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(54) **METHOD FOR FABRICATING AN ARRAY OF MAGNETS AND ASSOCIATED METHOD FOR CONFIGURING AND ARRAY OF MAGNETS**

(57) The invention concerns a method for fabricating an array of magnets (10), the method comprising:
- a step of deposition of a coercivity changing element according to a pattern on a first material having a first coercivity value, the coercivity changing element being adapted to change the coercivity of the first material, and
- a step of diffusion of the coercivity changing element into certain regions to form a magnetic layer (16) having first areas (A1) made of the first material and second areas (A2) having a second coercivity, made of a second material comprising the first material and the coercivity changing element.

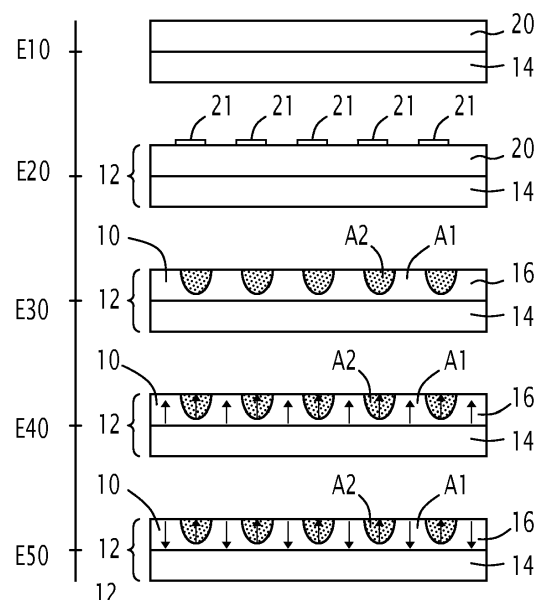


FIG.1

Description

FIELD OF THE INVENTION

[0001] The present invention concerns a method for fabricating an array of magnets. The present invention also relates to a method for configuring such an array of magnets and to an associated array of magnets.

BACKGROUND OF THE INVENTION

[0002] Hard magnets maintain a remanent magnetisation in zero applied field, thanks to their non-negligible value of coercivity. Hence the term "hard". A multipole array consists of multiple individual magnets with the direction of magnetisation varying from one sub-set of magnets to another.

[0003] Multipole arrays of hard micro-magnets can be used in various types of micro-scaled devices, including those that exploit magnet-coil interactions (e.g. motors, generators, actuators...) or magnetic field gradient forces (e.g. magnetic particle trapping), thus rendering them of interest for applications in fields as diverse as telecommunications, energy management, Internet of Things, diagnostics, bio-technology... For certain applications, it may be desirable to have arrays of micro-magnets which are magnetized in a multipole fashion (i.e. different magnets in the array being magnetized in different directions).

[0004] Hard micro-magnet arrays can be made by the controlled assembly of sub-mm sintered magnets or polymer bonded hard magnetic powders or alternatively by patterning hard magnetic layers fabricated by methods such as electro-deposition or physical vapour deposition (e.g. sputtering, evaporation, pulsed laser deposition...).

[0005] Several techniques are known to achieve such micro-patterning of hard magnetic layers.

[0006] A first kind of technique consists in physically removing sections of the magnetic layer, for instance through lift-off or etching.

[0007] A second kind of technique consists in physically patterning the substrate prior to the deposition of the magnetic layer, so as to introduce cavities in the substrate of controlled size, shape and disposition. Deep Reactive Ion Etching of the substrate is a specific example of this second kind of technique.

[0008] A third kind of technique is thermo-magnetic patterning of the magnetic layer. In such an approach, the magnetic layer is temporarily locally heated so as to temporarily and locally modify the coercivity, and the direction of magnetisation of the heated regions can be modified by applying a magnetic field with the appropriate intensity value.

[0009] A fourth kind of technique is magnetic field patterning of the magnetic layer using an array of micro-scaled soft magnetic elements, which serve to locally concentrate the flux of an externally applied magnetic

field, or an array of micro-scaled electro-magnets.

[0010] Both the third and fourth techniques which by definition produce multipole arrays of hard micro-magnets, require access at close proximity to the surface of the magnetic layer, and thus must be carried out before materials other than simple capping or thin protective layers are deposited on the magnetic layer. Consequently, neither thermo-magnetic patterning nor magnetic field patterning can be applied once the magnetic layer is buried below other system components that block heat or magnetic field transmission, nor after the device has been packaged, which may be very constraining when wanting to integrate the hard micro-magnets into a device.

