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(54) TWO-DIMENSIONAL-EFFECTIVE ANTI-SCATTER GRID

(57) The present invention provides a two-dimensional-effective anti-scatter grid (ASG). The anti-scatter grid comprises a plurality of septa walls (131). Thereby, each septa wall (131) comprises a continuous, X-ray opaque material strip having formed along its elongated extension a profiled structure with alternating peaks and valleys. Further, the plurality of septa walls (131) is stacked with commonly extending profiled structures facing each other to form a two-dimensional grid in which the peaks of one of two adjacent septa walls (131) at least approach or reach an imaginary line extending through the valleys of the other of the two adjacent septa walls (131), or overlap with the valleys of the other of the two adjacent septa walls (131). And, the profiled structures and/or the septa walls (131) of the two adjacent septa walls (131) complement each other to block ray paths along the profiled structure and in at least one further direction transverse thereto.

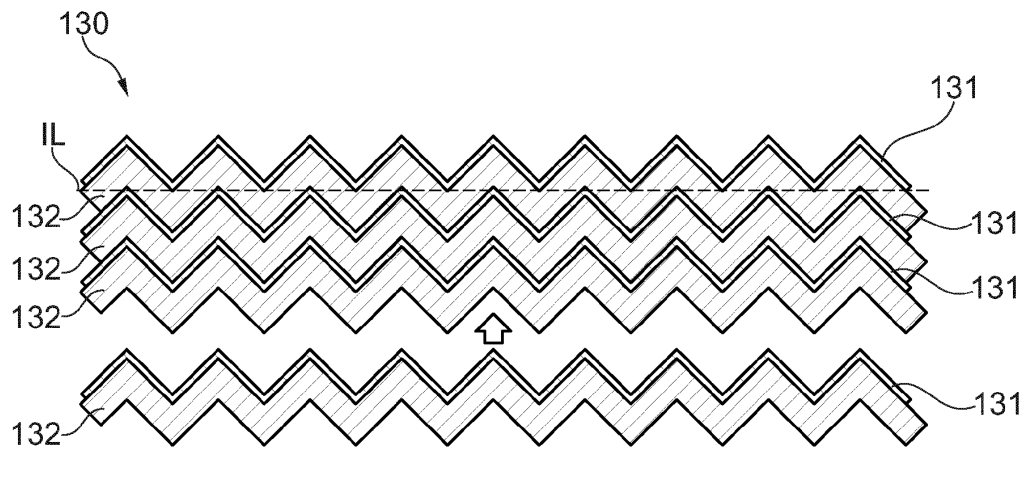

Fig. 3

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Description

FIELD OF THE INVENTION

[0001] The present invention relates to an anti-scatter grid (ASG) for X-ray imaging, a method for providing such an anti-scatter grid for X-ray imaging, and the use of such an anti-scatter grid in X-ray imaging.

BACKGROUND OF THE INVENTION

[0002] In X-ray imaging, scattered radiation may be emanated from an X-rayed subject and may reach an X-ray detector. To prevent scattered radiation from reaching an X-ray detector, anti-scatter devices, also known and referred to as anti-scatter grids (ASG), are arranged between the subject and the X-ray detector, wherein the subject is exposed to radiation delivered by an X-ray radiation source. Conventional ASGs applied in X-ray imaging use an alternating sequence of X-ray opaque septa and X-ray transparent spacers or filler material arranged between the septa, effectively forming a onedimensional (1D) grid even with fine spacing between the septa for X-ray imaging. However, those conventional 1D ASGs are not effective for scattered radiation along the direction of septa, as schematically shown in Fig. 1A in a view seen from a radiation source. The ASG 10 shown in Fig. 1A comprises a plurality of septa walls 11 and spacers and/or filler material 12 arranged therebetween, and is only effective, in terms of blocking and/or preventing scattered radiation, in a direction transverse to an extension direction of the septa walls 11, as indicated by corresponding arrows X designating the prevented scattered radiation, but is not effective along the direction of the septa walls 11, as indicated by corresponding arrows Y designating the non-prevented scattered radiation. Another conventional type of ASG is a true two-dimensional (2D) grid as shown in Fig. 1B in a view seen from a radiation source, which 2D ASG 10 blocks scattered X-rays with at least nearly equal effectivity in all directions relative to the septa walls 11. Again, the ASG 1 according to Fig. 1B comprises a plurality of septa walls 10, preventing or blocking the scattered radiation in multiple directions as indicated by arrows X. However, those 2D ASGs are difficult, currently even impossible, to be manufactured with sufficiently thin septa and fine grid spacing for X-ray imaging as in the only 1D-effective ASG. Also, such 2D ASGs are commonly formed by using an additive manufacturing process, which, however, is complex with regard to e.g. the tools used, the raw material of septa walls used, etc.

SUMMARY OF THE INVENTION

[0003] Therefore, there may be a need for providing an anti-scatter grid (ASG) that can reduce or prevent scattered in two dimensions but can preferably be manufactured with thin septa walls and/or a fine grid spacing.

[0004] The object of the present invention is solved by the subject-matter of the independent claims, wherein further embodiments are incorporated in the dependent claims.

