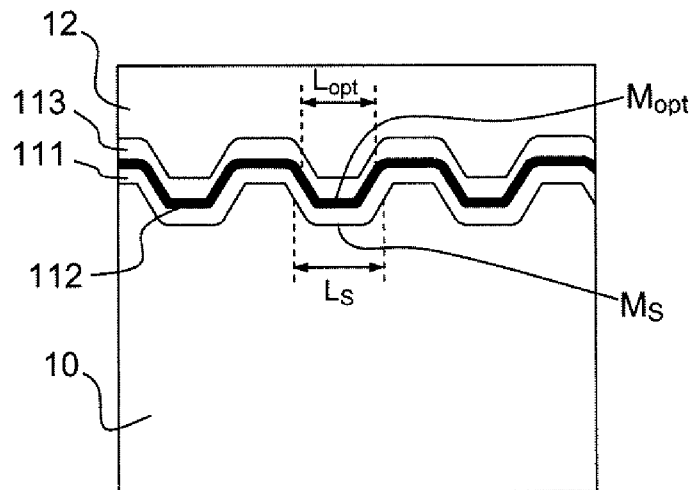


FIG.4a

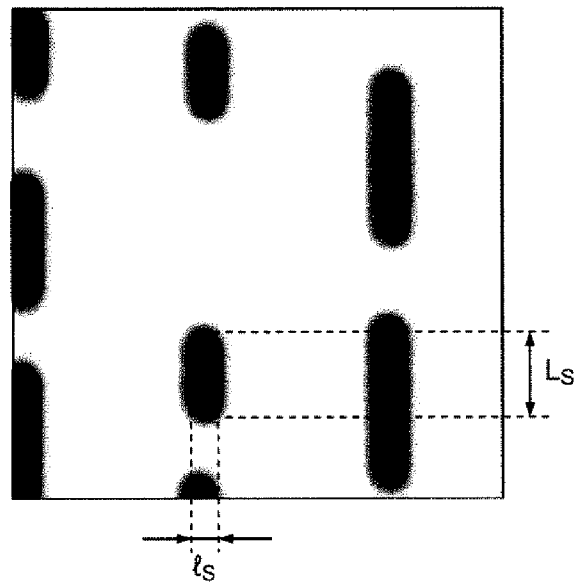


FIG.4b

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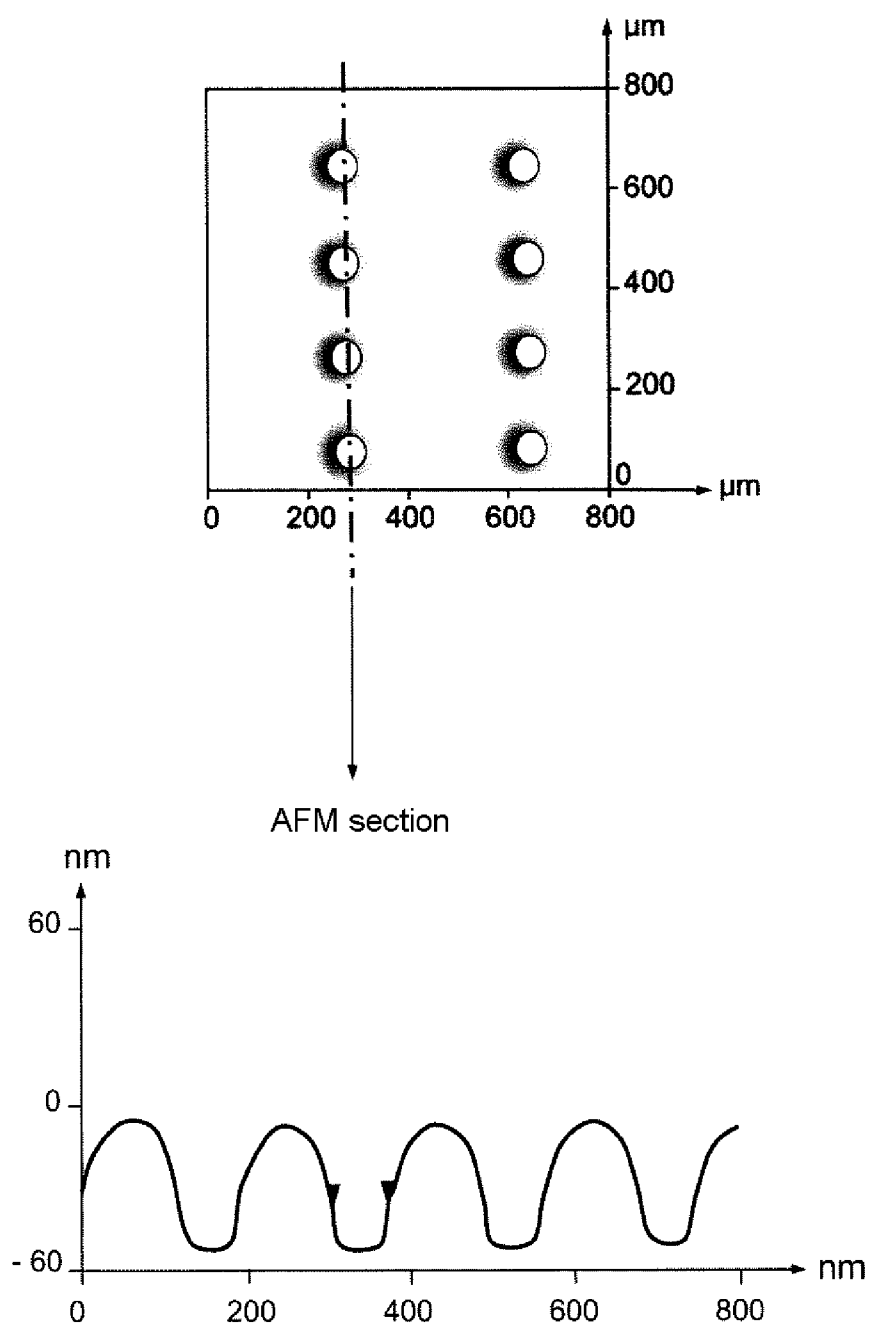


