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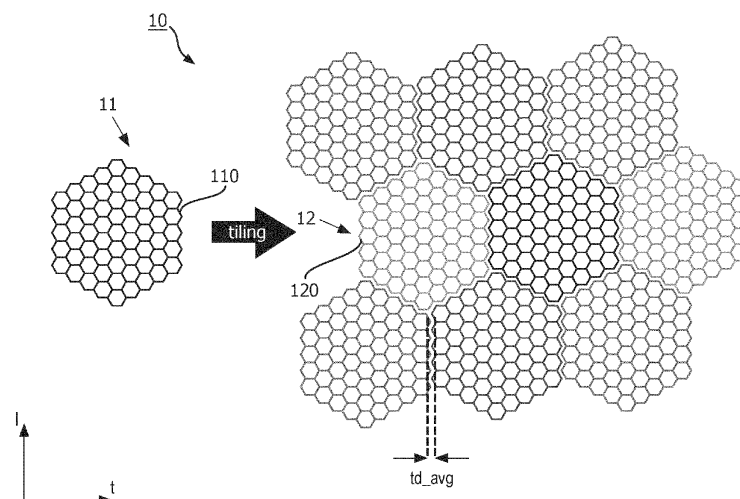
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(54) TILED MICROSTRUCTURE FOR SELECTIVE TRANSMISSION OF RADIATION

(57) The invention aims to provide improved tiling of microstructures for selective transmission of radiation. A microstructure (10) for selective transmission of radiation is proposed. The microstructure (10) comprises a first module (11) and a second module (12), wherein each of the first module (11) and the second module (12) comprises multiple walls with a height (h). For each of the first module (11) and the second module (12), the walls form multiple repeating grid units with a pitch (p). The first module (11) and the second module (12) are tiled together in a tiling direction (t) transverse to the height (h) of the walls, such that a side (110) of the first module faces

an adjacent side (120) of the second module along a longitudinal direction (1) transverse to the tiling direction (t) and to the height (h). For each coordinate along the longitudinal direction (1) where the side (110) of the first module faces the adjacent side (120) of the second module, the side (110) and the adjacent side (120) are separated in the tiling direction (t) by a tiling distance (td). An average (td_avg) of all the tiling distances (td) between the side (110) and the adjacent side (120) along the longitudinal direction (1) is larger than zero and less than 200% of the pitch (p), preferably larger than zero and less than 100% of the pitch (p).

**FIG. 3**

Description

FIELD OF THE INVENTION

[0001] The invention relates to a microstructure for selective transmission of radiation. In particular, the invention relates to a microstructure comprising a first module and a second module that are tiled together. The invention relates to an imaging component comprising a microstructure for selective transmission of radiation and to an imaging system comprising such an imaging component.

BACKGROUND OF THE INVENTION

[0002] Manufacturing of high-performance microstructures for selective transmission of radiation, such as e.g. X-ray anti-scatter grids for advanced X-ray imaging systems, with a large surface area is challenging, as it requires very accurate and consistent dimensioning and positioning of the thin and high wall structures uniformly over the complete area. There are typically limitations to the size of the manufacturing platforms that can be used, e.g. when manufacturing the microstructures with 3D printing technology. Consequently, manufacturing process yields may be low for large area structures, such as microstructures larger than $20 \times 20 \text{ cm}^2$. One option to mitigate this challenge is manufacturing of smaller grid tiles and subsequently merging (tiling) multiple such small grid tiles to form a larger structure. However, the interfaces between adjacent grid tiles can lead to image artifacts as well as structural instabilities and risk of breakage. Hence, there is a need to improve such manufacturing.

SUMMARY OF THE INVENTION

[0003] It is an object of the invention to provide improved tiling of microstructures for selective transmission of radiation.

[0004] The invention is defined by the independent claims. Advantageous embodiments are defined in the dependent claims.

[0005] According to a first aspect of the invention, there is provided a microstructure for selective transmission of radiation. The microstructure comprises a first module and a second module. Each of the first module and the second module comprises multiple walls with a height, wherein for each of the first module and the second module, the walls form multiple repeating grid units with a defined pitch. The first module and the second module are tiled together in a tiling direction transverse to the height of the walls, such that a side of the first module faces an adjacent side of the second module along a longitudinal direction transverse to the tiling direction and to the height. For each coordinate along the longitudinal direction where the side of the first module faces the adjacent side of the second module, the side and the

adjacent side are separated in the tiling direction by a tiling distance. An average of all the tiling distances between the side and the adjacent side along the longitudinal direction is larger than zero and less than 200% of the pitch. Preferably, the average of all the tiling distances is larger than zero and less than 100% of the pitch.

[0006] Because of the non-zero average distance between the sides of the modules of the microstructure, disturbance to a radiation scatter profile of the tiled structure can be reduced and performance improved compared to e.g. a tiled structure where the modules are placed in contact with each other such that the distance is substantially zero. This is because with the proposed microstructure, 'double walls' from the combined modules can be avoided.

[0007] In the context of the present invention, pitch p is the smallest distance between the center of adjacent repeating grid units. Grid units may also be referred to as (grid) pixels. The pitch is preferably (substantially) the same over the area of each module and preferably (substantially) the same for all modules that together form the tiled microstructure. By keeping the average distance between adjacent modules to be less than 200% (preferably less than 100%) of the pitch p when the modules are tiled together to form the microstructure, the scatter profile of the microstructure for selective transmission of radiation is improved compared to if the average distance would be larger.

[0008] The modules may have sides that are straight lines in at least one direction or may have other shapes. E.g. in the case of a module with hexagonal pixels, the sides of the module may form a 'zigzag' pattern in the longitudinal direction. The modules may also be referred to as tiles. The microstructure may comprise more than two modules. A module may be tiled together with multiple other modules in multiple tiling directions.

[0009] The longitudinal direction l and the tiling direction t , which is transverse to the longitudinal direction l , can be said to form a coordinate system. Along the interface between two adjacent modules, the tiling distance t_d , i.e. a distance between the sides of the adjacent modules in the tiling direction, can be determined at multiple discrete points, such as multiple equidistant discrete points, along the longitudinal direction l . The average tiling distance t_{d_avg} is then the sum of the discrete tiling distances t_d , divided by the number of tiling distances.

[0010] According to an embodiment of the invention, the tiling distances are constant along the longitudinal direction. In other words, the respective tiling distances are the same as the average tiling distance. This way of tiling modules together to form the tiled microstructure is in the present disclosure referred to as "controlled gap mode" and enable e.g. anti-scatter grids with good performance.