[0005] According to a first aspect, there is provided an anti-scatter grid (ASG) for X-ray imaging, for example, in medical X-ray imaging, non-destructive testing using X-ray imaging, X-ray computed tomography (X-ray CT), nuclear medicine (SPECT), etc. The ASG comprises a plurality of septa walls, i.e. at least two, preferably three or more, wherein each septa wall comprises or is formed from a continuous X-ray opaque material strip having formed along its elongated extension a profiled structure with alternating peaks and valleys. The plurality of septa walls is stacked together with commonly extending profiled structures facing each other to form a two-dimensional grid in which the peaks of one of two adjacent septa walls at least approach or reach an imaginary line extending through the valleys of the other of the two adjacent septa walls, or overlap with the valleys of the other of the two adjacent septa walls. Further, the profiled structures and/or the septa walls of the two adjacent septa walls complement each other to block X-ray paths along the profiled structure and in at least one further direction transverse thereto.

[0006] In this way, a 2D-effective ASG can be provided, which, however, can be manufactured in a particularly simple manner, especially like or similar to the manufacturing of an only 1D-effective ASG. In other words, two or more assemblies of septa walls, i.e. two or more septa walls, are stacked together, and their complementary profiled structures act together to block, eliminate, absorb, etc., scattered radiation travelling in any direction, or at least two different directions, in the plane of those assemblies, i.e. septa walls. In particular, the scattered radiation is absorbed, blocked, or the like in the direction of or parallel to the extension direction of the septa walls and, additionally, in at least one further direction transverse to the extension direction of the septa walls. Accordingly, the ASG described herein provides a way to manufacture and/or provide a 2D-effective ASG essentially with a manufacturing method at least similar to current manufacturing methods for only 1D-effective ASGs. The interaction of the profiled structures of adjacently arranged septa walls allow the septa walls to absorb scattered radiation in at least two directions, one of which is the direction along or parallel to the extension direction of the septa walls, to provide a 2D-effective ASG. At the same time, the individual septa walls can be provided as single assemblies manufactured from the continuous material, i.e. similar to or like an only 1D-effective ASG.

[0007] As used herein, an ASG may be considered to be "effective" if it blocks, absorbs, stops, prevents, etc., scattered radiation by its septa walls, so that the scattered radiation is at least reduced or is prevented from reaching an X-ray detector. Accordingly, an ASG may be considered to be "2D-effective" if it blocks, absorbs, prevents, etc., scattered radiation at least along or parallel to the extension direction of its septa walls and at least one further direction transverse to the extension direction of the septa walls. Likewise, an ASG may be considered to be "only ID-effective" if it blocks, absorbs, prevents, etc., scattered radiation in only one of the above directions, wherein the anti-scatter function is particularly not given along the extension direction along the extension of the septa walls. It is noted that the ASG described herein, or provided by the method as described herein, is a 2D-effective ASG.

[0008] As used herein, the term "septum" or "septa" may be understood as the grid's wall(s), and may also be referred to as lamella(e). The septa wall may be comprised of thin formations, which may be blade-like, lamella-like or the like, and may be formed from a suitable X-ray absorbing material such as lead, tungsten, molybdenum, tin, or the like. The septa walls may optionally be focused at the x-ray focal spot and generally located between columns and/or rows of an X-ray detector.

[0009] Further, as used herein, that the X-ray opaque material from which the septa wall is formed is "continuous" can be considered in distinction to a 3D-printed material, i.e., material used with an additive manufacturing process, i.e. in a 3D printing process, where the material, such as plastics, liquids or powder grains, is usually applied layer-by-layer, i.e., discontinuously, to a substrate. The continuous material may be provided as, for example, sheet metal, foil or the like, the two-dimensional extension of which is greater than its thickness. For example, the continuous material may be processed by a separating manufacturing process, such as cutting, etc., and a forming manufacturing process, such as pressing, rolling, bending, etc., wherein the order of the manufacturing processes or steps used may vary. As described above, the ASG as described herein can be manufactured like an only 1D-effective ASG.

[0010] The profiled structure may be formed from the continuous material using a forming process, such as pressing, stamping, embossing, bending, or the like. The peaks and valleys of the profiled structure may also be understood as elevations and depressions in the direction of the longitudinal extension of the septa walls or the respective assembly, i.e. when considered over a flat side along the longitudinal extension of the continuous material strip. The profiled structure, particularly the peaks and valleys thereof, may be sharp, blunt, curved, etc.

[0011] The imaginary line described herein may extend, in particular, along the longitudinal extent of the continuous material, i.e., the septa walls, in a plane as seen from the direction of a radiation source. In this regard, that the peaks and/or valley of the profiled structures approach the imaginary line may be understood as meaning that in each case there is only a small distance, e.g. in the range of a few tens of micrometers down to micrometers, from the imaginary line.

[0012] According to an embodiment, the ASG may further comprise at least one interspacer and/or filler material arranged between two adjacent septa walls, wherein the at least one interspacer or the filler material is at least less X-ray opaque than the X-ray opaque material of the septa walls or is at least essentially X-ray transparent. For example, a material for the interspacer and/or the filler material may comprise paper, cotton fiber-based materials, polymers, aluminum, carbon, carbon fiber composites, or the like. Such a material is at least more transparent for X-ray radiation than the X-ray opaque material of the septa walls. The interspacer and/or the filler material may be attached to or formed at the septa walls so as to keep two adjacent septa walls, i.e. assemblies, attached to and/or in distance to each other, e.g. with a gap therebetween which may also be referred to as a grid spacing. Thus, a two-dimensional grid structure with specific spacing between septa walls can be provided.

[0013] According to an embodiment, two adjacent septa walls may be spaced apart from each other by a spacing being equal to or greater than a wall thickness of the septa walls corresponding to a respective thickness of the formed continuous material. In other words, an individual septa wall may be particularly thin-walled. In this way, the ASG can be provided with a particularly thin septa, fine grid spacing and high transparency for primary radiation.