FIG.5a

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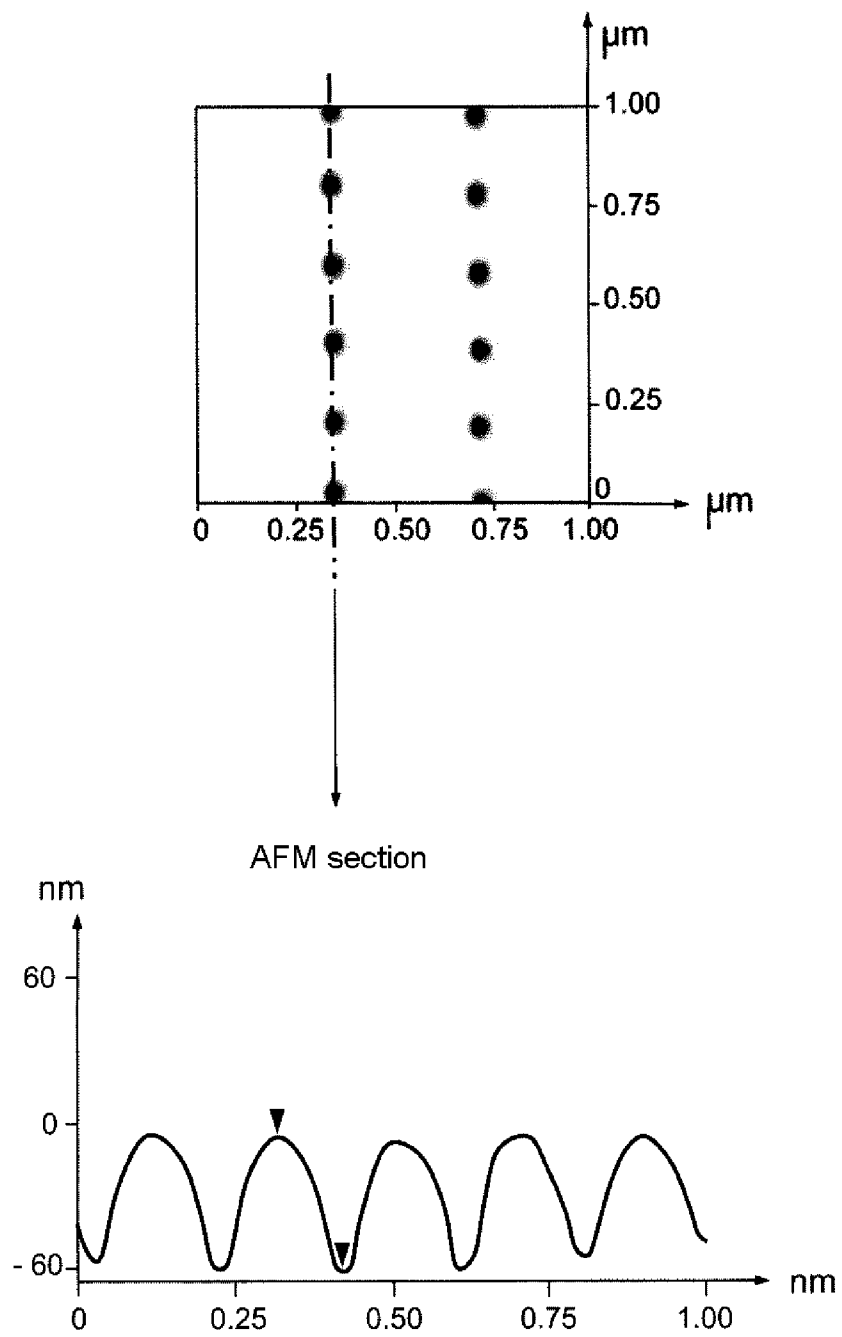