SUMMARY OF THE INVENTION

[0011] There is therefore a need for a method for fabricating which alleviates the above-mentioned defects.

[0012] To this end, the specification describes a method for fabricating an array of magnets, the method comprising:

- a step of deposition of a coercivity changing element according to a pattern on a first material having a first coercivity value, the coercivity changing element being adapted to change the coercivity of the first material, and
- a step of diffusion of the coercivity changing element into certain regions to form a magnetic layer having first areas made of the first material and second areas having a second coercivity, made of a second material comprising the first material and the coercivity changing element.

[0013] According to further aspects of the method for fabricating, which are advantageous but not compulsory, the method for fabricating might incorporate one or several of the following features, taken in any technically admissible combination:

- the step of diffusion is achieved by heating.
- the method further comprises a step of forming an initial magnetic layer by deposition of the first material on a substrate, the coercivity changing element being deposited on the initial magnetic layer.
- the substrate is made of a material chosen among Si, quartz, sapphire, MgO, fused silica, glass, NaCl, tungsten, molybdenum, tantalum and soft ferromagnetic metals such as iron, cobalt, nickel and their alloys.
- the method further comprises a step of providing a magnet, the magnet being in the first material, the coercivity changing element being deposited on an external face of the magnet during the step of depositing.
- the first material based on a phase is chosen in the

list consisting of $\text{Nd}_2\text{Fe}_{14}\text{B}$, SmCo_5 , SmCo_7 , $\text{Sm}_2\text{Co}_{17}$, $\text{Sm}_2\text{Fe}_{17}\text{N}_3$, L_{10}FePt , L_{10}CoPt and $\text{Ba-Fe}_{12}\text{O}_{19}$.

- the coercivity changing element is a coercivity enhancing element, resulting in a second coercivity value for the second area being superior to the first coercivity value, the coercivity enhancing element being preferably chosen from the list consisting of Dy, Tb, Ho and low-melting alloys which include at least one of Dy, Tb, Ho, Nd, Pr, La and Ce.
- the coercivity changing element is a coercivity reducing element, resulting in a second coercivity value for the second area being inferior to the first coercivity value, the coercivity reducing element being preferably chosen from the list consisting of Ce, La, Gd and low-melting alloys which include Ce, La and Gd.
- the method comprises:

- carrying out a method for fabricating an array of magnets,
- global magnetisation of the magnetic layer along a first direction, and
- local magnetisation of areas of the magnetic layer along a second direction, which is different from the first direction.

- the magnetisation steps are carried out by applying magnetic field on the magnetic layer,

the magnetic field applied during the global magnetisation having an intensity superior to both the first coercivity value and the second coercivity value, and the magnetic field applied during the local magnetisation modifies the magnetisation direction of the first areas, the magnetic field having an intensity comprised between the first coercivity value and the second coercivity value when the second coercivity value is superior to the first coercivity value or the magnetic field applied during the local magnetisation modifies the magnetisation direction of the second areas, the magnetic field having an intensity comprised between the second coercivity value and the first coercivity value when the second coercivity value is inferior to the first coercivity value.

- the method comprises:
 - carrying out a method for fabricating an array of magnets, and
 - a step of application of a variable external magnetic field on the magnetic layer.

[0014] The specification also concerns an array of magnets comprising a magnetic layer comprising first areas and second areas arranged according to a pattern, the first area being made of a first material having a first coercivity value and the second area being made of a second material having a second coercivity value, the

first coercivity value and the second coercivity value being different.

[0015] According to further aspects of the method for configuring, which are advantageous but not compulsory, the method for configuring might incorporate one or several of the following features, taken in any technically admissible combination:

- the array of magnets is a multipole array.
- the second material is made of the first material and a coercivity changing element, a coercivity changing element being adapted to change the coercivity of the first material.

- [0016]** The specification also concerns an array of magnets, wherein the second material is obtained by a thermal diffusion of the coercivity changing element into the first material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The invention will be better understood on the basis of the following description which is given in correspondence with the annexed figures and as an illustrative example, without restricting the object of the invention. In the annexed figures:

- figure 1 shows schematically an example of carrying out a method for configuring an array of magnets, and
- figure 2 is a top-view perspective, showing examples of different patterns of such an array of magnets.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Figure 1 illustrates the different steps of a method for fabricating a multipole array of hard magnets.