[0011] According to another embodiment of the invention, the tiling distances are not constant along the longitudinal direction, and the tiling distance is less than $0.1p$

in at least one coordinate along the longitudinal direction. This way of tiling modules together may be an advantageous alternative to the "controlled distance" as mentioned above. In this case the modules come very close to each other (less than 0.1 pitch) in at least one coordinate. The modules may touch such that the minimum distance locally is zero or very close to zero. This way of tiling is in the present disclosure referred to as "kissing pixel mode". Advantageously, the tiling distance is less than 0.1p in multiple equally distributed coordinates along the longitudinal direction. This provides for a consistent scatter profile along the longitudinal direction.

[0012] According to an embodiment of the invention, the average of all the tiling distances is larger than 0.1p and smaller than 0.5p. Such a narrower selection of the average tiling distance may improve the radiation transmission properties of the microstructure even further. E.g. when the microstructure is included in an anti-scatter grid.

[0013] According to an embodiment of the invention, the grid units between the walls comprise a solid or semi-solid pixel material, and density of the pixel material is less than 10 g/cm³, preferably less than 5 g/cm³ and more preferably less than 3g/cm³. The addition of solid or semi-solid pixel materials between the walls of the grid unit may provide additional stability to the structure without interfering with the selective radiation transmission of the microstructure. Furthermore, radiation absorption, such as X-ray or gamma ray absorption, may be accurately modulated with the choice of material. The pixel material may advantageously comprise at least one of aluminum, glass, cotton fiber, glue, aerogel, foam, carbon, or paper.

[0014] According to an embodiment of the invention, the space between the side of the first module and the adjacent side of the second module comprises a solid or semi-solid tiling material, and wherein a density of the tiling material is less than 10 g/cm³, preferably less than 5 g/cm³ and more preferably less than 3g/cm³. A solid or semi-solid material in the gap or gaps between two modules that are tiled together may increase the structural stability of the microstructure. The material may function as a glue that holds the modules together. The material may provide damping to reduce risk of structural damage to either of the modules when tiled together. Radiation absorption, such as X-ray or gamma ray absorption, in the gap or gaps between the modules may be accurately modulated with the choice of material. The tiling material may be applied free standing between the modules. Alternatively, or additionally, the tiling material may be applied to one or both of the modules before tiling together. The tiling material may advantageously comprise at least one of aluminum, glass, cotton fiber, glue, aerogel, foam, carbon, or paper.

[0015] According to an embodiment of the invention, for each module the walls extend in the tiling direction, and for each module the grid units repeat only in the longitudinal direction to form a one-dimensional grid. In this way, tiled large area one-dimensional grids, such as

anti-scatter grids, with a good scatter profile may be manufactured.

[0016] According to an embodiment of the invention, for each module the grid units repeat in the tiling direction and in the longitudinal direction to form a two-dimensional grid. In this way, tiled large area two-dimensional grids, such as anti-scatter grids, with a good scatter profile may be manufactured. Advantageously, the grid units have a hexagonal shape. Hexagonal pixel shapes provide a higher anti-scatter performance than square (or rectangular) pixels at constant grid ratio, septa wall thickness, grid height and pixel pitch. Hexagonal pixels may reduce the amount of required material, e.g. for 3D printing of grids, and enhance mechanical stability compared to e.g. square pixels.

[0017] According to an embodiment of the invention, each of the first module and the second module have a hexagonal outer shape. Hexagonal modules, such as hexagonal modules with hexagonal pixels, may advantageously provide microstructures with smooth scatter profiles and high mechanical stability.

[0018] According to a second aspect of the invention, there is provided an imaging component comprising the microstructure as described above. The imaging component comprises at least one of an X-ray or gamma-ray anti-scatter device, an X-ray or gamma-ray filter, an X-ray or gamma-ray collimator, or an X-ray or gamma-ray grating.

[0019] According to a third aspect of the invention, there is provide an imaging system comprising the imaging component.

[0020] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021]

Fig. 1A schematically illustrates an example of a one-dimensional grid.

Fig. 1B schematically illustrates an example of a two-dimensional grid.

Fig. 2-4 schematically illustrate examples of tiled microstructures.

Figs. 5-7 illustrate calculated scatter profiles of tiled microstructures.

DESCRIPTION OF EMBODIMENTS

[0022] Fig. 1A and 1B illustrate examples of a one-dimensional (1D) 100-A and two-dimensional (2D) grid 100-B, respectively. The grids may be (monolithic) anti-scatter grids, such as X-ray anti-scatter grids with walls made from Tungsten or another suitable X-ray absorbing material. Each of the grids 100-A, 100-B has septa walls 102 with a defined width w and height h. Pixels 104 for selectively transmitting radiation, such as X-ray radiation

are formed between the dense septa walls 102. Pixels are repeated with a pixel pitch p . In the case of a 1D grid 100-A, the pixels are repeated in one dimension and in the case of a 2D grid 100-B, the pixels are repeated in two dimensions. The pixel pitch p in the first dimension and the second dimension may be identical or different. Examples of ranges for anti-scatter grid design parameters may be: $p = 0.1\text{--}2\text{ mm}$ for grid pitch, $w = 20\text{--}100\text{ }\mu\text{m}$ for septa wall thickness, and $h = 2\text{--}10\text{ mm}$ for grid height. The grid ratio R , which is defined as $R = h / (p-w)$, typically varies between 4 and 20 but other configurations are also possible. The aspect ratio of the septa walls, which is the ratio between its height and its thickness is generally high for high performance anti-scatter grids. Such as between 10 and 100.

[0023] The sizes of high-quality focused grids required in medical flat panel detector applications can vary from e.g. $10 \times 10\text{ cm}^2$ to grids larger than 1 m in one or both dimensions. Manufacturing of grids with a large surface area requires accurate dimensioning and positioning of the thin and high septa wall structures uniformly over the complete area.

[0024] The current disclosure provides a robust and reliable solution to realize composite large area grids by joining multiple grid tiles together. Most medical image processing methods used for scatter rejection and/or scatter correction rely on the fact that changes in the level of scatter occur only gradually, i.e. that scatter is a low-frequency signal. Therefore, abrupt (high-frequency) changes in scatter signal caused by grid tile boundaries are avoided. Scatter simulations of different positioning geometries of grid tiles in a large area anti scatter grid assembly have shown that image artefacts at grid tile borders, e.g. caused by double walls, can effectively be reduced by introducing a controlled (average) distance, and optionally spacer material between the tiles.