FIG.5b

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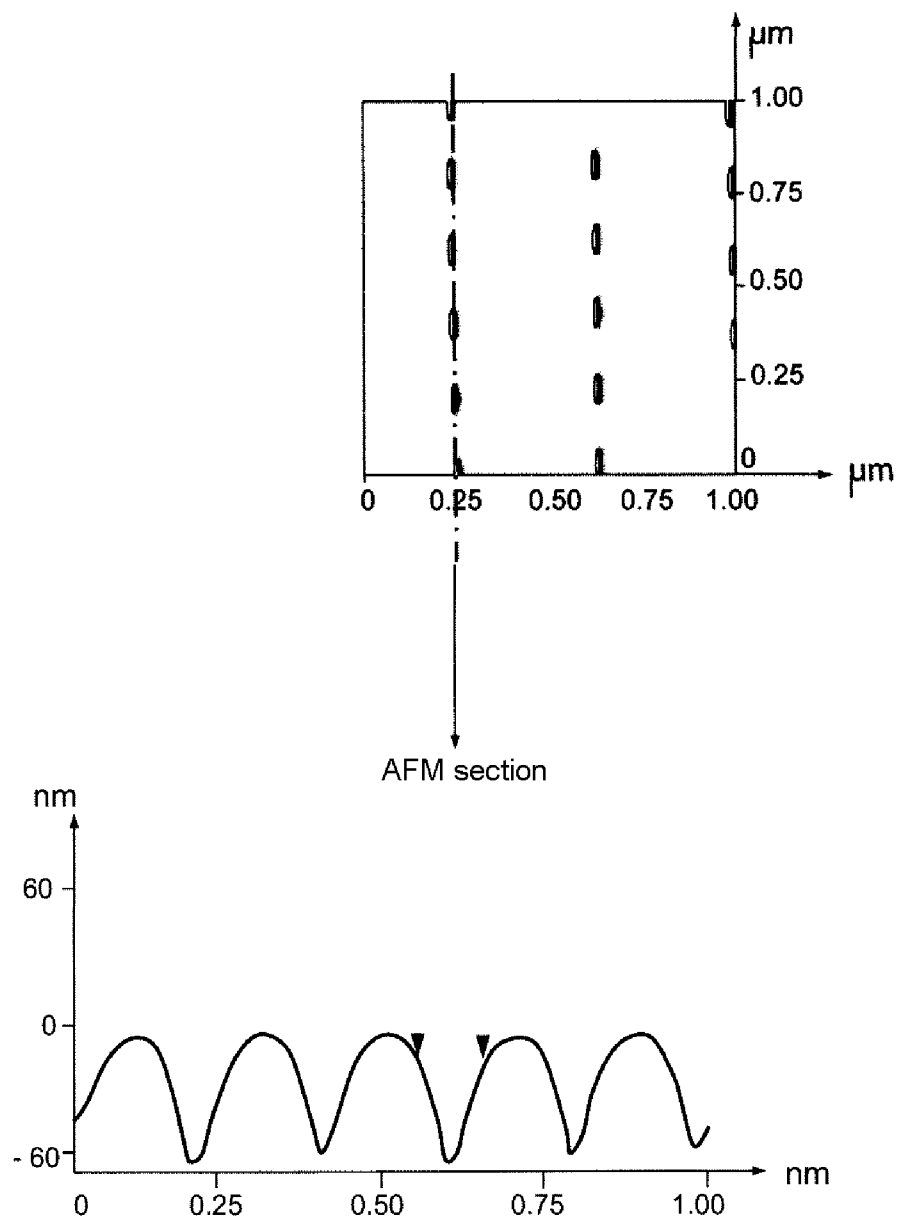