[0019] In the present example, the method for fabricating a multipole array of hard magnets comprises two distinct phases, each corresponding to a different method.

[0020] The first method is a method for fabricating an array of magnets 10 and corresponds to steps E10 to E30 in figure 1, while the second method is a method for configuring which further encompasses steps E40 and E50.

[0021] The first step E10 varies according to the embodiment.

First embodiment: case with a substrate

[0022] The array of magnets 10 comprises a magnetic layer 16, which will be described hereinafter.

[0023] According to the example of figure 1, such magnetic layer is part of a stack 12 of layers.

[0024] The stack 12 comprises several layers stacked (superimposed) along a stacking direction, which corre-

sponds to the vertical direction.

[0025] Hereinafter, so as to simplify the representation, only a substrate 14 which is part of the stack 12 is represented on figure 1.

[0026] The layers extend in a substantially horizontal plane.

[0027] The stack 12 of layers comprises a substrate 14 and a magnetic layer 16.

[0028] In fact, this does not preclude that the stack of layers of the array 10 comprises more layers.

[0029] Notably, the stack 12 generally comprises a buffer layer between the substrate 14 and the magnetic layer 16. The buffer layer prevents diffusion between the magnetic layer 16 and the substrate 14.

[0030] Such a buffer layer is, for instance, in tantalum (Ta).

[0031] The stack 12 generally also comprises a capping layer, for instance made of Ta.

[0032] Such capping layer may be deposited after deposition of the coercivity modifying element.

[0033] According to another embodiment, the array 10 only comprises the magnetic layer 16.

[0034] The substrate 14 is, for instance, made of Si.

[0035] Alternatively, the material of the substrate 14 is quartz, sapphire, MgO, fused silica, glass and NaCl.

[0036] It may also be considered as material for the substrate 14 tungsten, molybdenum, tantalum, or soft ferromagnetic metals such as iron, cobalt, nickel and their alloys.

[0037] More generally, the material of the substrate 14 is any material which can be used as a support upon which the magnetic layer 16 can be deposited, allowing for the fact that high temperature is required during or after deposition to crystallise the hard magnetic phase and cause diffusion of the material deposited on specific regions of the magnetic layer 16. The magnetic layer 16 comprises first areas A1 and second areas A2.

[0038] Hereinafter, a first area A1 is named area A1 and a second area is named area A2. The area A1 are made of a first material M1.

[0039] The first material M1 has a first coercivity value H_{C1} .

[0040] To modify the direction of magnetisation of a magnetic material, a magnetic field which exceeds the material's value of coercivity must be applied.

[0041] In one specific example, the first material M1 is based on the $Nd_2Fe_{14}B$ phase.

[0042] The first material M1 is thus chosen in the list consisting of materials based on hard magnetic phases chosen in the list consisting in $R_2Fe_{14}B$ (where R is a rare earth element such as Nd, Pr, Ce, La, Dy, Tb, or a mixture thereof), $SmCo_5$, $SmCo_7$, Sm_2Co_{17} , $Sm_2Fe_{17}N_3$, $L1_0$ FePt, $L1_0$ CoPt and $BaFe_{12}O_{19}$.

[0043] In each area A1, the first material M1 has a magnetisation in a first direction (in the case in figure 1, the direction of magnetisation is from top to bottom, as indicated by the arrows).

[0044] The first direction is parallel to the vertical direc-

tion.

[0045] The second areas A2 are made of a second material M2.

[0046] The second material M2 has a second coercivity value H_{C2} .

[0047] The first coercivity value H_{C1} and the second coercivity value H_{C2} are different.

[0048] More specifically, the second material M2 is made of the first material M1 into which a coercivity changing element has been diffused, a coercivity changing element being a material adapted to change the coercivity of the first material M1.

[0049] In the example of figure 1, the coercivity changing element is Dy.

[0050] Dy has the property of enhancing the coercivity of the area A1 consisting of the first material M1 based on the $Nd_2Fe_{14}B$ phase.

[0051] In other words, in this specific case, the coercivity changing element is a coercivity enhancing element, resulting in a second coercivity value H_{C2} for the second areas A2 being superior to the first coercivity value H_{C1} .

[0052] Coercivity modification may be due to a number of factors including but not limited to 1) a change in an intrinsic magnetic property, namely the magnetocrystalline anisotropy, of all or part of the material within the areas A2, 2) magnetic decoupling of hard phase grains due to the formation of a grain boundary phase.