[0025] Fig. 2 illustrates an example of a tiled microstructure from rectangular grid tiles with hexagonal grid pixels. A first grid module (or tile) 11 is tiled next to a second grid module 12 in the tiling direction t , as indicated by the arrow. As a result, the side 110 of the first grid module 11 will be placed adjacent to the side 120 of the second grid module 12. As seen from the modules in the right part of the figure, the sides of adjacent modules are separated in the tiling direction t by an average tiling distance td_avg along the longitudinal direction of the interface between two modules.

[0026] As shown in Fig. 2, the grid tiles with hexagonal grid pixels are joined together without formation of double walls, such that a controlled small gap is introduced between the tiles. In this example, due to the rectangular shape of the grid tiles, the tiling distance td , between septa walls forming the respective sides of the adjacent tiles is uniform along the longitudinal direction l , but not along the tiling direction t .

[0027] Fig. 3 illustrates an example of a tiled microstructure from hexagonal modules with hexagonal grid pixels. In this case, thanks to the hexagonal structure of

the modules, the gap between adjacent sides may be kept constant along all six sides of a module that is surrounded by other modules. In this way, a smooth and uniform scatter profile may be achieved.

[0028] Fig. 4 also illustrates an example of a tiled microstructure from hexagonal modules with hexagonal grid pixels. The structure is different from the microstructure in Fig. 3 in that in Fig. 4, the modules are tiled in "kissing pixel mode" where the sides of adjacent modules touch locally or come very close (less than $0.1p$) to each other locally. Diamond-shaped grid pixels are formed at the interface of two modules and triangle-shaped grid pixels are formed at the crossing point of three modules. This way of tiling the modules together may be simpler from a manufacturing point of view as compared to the controlled gap in Fig. 3.

[0029] In Figs. 5-7, calculated X-ray images of a 100-mm-thick water slab phantom positioned in a simple X-ray setup between a 120 kV tungsten-anode X-ray tube and a 154- μm -pixel flat x-ray detector are illustrated. The distance between tube and detector was 105 cm. A specific grid of interest was positioned at a distance of 15 mm from the detector imaging plane. Simulated 2D grids were 3D-printed air-interspaced tungsten grids with pixel pitch 1.5 mm, grid ratio 6, and septa wall thickness 100 μm . Simulated 1D grids were glass-interspaced lead grids with grid pitch 227 μm , grid ratio 12, and septa wall thickness 30 μm . Monte-Carlo simulations were carried out in two successive steps. Firstly, an x-ray photon database was generated in a simulation tool by bombarding 1 billion x-ray photons emitted from the X-ray focal spot of the tube on the water slab phantom. Secondly, another simulation tool took all relevant design parameters of a specific grid as input and then bombarded each photon from the generated photon database in the first step onto this grid. As a result, the numbers of primary and scatter transmission photons captured by a central area of $2 \times 2\text{ cm}^2$ on the detector was determined.

[0030] Fig. 5 illustrates an example of two modules 11, 12 with hexagonal pixels. From left to right, the figure shows the schematic grid module structures (left), the simulated scattered X-ray image (middle top) captured by the detector, the simulated primary X-ray transmission image of the interface between the modules (middle bottom) and the simulated scatter profile (right side) along the cross-section line A-A'. The modules are tiled together with a controlled distance between the sides of the modules. The tiling direction is between A and A' in the figure. The tiling distance td is constant along the longitudinal direction l . The tiling distance td is the same as the average td_avg along the longitudinal direction l . Fig. 5 shows that when 2D grid tiles with hexagonal pixels are joined together in controlled gap mode with a tile distance td of $\approx 200\text{ }\mu\text{m}$, the scatter profile at the border of the tiles is only very slightly disturbed. If the tiling distance increases, the scatter profile becomes more distorted (not shown in figure). This effect may partly be prevented by filling the air gap with a low x-ray absorbing material

such as glue, aerogel, foam, carbon, paper, cotton fiber, aluminum, or glass.

[0031] Fig. 6 illustrates, in a similar way as Fig. 5, that when hexagonal 2D grid modules with hexagonal tiles are joined together in kissing pixel mode such that the edges of the modules touch at evenly distributed points along the longitudinal direction, the scatter profile at the border of the tiles is only very slightly disturbed. If the distance between septa walls of "kissing pixels" at the tile edges is increased, the scatter profile becomes visually distorted (not shown in figure). This may partly be prevented by filling the air gap with a low x-ray absorbing material such as glue, aerogel, foam, carbon, paper, cotton fiber, aluminum or glass.

[0032] Fig. 7 illustrates tiling of 1D grid modules in 'series', i.e. septa walls (in this case lead lamella) in adjacent modules are positioned in line with each other. Simulations show that the scatter profile at the border of these modules is somewhat sensitive to the gap width and the gap spacer material between the tiles, but to a lesser extent than if the modules are tiled with the walls in 'parallel' (not shown in figure). Also in this case, distortion of the scatter profile may be reduced by filling the air gap between tiles with a low X-ray absorbing material. Furthermore, the scatter profile is only marginally affected by a lateral shift of a module in a direction perpendicular to the lamella walls.

[0033] The results as shown in examples above illustrate that multiple small grid tiles may be merged to form a high performance composite large area anti-scatter grid, such as larger than 20 x 20 cm². Manufacturing yield of such composite, tiled grids may be higher compared to manufacturing of monolithic large area grids.

[0034] Grid tiles preferably provide full tessellation of XL grid surface area. The sizes of gaps or other "non-active areas" between grid tiles are minimized in order to avoid a drop in anti-scatter performance near the edges of grid tiles. For 2D grids it was found that grid pixels with square (rectangular) or hexagonal shape providing full grid tessellation have the best anti-scatter performance. Full tessellation structures can also be obtained by combining different polygons in a grid pixel (e.g. octagon and square), but these designs may offer limited advantages at the expense of more design complexity. Grid pixels and grid tiles may be configured in such a way that a "unit cell design" can repetitively be used to realize a composite XL grid. Such a unit cell approach is preferred to reduce complexity of designing and manufacturing all required (different) small grid tiles and to facilitate assembly of the final XL grid. Use of mechanically robust grid tiles is preferred to minimize manufacturing yield loss due to physical damage during tile production and subsequent handling and processing. Septa wall thickness is preferably small ($\leq 100 \mu\text{m}$), preferably smaller than X-ray detector pixel size to minimize the risk of losing relevant clinical information or low pixel signals in acquired X-ray images due to shadowing effects.