[0014] In an embodiment, the profiled structures of two adjacent septa walls may be aligned with each other. For example, the peaks and/or valleys of two adjacently arranged septa walls may lie on a common line extending transversely to a direction as seen from a radiation source. Of course, also all of the septa walls, if more than two are provided, may lie on such a common line. Also, the longitudinal ends of the septa walls may be flush with each other. In this way, particularly good blocking, absorption, etc. of scattered radiation can be achieved.

[0015] According to an embodiment, the profiled structures of two adjacent septa walls may be shifted to each other along the extension, i.e. the longitudinal extension of the septa walls and/or the continuous material strip. In this way, two adjacent septa walls can form a chamber in which the scattered radiation is blocked, absorbed, prevented, etc. in at least nearly each direction within the chamber.

[0016] In an embodiment, the profiled structure may be at least essentially periodic or quasi-periodic. In other words, the peaks and valleys, which can be sharp or blunt, may repeat their form in a regular interval. In this way, the scattered radiation travelling in any direction in the plane of the septa walls, i.e. the stacked assemblies, is blocked, absorbed, etc. after travelling a maximum of one period of the profiled structure. In addition, this shape can be made by simple tools by, for example, bending, pressing, embossing or similar manufacturing processes.

[0017] According to an embodiment, the profiled structure has a tooth shape. In other words, the profiled structure may be toothed, ridged with prongs, or the like. For example, the profiled structure may be triangular or polygonal in shape when viewed from one direction of the radiation source. This allows the septa walls to approach, reach or overlap the imaginary line particularly well. In addition, this shape can be formed by simple tools by, for example, bending, pressing, embossing or similar manufacturing processes.

[0018] In an embodiment, the peaks and/or valleys of each of the plurality of septa walls include an essentially perpendicular angle, i.e. ± 90° angle, an obtuse angle or an acute angle, forming a polygonal shape. This allows the septa walls to approach, reach or overlap the imaginary line particularly well. In addition, this shape can be formed by simple tools by, for example, bending, pressing, embossing or similar manufacturing processes.

[0019] According to an embodiment, the profiled structure may have an undulating shape. For example, the profiled structure may have e.g. a sinusoidal shape, or the like. This allows the septa walls to approach, reach or overlap the imaginary line particularly well. In addition, this shape can be formed by simple tools by, for example, bending, pressing, embossing or similar manufacturing processes.

[0020] It is noted that the profiled structure as described above and/or the shapes of the profiled structure as described above may have an amplitude A chosen such that the peaks and valleys of adjacent septa walls approach, reach or overlap with respect of the common imaginary line. Thereby, the amplitude A may be chosen to fulfill A ≥ t, wherein t is a distance, spacing, gap, etc., between the two adjacent septa walls and/or a thickness of an interspacer or filler material arranged between two adjacent septa walls. Further, by way of example, a period length P to fulfill the imaginary line approaching, reaching or overlap criterion may be determined by $P \geq \frac{2 \cdot t}{sin\left(\frac{\phi}{2}\right)}$, wherein φ is a bending angle, t is a thickness of the assembly and/or a distance, spacing, gap, etc., between the two adjacent septa walls.

[0021] In an embodiment, the continuous material and/or the septa walls may have a thickness of about 10 μm to about 300 μm. Especially in non-SPECT applications, the continuous material and/or the septa walls may have a thickness of about 10 μm to about 50 μm. In this way, the ASG may be particularly thin-walled.

[0022] According to an embodiment, the ASG may have a grid ratio of about 3 to about 40, wherein the grid ratio is expressed by $R = \frac{h}{p-w}$, wherein h is the grid's height, p is the grid's pitch and w is the septa wall's width. Alternatively or additionally, the ASG may have a grid line density of about 25 lines per cm, li/cm, to about 90 li/cm. The latter may be translated into a spacing of about 0.4 mm to 0.11 mm from grid cell to grid cell. In this way, the ASG may be particularly thin-walled and/or may have a fine grid spacing.

[0023] According to a second aspect, the present disclosure relates to the use of an anti-scatter grid (ASG) according to one or more of the above embodiments in an X-ray imaging device or system. The ASG may be particularly thin-walled and/or may have a fine grid spacing, so that the X-ray imaging can be improved in terms of scattered radiation reaching an X-ray detector of the X-ray imaging device or system.

[0024] According to a third aspect, there is provided an X-ray imaging device or system comprising an anti-scatter grid (ASG) according to one or more of the above embodiments. Due to the ASG described herein, the X-ray imaging device or system can be improved in terms of scattered radiation reaching an X-ray detector of the X-ray imaging device or system.

[0025] According to a fourth aspect, there is provided a method for providing an anti-scatter grid (ASG) for X-ray imaging. The method may be used to provide and/or manufacture the ASG according to one or more of the embodiments as described above.

[0026] The method comprises a step of forming of a continuous, X-ray opaque material by a forming tool to form and/or create a septa wall having a profiled structure with alternating peaks and valleys.

[0027] Further, the method comprises a step of stacking of a plurality of septa walls, i.e. the individual septa walls (pre-)formed in the above method step, with commonly extending profiled structures facing each other to form a two-dimensional (2D) grid in which the peaks of one of two adjacent septa walls at least approach or reach an imaginary line extending through the valleys of the other of the two adjacent septa walls, or overlap with the valleys of the other of the two adjacent septa walls. Further, the septa walls of two adjacent septa walls complement each other to block, absorb, prevent, etc., ray paths along the profiled structure and in at least one further direction transverse thereto.