[0053] Diffusion of Dy into a magnetic layer, in particular along grain boundaries, enhances coercivity through a localized increase of magnetocrystalline anisotropy.

[0054] However, other elements have such enhancing property.

[0055] Thus, the enhancing coercivity element are magnetocrystalline anisotropy enhancing coercivity element for $Nd_2Fe_{14}B$ and are chosen in a list including the heavy rare earth (HRE) metals Dy, Tb and Ho as well as low-melting multi-element alloys containing these HRE.

[0056] Coercivity modification through the formation of a continuous grain boundary phase that serves to magnetically decouple neighbouring grains can be achieved by diffusion of low-melting alloys including eutectic alloys such as those in the R-Cu, R-Al systems... (R = rare earth = Nd, Pr, Ce, La...) and multi-element alloys such as but not limited to Nd-Al-Cu, Pr-Al-Cu, Pr-Al-Ga and Ce-La-Cu.

[0057] Thus, the coercivity enhancing element is chosen from the list consisting of Dy, Tb, Ho and low-melting alloys which include at least one of Dy, Tb, Ho, Nd, Pr, La and Ce.

[0058] In each of the A2 areas, the second material M2 has a magnetisation along a direction which is different to that in the A1 areas.

[0059] In the example shown in Figure 1, the direction of magnetisation in A2 areas is opposite to that in the A1 areas.

[0060] The magnetisation direction of the area A2 is

thus represented on figure 1 by arrows going from bottom to top.

[0061] The method for fabricating comprises a first step E10 of deposition, a second step E20 of deposition, a step E30 of diffusion, a step E40 of global magnetisation and a step E50 of local magnetisation. During the first step E10 of deposition, NdFeB is deposited on the substrate 14 to form an initial layer 20.

[0062] It will appear from the rest of the specification that the initial layer 20 is a pre-diffusion layer with a constant coercivity value while the magnetic layer 16 is a post-diffusion layer with a spatially varying coercivity value.

[0063] For instance, such a first step E10 of deposition is carried out by sputtering.

[0064] Other techniques may be used, such as pulsed laser deposition or electrodeposition.

[0065] During the second step E20 of deposition, Dy is deposited on certain regions 21 of the initial layer 20 according to a pattern.

[0066] Examples of different patterns that could be used are schematised in Figure 2.

[0067] A top-view perspective showing different examples of possible in-plane shapes for the areas A2 are represented in figure 2. The shape of areas 2 as seen from the top-view is determined by the mask used to define the regions in which the coercivity modifying element has diffused.

[0068] For this, such a second step E20 of deposition may be carried out by depositing a resin, etching the resin with holes corresponding to the desired pattern, depositing Dy on the patterned resin and in the etched holes and then removing the resin and Dy deposited upon it. Alternatively, Dy could be deposited through a shadow mask.

[0069] The extent of coercivity enhancement can be adjusted by varying the quantity of Dy deposited, for instance by controlling the thickness of the layer of Dy which is deposited.

[0070] The thickness of the initial layer 20 is comprised between 10 nanometer (nm) and 100 μm .

[0071] During the step E30 of diffusion, heating is applied on the set of the substrate 14 and the initial layer 20 coated on regions 21.

[0072] Heating this set causes the diffusion of Dy into the initial layer 20 converting it into a magnetic layer 16 having distinct areas (A1 and A2) with different values of coercivity.

[0073] Such heating may be achieved in an annealing furnace either under vacuum or in an inert gas. The extent of coercivity enhancement can be adjusted by varying the annealing conditions.

[0074] At the end of this step E30 of diffusion, the structure obtained 16 consists of regions with different values of coercivity and is an array of magnets 10.

[0075] Areas A1 correspond to regions of the magnetic layer unaffected by diffusion of the material 21, while areas A2 correspond to regions of the magnetic layer modified due to diffusion of the coercivity changing ele-

ment.

[0076] Both types of regions are schematized from a side-view perspective in Figure 1. The cross-sectional shape of Areas 2 as seen from the side-view is determined by the diffusion profile.

[0077] The next steps of the illustrated method are the step E40 of global magnetisation and the step E50 of local magnetisation may be carried out before or after integration and packaging of the magnetic layer 16 in a device.

[0078] During the step E40 of global magnetisation, all areas A1 and A2 of the magnetic layer 16 are magnetised in the same direction.

[0079] To achieve such a step E40, a first magnetic field is applied to the magnetic layer 16.

[0080] The first magnetic field has an intensity superior to both the first coercivity value H_{C1} and the second coercivity value H_{C2} .