[0035] The previous examples illustrate how double

septa walls may be avoided to minimize the occurrence of image artefacts. Also, borders between grid tiles provide for a smooth x-ray scatter profile. Most medical image processing methods used for scatter rejection and/or scatter correction rely on the fact that changes in the level of scatter occur only gradually, i.e. that scatter is a low-frequency signal. Hence abrupt (high-frequency) changes in scatter signal caused by grid tile boundaries should be avoided.

[0036] As an example, tungsten hexagonal-shaped 2D grid tiles composed of hexagonal grid pixels enable the assembly of tiled composite 2DXL grids with a controlled gap between the tiles (or "kissing pixel mode"). These 2DXL grids provide improved anti-scatter performance, smooth x-ray scatter profiles, low tungsten weight and enhanced mechanical robustness.

[0037] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. As an example, in the figures above, 2D grids are illustrated with hexagonal pixels but many other shapes are also possible to carry out the invention. Such as square pixels, rectangular pixels etc.

[0038] In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. Measures recited in mutually different dependent claims may advantageously be used in combination.

Claims

1. A microstructure (10) for selective transmission of radiation, the microstructure (10) comprising a first module (11) and a second module (12),

wherein each of the first module (11) and the second module (12) comprises multiple walls with a height (h),

wherein for each of the first module (11) and the second module (12), the walls form multiple repeating grid units with a pitch (p),

wherein the first module (11) and the second module (12) are tiled together in a tiling direction (t) transverse to the height (h) of the walls, such that a side (110) of the first module faces an adjacent side (120) of the second module along a longitudinal direction (l) transverse to the tiling direction (t) and to the height (h),

wherein for each coordinate along the longitudinal direction (l) where the side (110) of the first

- module faces the adjacent side (120) of the second module, the side (110) and the adjacent side (120) are separated in the tiling direction (t) by a tiling distance (td), and wherein an average (td_avg) of all the tiling distances (td) between the side (110) and the adjacent side (120) along the longitudinal direction (l) is larger than zero and less than 200% of the pitch (p), preferably larger than zero and less than 100% of the pitch.
2. The microstructure according to claim 1, wherein the tiling distances (td) are constant along the longitudinal direction (l).
 3. The microstructure according to claim 1, wherein the tiling distances (td) are not constant along the longitudinal direction (l), and wherein the tiling distance (td) is less than 10% of the pitch (p) in at least one coordinate along the longitudinal direction (l).
 4. The microstructure according to claim 3, wherein the tiling distance (td) is less than 10% of the pitch (p) in multiple equally distributed coordinates along the longitudinal direction (l).
 5. The microstructure according to any of the preceding claims, wherein the average (td_avg) of all the tiling distances (td) is larger than 10% of the pitch (p) and less than 50% of the pitch (p).
 6. The microstructure according to any of the preceding claims, wherein grid units between the walls comprise a solid or semi-solid pixel material, and wherein a density of the pixel material is less than 10 g/cm³, preferably less than 5 g/cm³ and more preferably less than 3g/cm³.
 7. The microstructure according to claim 6, wherein the pixel material comprises at least one of aluminum, glass, cotton fiber, glue, aerogel, foam, carbon, or paper.
 8. The microstructure according to any of the preceding claims, wherein the space between the side (110) of the first module (11) and the adjacent side (120) of the second module (12) comprises a solid or semi-solid tiling material, and wherein a density of the tiling material is less than 10 g/cm³, preferably less than 5 g/cm³ and more preferably less than 3g/cm³.
 9. The microstructure according to claim 6, wherein the tiling material comprises at least one of aluminum, glass, cotton fiber, glue, aerogel, foam, carbon, or paper.
 10. The microstructure according to any of the preceding claims, wherein for each module (11, 12) the walls extend in the tiling direction (t), and wherein for each module (11, 12) the grid units repeat only in the longitudinal direction (l) to form a one-dimensional grid.
 11. The microstructure according to any of claims 1-9, wherein for each module (11, 12) the grid units repeat in the tiling direction (t) and in the longitudinal direction (l) to form a two-dimensional grid.
 12. The microstructure according to claim 11, wherein each of the grid units have a hexagonal shape.
 13. The microstructure according to any of the preceding claims, wherein each of the first module (11) and the second module (12) have a hexagonal outer shape.
 14. An imaging component comprising the microstructure according to any of the preceding claims, wherein the imaging component comprises at least one of:
 - an X-ray or gamma-ray anti-scatter device;
 - an X-ray or gamma-ray filter;
 - an X-ray or gamma-ray collimator;
 - an X-ray or gamma-ray grating.
 15. An imaging system comprising the imaging component according to claim 14.