[0028] In this way, as described above for the ASG, a 2D-effective ASG can be provided by a manufacturing method that is at least similar or equal to a 1D-effective ASG. As a result, the manufacturing is particularly easy and cost effective, since, for example, no additive manufacturing method has to be used to form the septa walls or the anti-scatter grid.

[0029] For example, the forming tool used may comprise a pressing tool, an embossing tool, a ruler, a bumper, a bending tool, a combination thereof such as a tooling compound, or other suitable tooling or other suitable tooling compound, provided that the profiled structure can be formed from the continuous material strip.

[0030] By way of example, the forming tool may be or may comprise two suitably shaped, interacting rotating embossing drums or suitably shaped, interacting embossing dies, e.g. a bumper and a ruler, which are brought together while the continuous material strip is placed and/or inserted in between. Thereby, it may be provided the quasi-periodic structure is varied in such a way that the septa and periodic teeth or undulations are focused to the X-ray source of the X-ray system where the invention is to be used.

[0031] According to an embodiment, the step of forming of the septa walls may comprise pressing, stamping and/or bending of the continuous material into the profiled structure. For this purpose, a suitable tool can be used as described above.

[0032] According to an embodiment, the method may further comprise a step of providing at least one interspacer and/or filler material arranged between two adjacent septa walls. For example, an individual septa wall and an interspacer and/or filler material may be provided as one assembly, wherein such an assembly of septa wall and interspacer and/or filler material may be shaped, e.g. by pressing, bending, or the like. Alternatively or additionally, such an assembly of septa wall and interspacer and/or filler material may comprise small blocks of filler material attached to the shaped septa wall such that a next assembly, i.e. an adjacent assembly of the stack to be formed, fits into the gaps of the preceding assembly of septa wall and interspacer and/or filler material in the stack.

[0033] In an embodiment, two adjacent septa walls of the stack are frictionally and/or positively and/or materially connected to each other. For example, the septa walls can be joined together by pressing them together, interlocking them by appropriate forming, by welding and/or soldering, gluing, or the like. This is particularly useful if no interspacer or filler material is arranged between the septa walls. In this way, septa walls can be easily attached to each other without the need for interspacing and/or filler material.

[0034] According to an embodiment, the steps of forming the septa walls or assembly of septa walls and interspacer and/or filler material may be combined into a single step, e.g. by using a suitably formed and/or shaped pressing tool, which may comprise, for example, a ruler and bumper. Thereby, initially, the septa wall or assembly of septa wall and interspacer and/or filler material may be straight, but may then be formed into the profiled structure when one tool part, e.g. the bumper, presses it against the other tool part, e.g. the ruler, or against a previously formed septa wall or a previously formed assembly of septa wall and interspacer and/or filler material.

[0035] It is noted that the above embodiments may be combined with each other irrespective of the aspect involved. Accordingly, the method may be combined with structural features of the device and/or system of the other aspects and, likewise, the device and/or the system may be combined with features of each other, and may also be combined with features described above with regard to the method.

[0036] 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

[0037] The subject matter of the invention will be explained in more detail in the following with reference to exemplary embodiments which are illustrated in the attached drawings.

Fig 1A shows in a view seen from a radiation source a one-dimensional-(ID)-effective anti-scatter grid (ASG) according to prior art.

Fig. 1B shows in a view seen from a radiation source a two-dimensional-(2D)-effective anti-scatter grid (ASG) according to prior art.

Fig. 2 shows in a side view an X-ray imaging device or system comprising a radiation source, an X-ray detector and an anti-scatter grid (ASG) according to an embodiment.

Fig. 3 shows in a view seen from a radiation source an anti-scatter grid (ASG) according to an embodiment.

Fig. 4 shows in a view seen from a radiation source an anti-scatter grid (ASG) according to an embodiment.

Fig. 5 shows in a view seen from a radiation source an anti-scatter grid (ASG) according to an embodiment.

Fig. 6 shows in a view seen from a radiation source an anti-scatter grid (ASG) according to an embodiment.

Fig. 7 shows in a view seen from a radiation source an anti-scatter grid (ASG) according to an embodiment.

Fig. 8 shows in a view seen from a radiation source an anti-scatter grid (ASG) according to an embodiment.

Fig. 9 shows in a side view a method and/or tooling for providing an anti-scatter grid (ASG) according to an embodiment.

Fig. 10 illustrates in a diagram an amplitude criterion of a profiled structure with respect to an imaginary line of an anti-scatter grid (ASG) according to an embodiment.

Fig. 11 illustrates in a diagram a shape criterion of a profiled structure with respect to an imaginary line of an anti-scatter grid (ASG) according to an embodiment.

Fig. 12 shows in side view a method and/or tooling for providing a pre-formed and/or profiled assembly of a septa wall and optionally interspacer and/or filler material for an anti-scatter grid according to an embodiment.

Fig. 13 shows in a side view a method and/or tooling for providing an anti-scatter grid (ASG) according to an embodiment.

Fig. 14 shows in a side view a method and/or tooling for providing an anti-scatter grid (ASG) according to an embodiment.

Fig. 15 shows in a side view a method and/or tooling for providing an anti-scatter grid (ASG) according to an embodiment.

Fig. 16 shows in a side view a method and/or tooling for providing an anti-scatter grid (ASG) according to an embodiment.

Fig. 17 shows in a side view a method and/or tooling for providing an anti-scatter grid (ASG) according to an embodiment.

Fig. 18 shows in flow diagram a method for providing an anti-scatter grid (ASG) according to an embodiment.

[0038] In principle, in the drawings, identical parts or features are provided with the same reference signs.