[0081] The direction of the first magnetic field is here the first direction (upwards in the example shown in Figure 1).

[0082] During the step E50 of local magnetisation, the direction of magnetisation of areas A1 is modified (reversed, so as to point downwards, in the example shown in Figure 1).

[0083] Such a modification in the direction of magnetisation is obtained by applying a second magnetic field in a direction different from that of the first magnetic field.

[0084] The value of the intensity of the second magnetic field is comprised between the first coercivity value H_{C1} and the second coercivity value H_{C2} .

[0085] In the example shown in Figure 1, the second magnetic field is flipped by 180° with respect to the first magnetic field. This implies that the direction of the second magnetic field is the second direction.

[0086] The present method is thus a process of locally modifying the coercivity of a hard magnet layer, through diffusion induced chemical / microstructural modification of specific regions of the magnet layer, to allow subsequent multipole magnetisation.

[0087] The response of a hard magnetic material to an applied field depends on its coercivity, and thus regions of a magnet with different values of coercivity will respond differently in a given applied magnetic field.

[0088] Successive applications of an external (homogeneous) magnetic field, with both the direction and intensity of the field being modified between each step, can be used to produce magnetic domain patterns, each magnetic domain corresponding to a magnet with a given direction of magnetisation in the magnetic layer. The multipole array of magnets thus produced results in a specific stray magnetic field profile. The multipole array of magnets and the resultant stray field profile can be modified to suit a particular application.

[0089] This enables to obtain an array of magnets 10 with a permanent modification of the coercivity in the second areas A2 due to localised diffusion (an increase in coercivity for the example shown in Figure 1 where Dy

is diffused into a $\text{Nd}_2\text{Fe}_{14}\text{B}$ based layer).

[0090] Such a permanent modification of coercivity renders the magnetic layer 16 remagnetisable and the array reconfigurable.

[0091] Indeed, by re-exposing the magnetic layer to the previous steps of magnetisation, the 10 will have the magnetisation pattern as the one represented on the last part of figure 1.

[0092] In other words, it is possible to remagnetise the magnetic layer 16 even after it has been integrated into a device.

[0093] The interest in such remagnetisation is due to the fact that demagnetisation may occur, for instance due to heating of the array 10 over a predefined temperature. Such heating could happen during device packaging.

[0094] Alternatively, steps E40 and E50 could be performed for the first time after integration of the magnetic layer 16 into a device.

[0095] Alternatively, by exposing the array 10 to new steps of magnetisation, it may be reconfigured, meaning that the direction of magnetisation of individual magnets may be modified compared to the one represented on the last part of figure 1.

Second embodiment: case without a substrate

[0096] According to another embodiment, the method is carried out with an initial magnet as first material.

[0097] In other words, instead of forming an initial magnetic layer 20 by deposition of the first material M1 on a substrate 14 in step E10 as in figure 1, a magnet is provided, the magnet being in the first material M1.

[0098] The magnetic layer 16 is therefore a part of the magnet, which has been modified to form an array 10.

[0099] The other steps remain the same.

[0100] This enables to obtain another multipole array of magnets.

Other embodiments

[0101] Other embodiments of the method can be considered.

[0102] According to another embodiment, the coercivity changing element is a coercivity reducing element.

[0103] This implies that the second coercivity value H_{C2} for the second area A2 is inferior to the first coercivity value H_{C1} .

[0104] Such a reducing effect can for instance be obtained by diffusion of Ce into a $\text{Nd}_2\text{Fe}_{14}\text{B}$ -based layer.

[0105] However, other elements have such a coercivity reducing effect.

[0106] Thus, the coercivity reducing element for $\text{Nd}_2\text{Fe}_{14}\text{B}$ -based layers is chosen in the list consisting of Ce, La and Gd.

[0107] Their alloys may also be considered.

[0108] For other hard magnetic layers, different coercivity reducing elements may be diffused.

[0109] Therefore, the coercivity reducing element may

be chosen in a list consisting of Ce, La, Gd and low-melting alloys which include Ce, La and Gd.

[0110] In such a case, modification of the direction of magnetisation induced during the step E50 of local magnetisation is different.

[0111] Indeed, modification of the direction of magnetisation applies to the areas A2 and not the areas A1.

[0112] Thus, in such an example where coercivity is reduced in areas A2, the areas A1 have a magnetisation oriented in the direction of the first magnetic field while the second areas A2 have a magnetisation oriented in the direction of the second magnetic field.