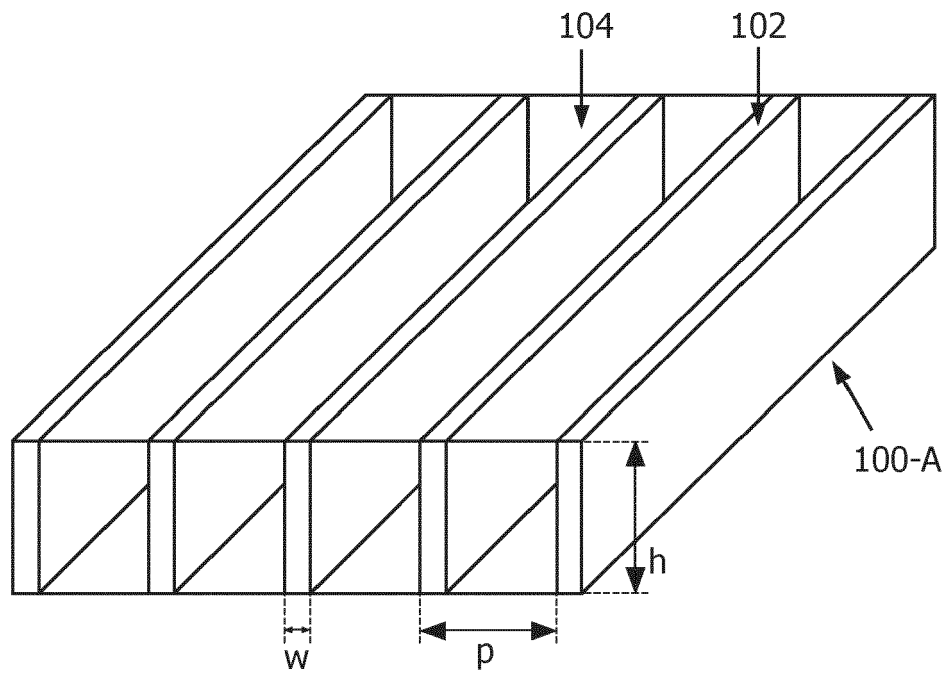


FIG. 1A

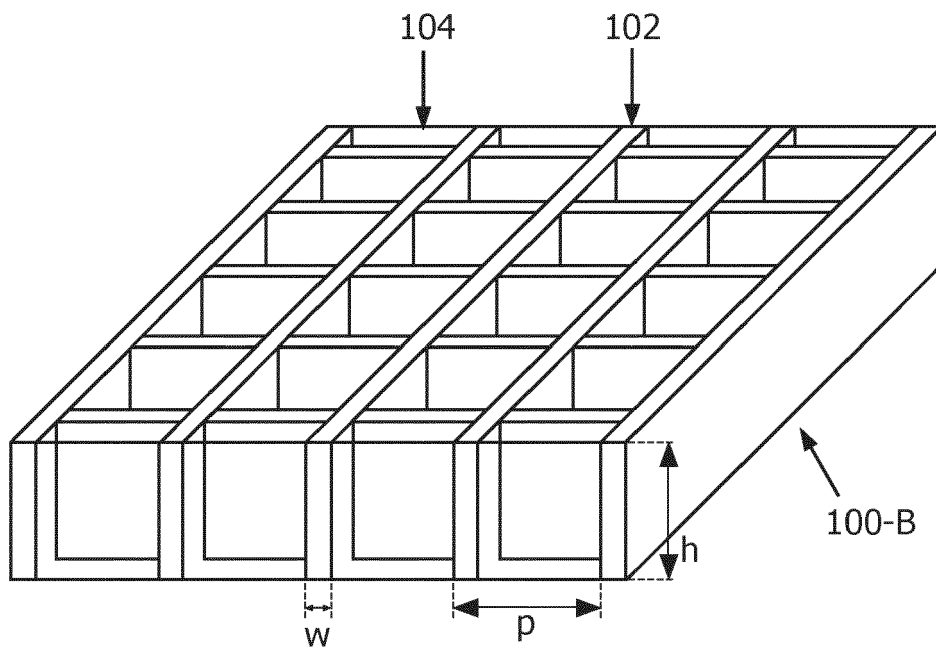


FIG. 1B