DETAILED DESCRIPTION OF EMBODIMENTS

[0039] Fig. 2 shows in schematic side view an X-ray device or system 100 for X-ray imaging of a subject S, which may be a patient or another object to be examined. The X-ray device or system 100 comprises an X-ray radiation source 110, such as an X-ray tube or the like, configured to emit X-rays onto the subject S, and X-ray detector 120 configured to receive the X-rays after passing the subject S, and an anti-scatter grid (ASG) 130 arranged between the subject S and the X-ray detector 120.

[0040] The ASG 130 described herein is a two-dimensional (2D)-effective ASG and extends into the sheet plane in Fig. 1 and is configured to block, absorb, prevent, etc., scattered radiation A (see also Fig. 4) from reaching the X-ray detector 120, or at least to a reduced extent.

[0041] Fig. 3 shows an exemplary embodiment of the ASG 130 in a view seen from the X-ray radiation source 110, wherein the corresponding view direction VD is indicated in Fig. 2 by an arrow. Referring to Fig. 3, the ASG 130 comprises a plurality of septa walls 131 and an optional plurality of interspacers and/or filler material 132. The septa walls 131 and the interspacers and/or filler material 132 together form and may also be referred to as an assembly of septa walls 131 and optional interspacers and/or filler material 132. Accordingly, the ASG 130 may also be referred to as comprising a plurality of assemblies of septa walls 131 and optional interspacers and/or filler material 132. Thereby, the individual assemblies of septa walls 131 and optional interspacers and/or filler material 132 may be basically identical to each other. As can be seen from Fig. 3, the assemblies of septa walls 131 and interspacers and/or filler material 132 are stacked together to form a stack, thereby forming the 2D(-effective) ASG 130. With reference to Fig. 3, each septa wall 131 or assembly of septa wall 131 and interspacer and/or filler material 132 has a longitudinal extension that extends along the left/right direction in Fig. 3. It should be noted that each septa wall 131 and interspacer and/or filler material 132 also extends into the sheet plane of Fig. 3. Further, each one or at least most of the septa walls 131 comprises or is made or formed from a continuous, X-ray opaque material strip having formed along its elongated extension a profiled structure with alternating peaks and valleys. The individual septa walls 131 are comprised of thin formations, which may be blade-like, lamella-like or the like, and may be formed from a suitable X-ray absorbing material such as lead, tungsten, molybdenum, tin, or the like. The septa walls 131 may optionally be focused on the X-ray focal spot and generally located between columns and/or rows of an X-ray detector. In other words, the continuous material strip is formed from a substantially straight or planar initial shape such that it has a plurality of elevations, i.e. peaks, and depressions, i.e. valleys, along its length, i.e. its longitudinal extension.

[0042] As indicated by a dashed line in Fig. 3, there is an imaginary line IL, i.e., imaginary, but drawn in Fig. 3, which is respectively approached, reached or overlapped by two adjacent septa walls 131 and/or assemblies of septa walls 131 and interspacers and/or filler material 132 through their peaks and valleys. In other words, the plurality of septa walls 132 is stacked with commonly extending profiled structures facing each other to form a 2D-grid in which the peaks of one of two adjacent septa walls 132 at least approach or reach the imaginary line IL extending through the valleys of the other of the two adjacent septa walls 131, or overlap with the valleys of the other of the two adjacent septa walls 131. According to Fig. 3, the valleys of the first, i.e. uppermost, septa wall 131 in Fig. 3 reach or overlap the imaginary line IL, as do the peaks of the second, i.e. following the first septa wall 131, arranged adjacent thereto.

[0043] In this way, the profiled structures of the septa walls 131 and/or the septa walls 131 of the two adjacent septa walls 131 complement each other to block, absorb, etc. X-ray paths along the profiled structure, i.e. along the longitudinal direction of the septa walls 131, and in at least one further direction transverse thereto, thereby providing the 2D-effective ASG 130.

[0044] It is noted that Fig. 3 indicates a direction in which the individual septa walls 131 are stacked together by an arrow. Further, it is noted that although Fig. 3 shows an exemplary number of four septa walls 131, the ASG 130 may also comprise more or significantly more individual septa walls 131.

[0045] It is also noted that the basic principle of the 2D operation of the ASG 130 is based on approaching, reaching or overlapping with the imaginary line IL through sections of each two adjacent septa walls 131 of the stack. For the basic principle, it is irrelevant whether the individual septa walls 131 are provided with or without interspacer and/or filler material 132, so that the latter is optional. Thus, the individual septa walls 131 can be attached directly to each other to form the stack even without the optional interspacer and/or filler material 132. Although the interspacer and/or filler material 132 is optional, a material for the interspacer and/or the filler material 132 comprises paper, cotton fiber-based materials, polymers, aluminum, carbon, carbon fiber composites, or the like. Such a material is at least more transparent for X-ray radiation than the X-ray opaque material of the septa walls 131. The interspacer and/or the filler material may be attached to or formed at the septa walls so as to keep two adjacent septa walls, i.e. assemblies, attached to and/or in distance to each other, e.g. with a gap therebetween which may also be referred to as a grid spacing.

[0046] It is further noted that the pronged or toothed shape of the profiled structure shown in Fig. 3, i.e. the septa walls 131, is only exemplary and the above-mentioned basic principle is also valid for an e.g. undulating shape or the like.