[0113] Increasing the number of distinct coercivity values within the magnetic layer 16, for example by diffusion of different amounts of a given material at different regions or different materials at different regions, allows for even more complex patterns to be produced by application of additional magnetic fields with modified characteristics (field direction and intensity).

[0114] While simple reversal of the direction of magnetisation can be achieved (example shown in Figure 1) in magnetic layers 16 which are crystallographically isotropic or anisotropic, fabrication of an array 10 in which the different directions of magnetisation are non-colinear implies a crystallographically isotropic magnetic layer.

[0115] In all cases, the array 10 is multipole in nature.

[0116] This may be advantageous for the development of magnetic systems including microsystems such as micro-actuators, micro-motors, micro-generators and micro-sensors. Such devices have potential applications in a range of fields including consumer electronic (smart-phones), smart-buildings (energy harvesting), medical devices and bio-technology.

[0117] Note that the deposited magnetic layer must be heated either during or after deposition, so as to form the relevant hard magnetic phase (crystallization of $\text{Nd}_2\text{Fe}_{14}\text{B}$ in the example focused on here). If the required heat treatment is carried out after deposition, then formation of the hard magnetic phase and diffusion of the coercivity element may be done at the same time during the step E30 of diffusion, or alternatively between the step E10 of deposition and the step E20 of deposition.

[0118] It can also be noticed that this method is of particular interest for fabricating multipole arrays of hard micro-magnets, where the term "micro" implies that at least 2 of the dimensions of each magnet have a size which is less than 1 mm. This is because assembling pre-magnetised individual magnets into a multipole array becomes very challenging as the size of the individual magnets is reduced and it becomes more difficult to manipulate them either individually or collectively.

[0119] It can also be noted that the configuration of the array 10 may also be different.

[0120] Indeed, instead of carrying out the steps E40 and E50, a step of applying a variable external magnetic field can be carried out.

[0121] The least coercive zones can be reconfigured at will to be aligned with the most coercive zones or in the

other direction depending on the direction of the external field so as to generate or not a multipole (or homogeneous) structure.

[0122] In the extreme case where the coercivity of the low coercivity phase is very low, it will systematically tend to align in the opposite direction to the high coercivity phase, so as to create a multipole structure.

[0123] On the other hand, under the effect of an external field aligned with the most coercive phase, the array 10 can be reconfigure so as to have only one magnetization, knowing that once the external field is cut, the system falls back in a multipole state (it constitutes a sort of ON/OFF system).

Claims

1. Method for fabricating an array of magnets (10), the method comprising:

- a step of deposition of a coercivity changing element according to a pattern on a first material (M1) having a first coercivity value (H_{C1}), the coercivity changing element being adapted to change the coercivity of the first material (M1), and
- a step of diffusion of the coercivity changing element into certain regions to form a magnetic layer (16) having first areas (A1) made of the first material (M1) and second areas (A2) having a second coercivity (H_{C2}), made of a second material (M2) comprising the first material (M1) and the coercivity changing element.

2. Method for fabricating according to claim 1, wherein the step of diffusion is achieved by heating.

3. Method for fabricating according to claim 1 or 2, wherein the method further comprises a step of forming an initial magnetic layer (20) by deposition of the first material (M1) on a substrate (14), the coercivity changing element being deposited on the initial magnetic layer (20).

4. Method for fabricating according to claim 3, wherein the substrate (14) is made of of a material chosen among Si, quartz, sapphire, MgO, fused silica, glass, NaCl, tungsten, molybdenum, tantalum, and soft ferromagnetic metals such as iron, cobal, nickel and their alloys.

5. Method for fabricating according to claim 1 or 2, wherein the method further comprises a step of providing a magnet, the magnet being in the first material (M1), the coercivity changing element being deposited on an external face of the magnet during the step of depositing.

6. Method for fabricating according to any one of the claims 1 to 5, wherein the first material (M1) based on a phase is chosen in the list consisting of $Nd_2Fe_{14}B$, $SmCo_5$, $SmCo_7$, Sm_2Co_{17} , $Sm_2Fe_{17}N_3$, $L1_0$ FePt, $L1_0$ CoPt and $BaFe_{12}O_{19}$.