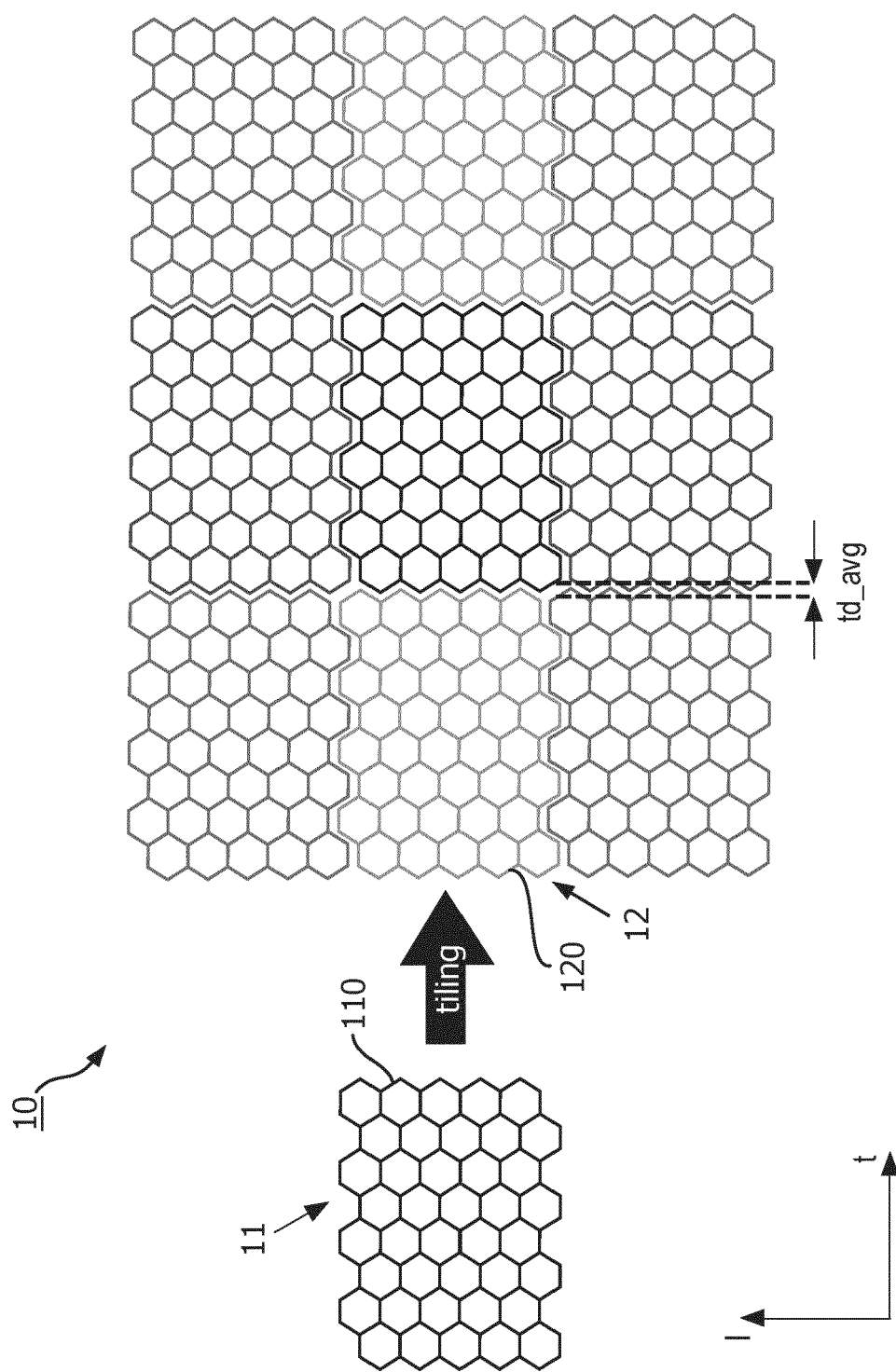


FIG. 2

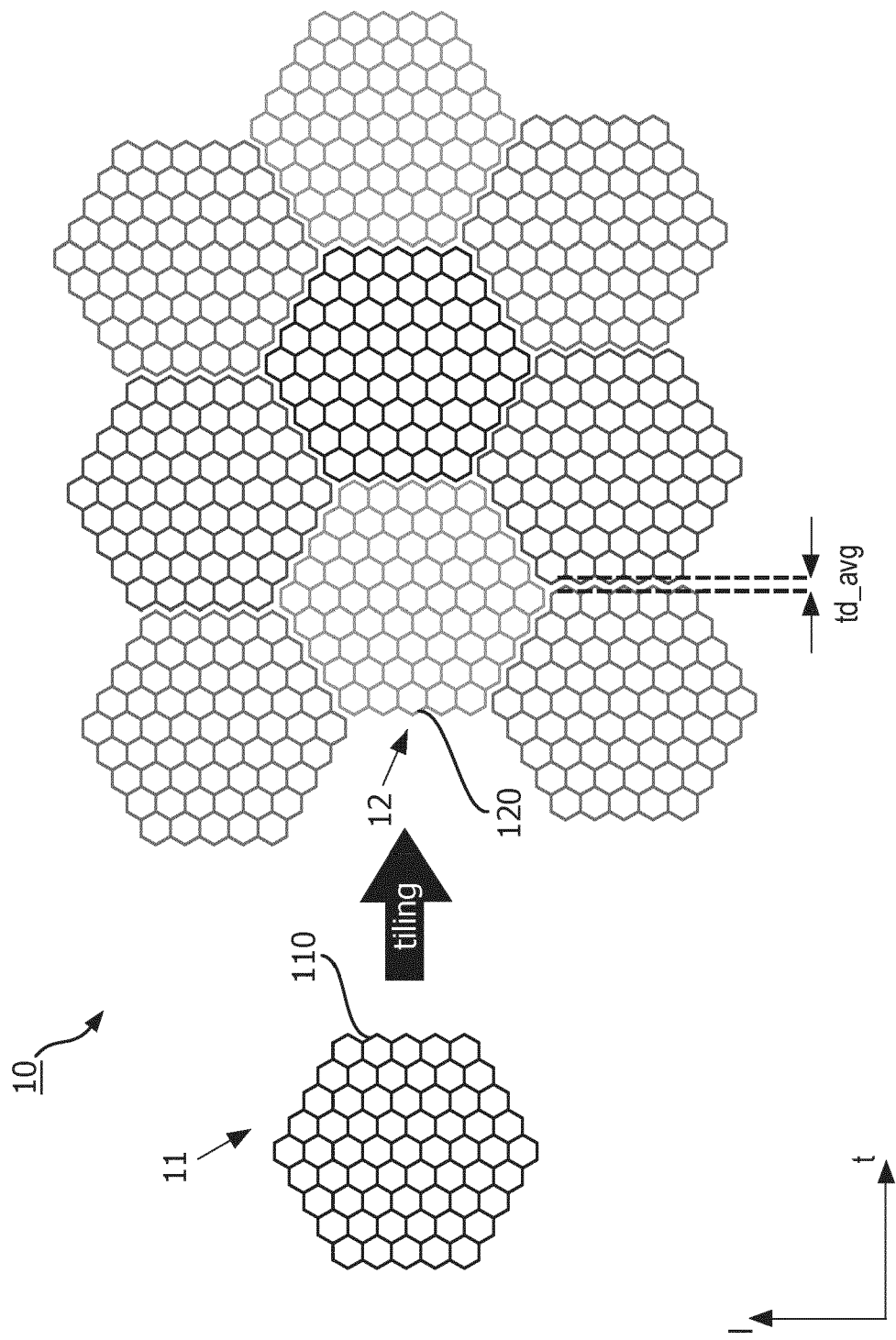


FIG. 3

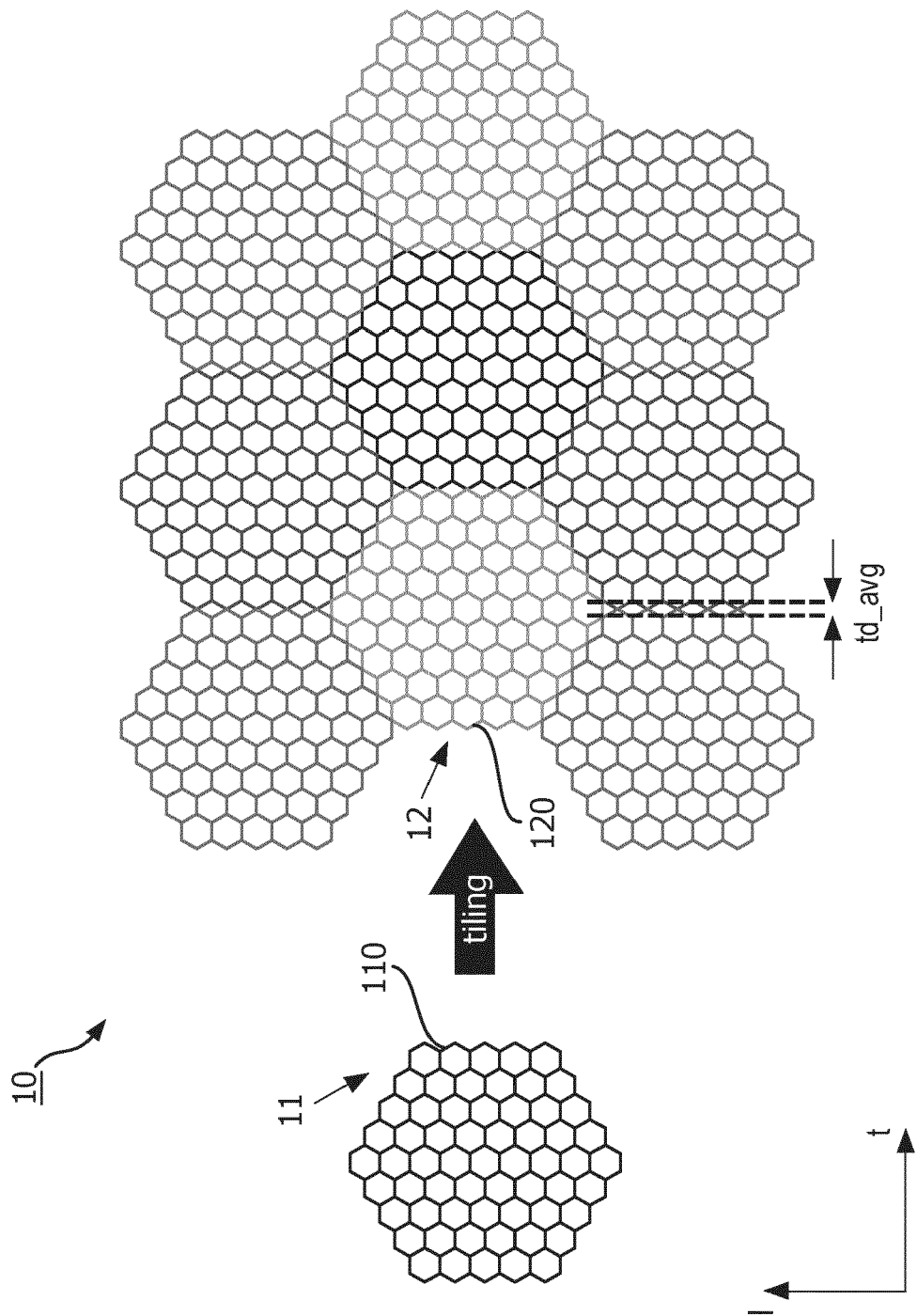