[0047] Fig. 4 illustrates in a view seen from the radiation source 110 the 2D-effect of the ASG 130 of Fig. 3. Therein, the scattered radiation is indicated and designated by arrows X, wherein the septa walls 131 complement to each other to block, absorb, etc. scattered radiation, i.e. X-ray paths, at least along the profiled structure, i.e. along the longitudinal direction of the septa walls 131, and in at least one further direction transverse thereto, thereby providing the 2D-effective ASG 130. It should be noted that the X-ray paths do not necessarily have to run in exactly the directions shown, but may deviate from them.

[0048] Further, according to Fig. 4, as in Fig. 3, the pronged or tooth shape of the profiled structure of the septa walls 130 includes at the peaks and/or valleys are essentially right angle.

[0049] Again, Fig. 4 indicates by an arrow how the stack of individual septa walls 131 is assembled, or how the plurality of septa walls 131 are stacked together to form the 2D grid of the ASG 130.

[0050] Fig. 5 shows an exemplary embodiment of the ASG 130 in a view seen from the X-ray radiation source 110. Thereby, the ASG 130 shown in Fig. 5 differs from the ASG 130 shown in Fig. 3 or 4 basically in that the peaks and valleys of the profiled structure of the septa walls 131 are flatter, i.e. include a smaller angle Φ (wherein the angle Φ is shown in Fig. 11). Whereas the pronged or toothed shape in Fig. 3 or 4 is more pointed with an essentially right angle, in Fig. 5 it is flatter with a correspondingly modified angle.

[0051] Again, Fig. 5 indicates by an arrow how the stack of individual septa walls 131 is assembled, or how the plurality of septa walls 131 are stacked together to form the 2D grid of the ASG 130.

[0052] Further again, for the basic principle, it is irrelevant whether the individual septa walls 131 are provided with or without interspacer and/or filler material 132, so that the latter is optional. Thus, the individual septa walls 131 can be attached directly to each other to form the stack even without the optional interspacer and/or filler material 132.

[0053] Fig. 6 shows an exemplary embodiment of the ASG 130 in a view seen from the X-ray radiation source 110. Thereby, the ASG 130 shown in Fig. 6 differs from the above ASG 130 shown in Fig. 3 to 5 basically in that the profiled structure has an undulating shape instead of being pronged or toothed. As indicated in Fig. 6, the peaks and valleys of the undulating shape, i.e. of the profiled structure of the septa walls 131 approach, reach or overlap with the imaginary line IL, so as to complement each other to block, absorb, etc. the scattered radiation.

[0054] Again, Fig. 6 indicates by an arrow how the stack of individual septa walls 131 is assembled, or how the plurality of septa walls 131 are stacked together to form the 2D grid of the ASG 130.

[0055] Further again, for the basic principle, it is irrelevant whether the individual septa walls 131 are provided with or without interspacer and/or filler material 132, so that the latter is optional. Thus, the individual septa walls 131 can be attached directly to each other to form the stack even without the optional interspacer and/or filler material 132.

[0056] Fig. 7 shows an exemplary embodiment of the ASG 130 in a view seen from the X-ray radiation source 110. In contrast to the embodiments described above, the interspacers and/or filler material 132 described above as optional are omitted here, but could also be present. Accordingly, according to Fig. 7, the individual septa walls 131 are attached to each other without these, which can be realized in a form-fit, force-fit and/or material-fit manner, for example.

[0057] According to Fig. 7, the individual septa walls 131 are shaped, e.g. by bending, in such a way that corners, i.e. the peaks and valleys, exhibit a 90° angle and sides have equal length. Consecutive preformed septa walls 130 are shifted by a half a period in each assembly step such that they from a regular 2D-grid. Other angles than 90° are possible, leading to a 2D-effective grid with a rhombic structure instead of square structure.

[0058] Again, Fig. 7 indicates by an arrow how the stack of individual septa walls 131 is assembled, or how the plurality of septa walls 131 are stacked together to form the 2D grid of the ASG 130.

[0059] Fig. 8 shows in a view seen from the radiation source 110 an exemplary embodiment of the ASG 130, similar to that shown in Fig. 7, with the interspacers and/or filler material 132. Here, the septa walls 131 or assemblies of septa wall 131 and interspacer and/or filler material 132 comprise small blocks of filler material attached to the individual shaped septa wall 131 such that the next septa wall 131 or assembly, i.e. the preceding septa wall 131 of the stack, fits into the gaps of the preceding septa wall 131 or assembly.

[0060] Again, Fig. 8 indicates by an arrow how the stack of individual septa walls 131 is assembled, or how the plurality of septa walls 131 are stacked together to form the 2D grid of the ASG 130.

[0061] Fig. 9 shows a method of how the individual septa wall 131, and particularly the assembly of septa wall 131 and interspacer and/or filler material 132 required for the anti-scatter grid of Fig. 8, can be formed. It can be formed or made by first attaching blocks of filler material 132 to the septa wall 131 forming continuous material strip and then forming, e.g. pressing, bending or the like, the septa wall 131 into shape, i.e. into the profiled structure. In this exemplary embodiment, an angle included by the profiled structure, and particularly by the peaks and valleys thereof, is an essentially right angle, since this requires just a cubic block of filler material

132. Other angles will require filler material 132 blocks of rhombic shape.

[0062] Fig. 10 illustrates in a diagram an amplitude criterion of the above-explained profiled structure of the individual septa wall 131 of the ASG 130 with respect to the imaginary line IL. As illustrated in Fig. 10, the profiled structure as described above has an amplitude A, i.e. an extension from a top of its peaks to a bottom of its valleys, chosen such that the peaks and valleys of adjacent septa walls approach, reach or overlap with respect of the common imaginary line IL. Thereby, the amplitude A may be chosen to fulfill the criterion $A \geq d$, wherein d is a distance, preferably, perpendicular distance, spacing, gap, etc., between the two adjacent septa walls and/or a thickness of an interspacer or filler material arranged between two adjacent septa walls.