FIG.5c

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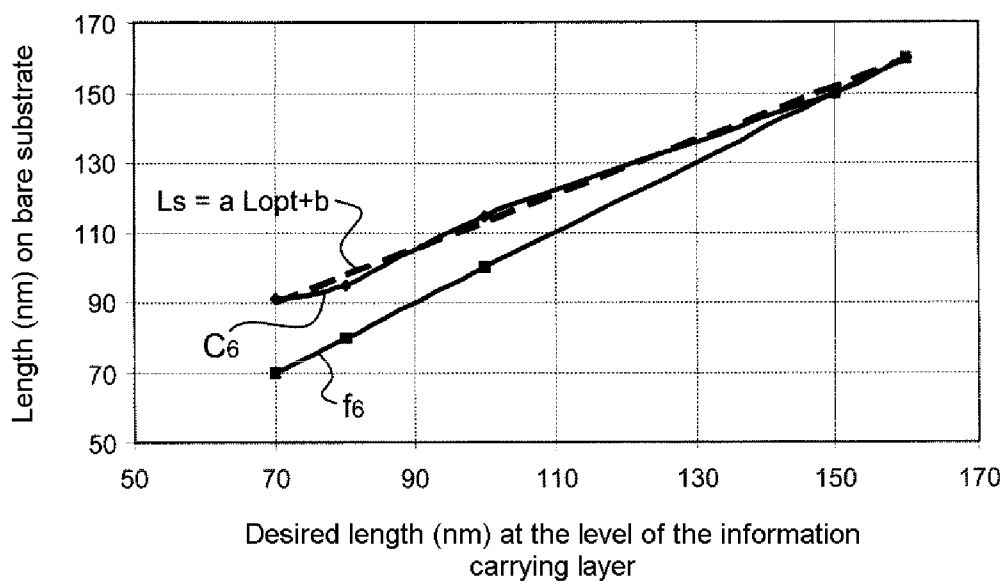


FIG. 6

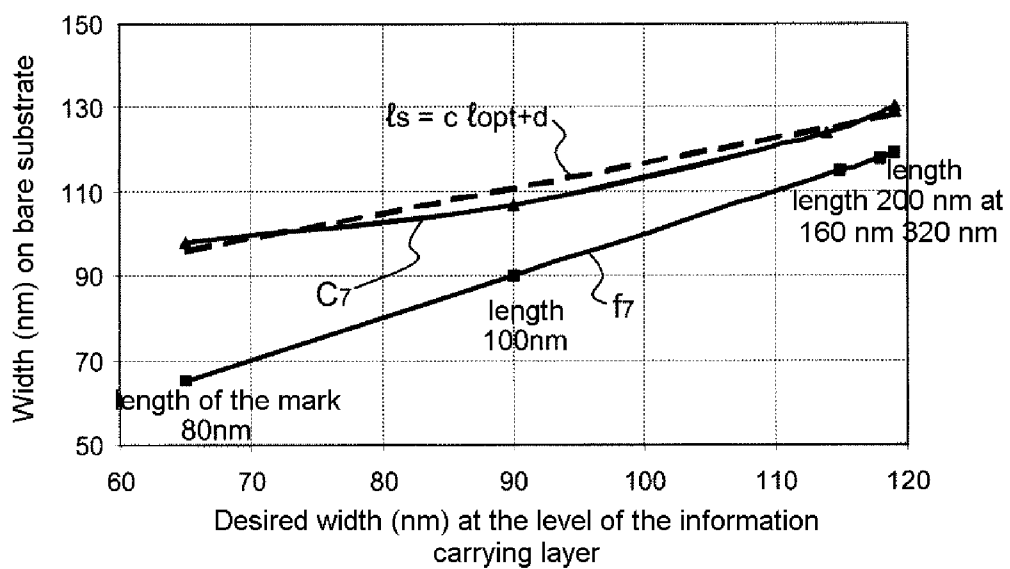


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/053635

A. CLASSIFICATION OF SUBJECT MATTER
INV. G11B7/013 G11B7/24
ADD.

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)
G11B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	FR 2 914 775 A (COMMISSARIAT ENERGIE ATOMIQUE [FR]) 10 October 2008 (2008-10-10) cited in the application the whole document	1-13
A	US 2005/286401 A1 (OYAKE HISAJI [JP] ET AL) 29 December 2005 (2005-12-29) the whole document	1-13
A	US 2003/169677 A1 (IIMURA SHINICHIRO [JP] ET AL) 11 September 2003 (2003-09-11) the whole document	1-13
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search

22 April 2010

Date of mailing of the international search report

04/05/2010

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2010/053635

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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