FIG. 4

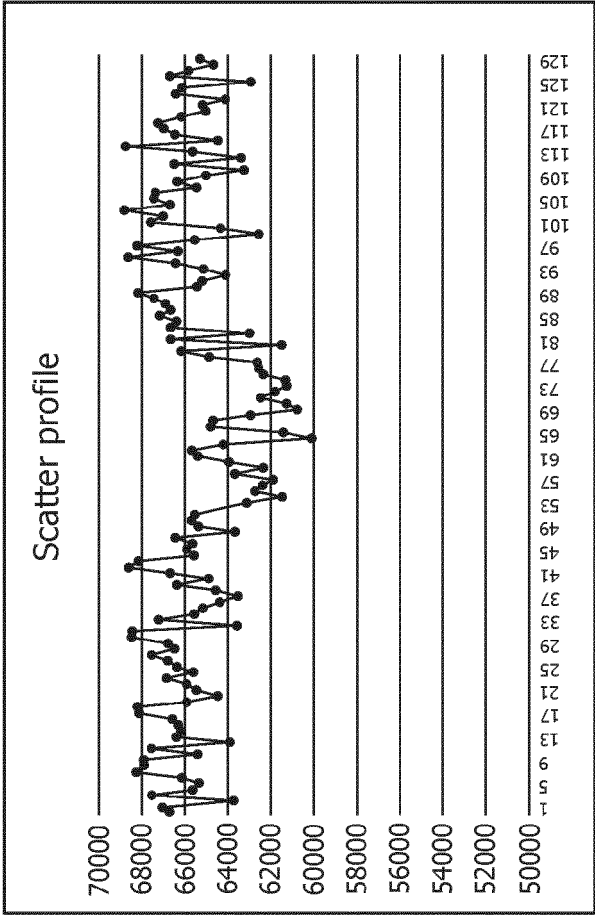
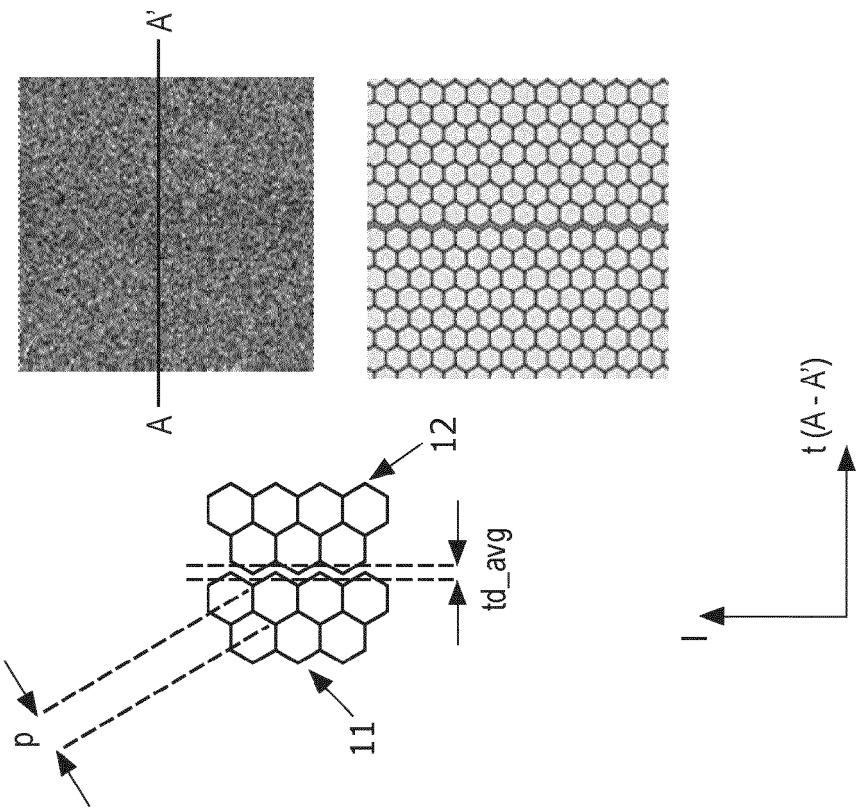