[0063] Fig. 11 illustrates in a diagram a shape criterion of the profiled structure of the individual septa wall 131 of the ASG 130 with respect to the imaginary line IL. Therein, a period length P to fulfill the imaginary line IL approaching, reaching or overlap criterion may be determined by $P \geq \frac{2 \cdot t}{sin\left(\frac{\phi}{2}\right)}$, wherein φ is an, e.g. bending, angle, t is a thickness of the assembly, i.e. the individual septa wall 131, and/or a distance, spacing, gap, etc., between the two adjacent septa walls 132.

[0064] Based on the exemplary embodiments of the ASG 130 described above, the ASG 130 can be modified in many ways.

[0065] As described above, the at least one interspacer and/or filler material 132 arranged between two adjacent septa walls 131 is optional. For example, the at least one interspacer or filler material 132 is at least less X-ray opaque than the X-ray opaque material of the septa walls, or is X-ray transparent. Further, in at least some embodiments, the two adjacent septa walls 131 are spaced from each other by a spacing being equal to or greater than a wall thickness of the septa walls 131 corresponding to a respective thickness of the formed continuous material.

[0066] Optionally, the profiled structures of two adjacent septa walls 131 are aligned with each other. This is illustrated in e.g. Fig. 3 to Fig. 6, where the peaks and valleys of the individual septa walls 132 are aligned with each other.

[0067] Optionally, the profiled structure of two adjacent septa walls 131 are shifted to each other along their extension, particularly along their longitudinal extension. For example, the septa walls 131, and particularly their peaks and valleys of their profiled structure, may be shifted by half a period. This is illustrated in e.g. Fig. 7 and Fig. 8.

[0068] Optionally, the profiled structure is essentially periodic. This can be provided by both the toothed and the undulating profiled structure of the septa walls 131.

[0069] Optionally, the continuous material and/or the septa walls has a thickness of about 10 μm to about 300 μm.

[0070] Optionally, the ASG 130 has a grid ratio of 3 to 40, wherein the grid ratio is expressed by $R = \frac{h}{p-w}$, wherein h is the grid's height, p is the grid's pitch and w is the septa wall's width.

[0071] In the following, a method of providing the ASG 130 is explained with reference to Fig. 12 to Fig. 18 is described. Therein, each of Fig. 12 to Fig. 17 shows in a side view a method and/or tooling for providing the ASG, and Fig. 18 shows in a flow diagram method steps for providing the ASG 130.

[0072] According to Fig. 12, the continuous material used to form the septa walls 131 is provided as a strip of material, preferably in a straight or planar initial shape. As illustrated, the tooling used in the method may comprise two suitably shaped rotating embossing drums 200A and 200B. Alternatively, a sequence of embossing drums with increasing bending angles may be used to reach a desired bending angle. According to Fig. 13, the tooling used in the method may be a suitably shaped ruler 300A and a matching bumper 300B, forming a pressing tool. As illustrated, the tooling may also be used to maintain the shape of the septa walls 131 or assemblies at the start and throughout the stacking process to form the 2D-grid.

[0073] According to Fig. 14, the process or the steps of shaping and/or forming the septa walls 131 or assemblies of septa wall 131 and interspacer and/or filler material 132 and stacking them together is combined into a single step by using a suitably shaped pressing tool, such as ruler 400A and bumper 400B. Initially, the individual septa wall 131 or assembly is straight or planar, and is then formed into shape when the bumper 400B presses it against the ruler 400A or previously stacked septa walls 131 or assemblies. Ruler 400A and bumper 400B can be shaped as described above.

[0074] According to Fig. 15, the bumper 500B has a curved shape, so that it can be moved in a "rolling motion" over the ruler 500A. This rolling motion will shape the individual septa wall 131 or assembly during the stacking process. Thereby, the material of the individual septa wall 131 or assembly may be allowed to be "pulled in" from the side. Such pulling may facilitate the manufacturing process if the amplitude of undulations is large compared to the period of undulations and the first assemblies cannot stretch sufficiently to provide the additional length needed.

[0075] According to Fig. 16, the individual septa wall 131 is arranged without an interspacer and/or filler material 132 in between. That is, instead of an assembly of septa wall 131 and interspacer and/or filler material 132, a sheet to be formed into the septa wall 131 with having a periodic structure imprinted on is manufactured by a set of two embossing drums 600A, 600B (see Fig. 16, left side). Thereby, angles of approx. 90° are preferred. Referring to Fig. 16, center, to obtain the necessary stability of the ASG sheet, a support 600C, a comb 600D with approximately squared needles and a third embossing drum 600E are used to press two structured septa layers against each other at their protruding tips, i.e. peaks, (see Fig, 16, center). Optionally, before the third septa wall 131 forming sheet is pressed to the preceding second one, another comb of needles 600F is laid into the wells of the second septa sheet, thereby improving stability. The needles 600D used in the previous step may be removed and used again for this step, alternatively. In the end, an ASG sheet with a multitude of septa walls 131 is obtained. As indicated in Fig. 16, the arrangement of septa sheets should be supported at the back side and at the two adjacent sides (not shown) to keep it stable and undistorted. The angle of the teeth of the third embossing drum 600E may be smaller than 90° to apply pressure only at the tips of the structured septa wall 131. In addition to mechanical pressure, heat can be used to weld the tips of the profiled structure, e.g. by electrically heating the tips of the third embossing wheel 600E. The tips of the embossing wheels are optionally rounded to obtain a sustainable manufacturing process and better stability of the septa sheets. Instead of the third wheel 600E, a comb of sharp heated blades 600G (or single blades) can be used for welding (see Fig. 16, right side).