7. Method for fabricating according to any one of the claims 1 to 6, wherein the coercivity changing element is a coercivity enhancing element, resulting in a second coercivity value (H_{C2}) for the second area (A2) being superior to the first coercivity value (H_{C1}), the coercivity enhancing element being preferably chosen from the list consisting of Dy, Tb, Ho and low-melting alloys which include at least one of Dy, Tb, Ho, Nd, Pr, La and Ce.

8. Method for fabricating according to any one of the claims 1 to 7, wherein the coercivity changing element is a coercivity reducing element, resulting in a second coercivity value (H_{C2}) for the second area (A2) being inferior to the first coercivity value (H_{C1}), the coercivity reducing element being preferably chosen from the list consisting of Ce, La, Gd and low-melting alloys which include Ce, La and Gd.

9. Method for configuring an array of magnets to obtain a multipole array of magnets, wherein the method comprises:

- carrying out a method for fabricating an array of magnets (10), the method for fabricating being according to any one of claims 1 to 8,
- global magnetisation of the magnetic layer (16) along a first direction, and
- local magnetisation of areas of the magnetic layer (16) along a second direction which is different from the first direction.

10. Method for configuring according to claim 9, wherein the magnetisation steps are carried out by applying magnetic field on the magnetic layer (16),

the magnetic field applied during the global magnetisation having an intensity superior to both the first coercivity value (H_{C1}) and the second coercivity value (H_{C2}), and the magnetic field applied during the local magnetisation modifies the magnetisation direction of the first areas (A1), the magnetic field having an intensity comprised between the first coercivity value (H_{C1}) and the second coercivity value (H_{C2}) when the second coercivity value (H_{C2}) is superior to the first coercivity value (H_{C1}) or the magnetic field applied during the local magnetisation modifies the magnetisation direction of the second areas (A2), the magnetic field having an intensity comprised between the sec-

ond coercivity value (H_{C2}) and the first coercivity value (H_{C1}) when the second coercivity value (H_{C2}) is inferior to the first coercivity value (H_{C1}).

11. Method configuring an array of magnets, wherein the method comprises:
 - carrying out a method for fabricating an array of magnets (10), the method for fabricating being according to any one of claims 1 to 8, and
 - a step of application of a variable external magnetic field on the magnetic layer (16).
12. An array of magnets comprising a magnetic layer (16) comprising first areas (A1) and second areas (A2) arranged according to a pattern, the first area (A1) being made of a first material (M1) having a first coercivity value (H_{C1}) and the second area (A2) being made of a second material (M2) having a second coercivity value (H_{C2}), the first coercivity value (H_{C1}) and the second coercivity value (H_{C2}) being different.
13. Array of magnets according to claim 12, wherein the array of magnets is a multipole array.
14. Array of magnets according to claim 12 or 13, wherein the second material (M2) is made of the first material (M1) and a coercivity changing element, a coercivity changing element being adapted to change the coercivity of the first material (M1).
15. Array of magnets according to claim 14, wherein the second material (M2) is obtained by a thermal diffusion of the coercivity changing element into the first material (M1).

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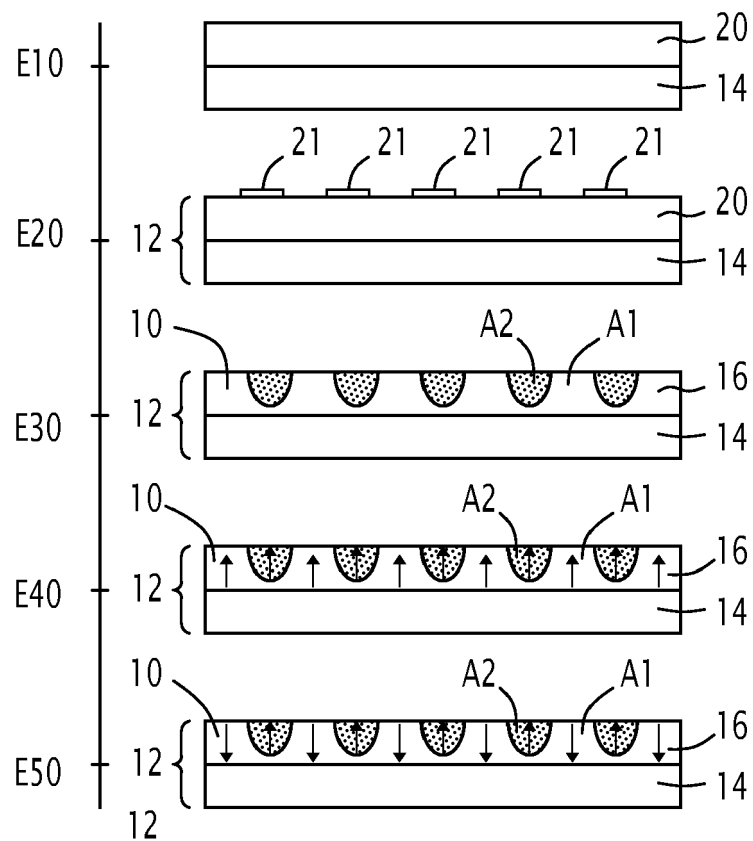