FIG. 5

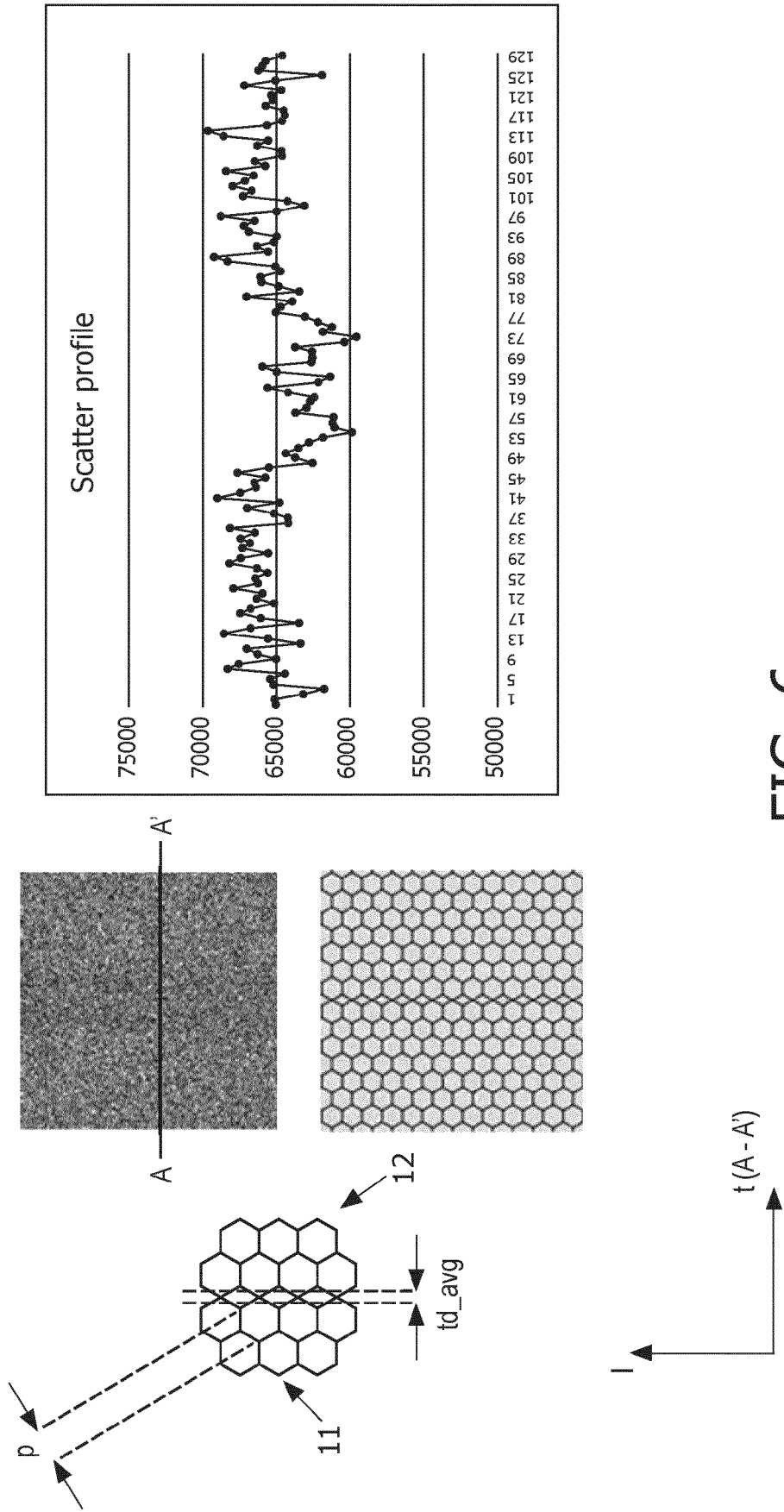


FIG. 6

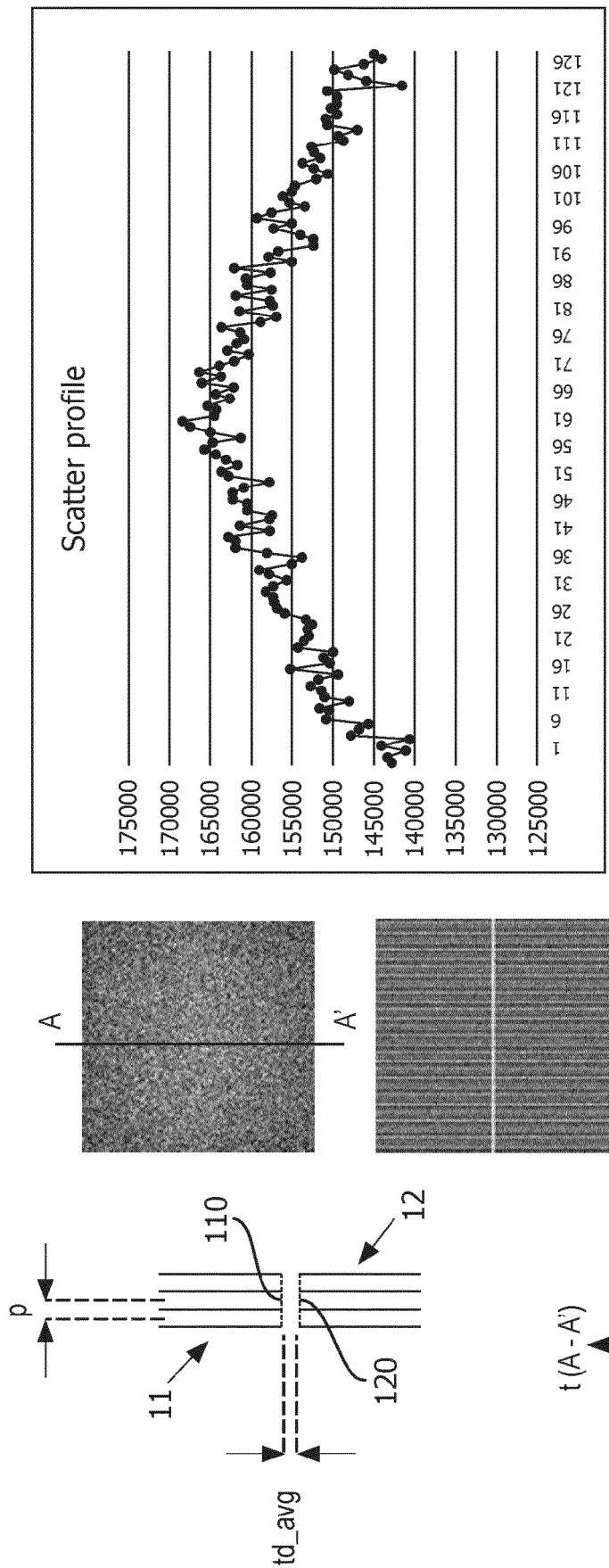


FIG. 7



EUROPEAN SEARCH REPORT

Application Number

EP 23 19 8437

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	US 9 076 563 B2 (YING ZHENGRONG [US]) 7 July 2015 (2015-07-07) * paragraphs [0001] - [0041]; figures 1-2C *	1, 2, 5, 6, 11, 14, 15	INV. G21K1/02
			TECHNICAL FIELDS SEARCHED (IPC)
			G21K
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		4 March 2024	Krauss, Jan
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			

EPO FORM 1503 03.82 (P04C01)



Application Number

EP 23 19 8437

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1, 2, 5, 6, 11, 14, 15

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).



LACK OF UNITY OF INVENTION **SHEET B**

Application Number

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The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1, 2, 5, 6, 11, 14, 15

directed to a microstructure wherein the tiling distances
are constant along the longitudinal direction as defined in
claim 2

2. claims: 3, 4

directed to a microstructure wherein the tiling distances
are not constant along the longitudinal direction as defined
in claim 3

3. claims: 7-9

directed to a microstructure with the (apparently
corresponding) particular material(s) (densities) defined in
claims 7 to 9

4. claim: 10

directed to a microstructure wherein for each module the
grid units repeat only in the longitudinal direction to form
a one-dimensional grid as defined in claim 10

5. claims: 12, 13

directed to a microstructure with the (apparently
corresponding) hexagonal shapes defined in claims 12 and 13

ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 23 19 8437

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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.

04 - 03 - 2024

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		104161535 A	26-11-2014
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			04-12-2014

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