FIG.1

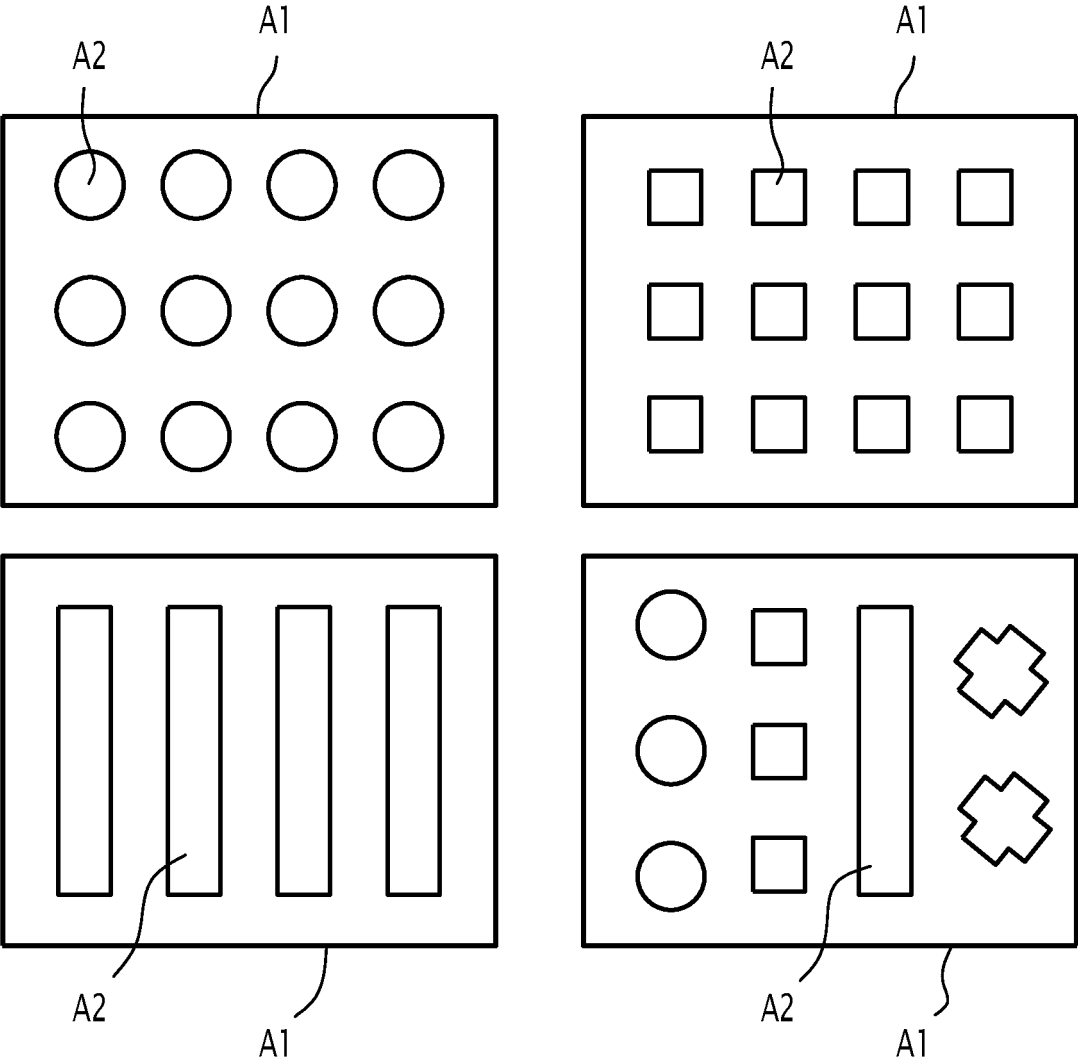


FIG.2



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Application Number

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Place of search		Date of completion of the search	Examiner
Munich		2 April 2024	Brächer, Thomas
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