[0076] According to Fig. 17, the teeth of the embossing wheels 600A, 600B may also be modified to obtain a flat part instead of the tips in the sheet forming the individual septa wall 131 with the profiled structure. The width of this flat part may be approx. equal to the width of the two adjacent oblique parts so that after welding a multitude of septa walls 131 forming sheets with a quasi-hexagonal grid is obtained.

[0077] Fig. 18 illustrates in a flow diagram a method for providing an anti-scatter grid (ASG) for X-ray imaging. The method may be used to provide the ASG 130 as explained above.

[0078] In a step S1, the method comprises forming of a continuous, X-ray opaque material by a forming tool, e.g. one or more of the above forming tools 200, 300, 400, 500, 600, to create a septa wall 131 having a profiled structure with alternating peaks and valleys.

[0079] In a step S2, the method comprises stacking of a plurality of septa walls 131, e.g. preformed by the above method step S1, with commonly extending profiled structures facing each other together to form a two-dimensional grid in which the peaks of one of two adjacent septa walls 131 at least approach or reach an imaginary line, i.e. the imaginary line IL as explained above, extending through the valleys of the other of the two adjacent septa walls 131, or overlap with the valleys of the other of the two adjacent septa walls 131, wherein the two septa walls 131 complement each other to block ray paths along the profiled structure and in at least one further direction transverse thereto.

[0080] The above method step S1 of forming a continuous, X-ray opaque material and step S2 of stacking of a plurality of septa walls 131 may be combined into one step/process.

[0081] While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art and practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

[0082] In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

LIST OF REFERENCE SIGNS:

[0083]

100	X-ray imaging device or system
110	X-ray radiation source
120	X-ray detector
130	anti-scatter grid (ASG)
131	septa wall / continuous material strip
132	interspacer and/or filler material
200	tool
300	tool
400	tool
500	tool
600	tool
X, Y	scattered radiation
IL	imaginary line
S	subject
VD	view direction

Claims

1. An anti-scatter grid (130) for X-ray imaging, comprising:

    a plurality of septa walls (131);
    wherein each septa wall (131) comprises a continuous, X-ray opaque material strip having formed along its elongated extension a profiled structure with alternating peaks and valleys;
    wherein the plurality of septa walls (131) is stacked with commonly extending profiled structures facing each other to form a two-dimensional grid in which the peaks of one of two adjacent septa walls (131) at least approach or reach an imaginary line extending through the valleys of the other of the two adjacent septa walls (131), or overlap with the valleys of the other of the two

adjacent septa walls (131), and

wherein the profiled structures and/or the septa walls (131) of the two adjacent septa walls (131) complement each other to block ray paths along the profiled structure and in at least one further direction transverse thereto.

2. The anti-scatter grid of claim 1, further comprising at least one interspacer and/or filler material (132) arranged between two adjacent septa walls (131), wherein the at least one interspacer and/or filler material (132) is less X-ray opaque than the X-ray opaque material of the septa walls (131).

3. The anti-scatter grid of claim 1 or 2, wherein two adjacent septa walls (131) are spaced from each other by a spacing being equal to or greater than a wall thickness of the septa walls (131) corresponding to a respective thickness of the formed continuous material.

4. The anti-scatter grid of any one of the preceding claims, wherein the profiled structures of two adjacent septa walls (131) are aligned with each other.

5. The anti-scatter grid of any one of claims 1 to 3, wherein the profiled structures of two adjacent septa walls (132) are shifted to each other along their extension.

6. The anti-scatter grid of any one of the preceding claims, wherein the profiled structure has a tooth shape.

7. The anti-scatter grid of any one of the preceding claims, wherein the peaks and/or valleys of each of the plurality of septa walls include an angle, an obtuse angle or an acute angle, forming a polygonal shape.

8. The anti-scatter grid of any one of the preceding claims, wherein the profiled structure has an undulating shape.

9. The anti-scatter grid of any one of the preceding claims, wherein the continuous material and/or the septa walls (131) have a thickness of about 10 μm to about 300 μm.

10. The anti-scatter grid of any one of the preceding claims, having a grid ratio of 3 to 40, wherein the grid ratio is expressed by $R = h / (p - w)$, wherein h is the grid's height, p is the grid's pitch and w is the septa wall's width.

11. The use of an anti-scatter grid (130) of any one of the preceding claims in an X-ray imaging device (100).

12. A method for providing an anti-scatter grid (130) for X-ray imaging, the method comprising:

forming of a continuous, X-ray opaque material by a forming tool to create a septa wall (131) having a profiled structure with alternating peaks and valleys;

stacking of a plurality of septa walls (131) with commonly extending profiled structures facing each other together to form a two-dimensional grid in which the peaks of one of two adjacent septa walls (131) at least approach or reach an imaginary line extending through the valleys of the other of the two adjacent septa walls (131), or overlap with the valleys of the other of the two adjacent septa walls (131), wherein the two septa walls (131) complement each other to block ray paths along the profiled structure and in at least one further direction transverse thereto.

13. The method of claim 12, wherein the forming of the continuous material and/or the septa wall (131) comprises pressing and/or bending the continuous material into the profiled structure.

14. The method of claim 12 or 13, further comprising providing at least one interspacer and/or filler material (132) arranged between two adjacent septa walls (131).

15. The method of claim 12 or 13, wherein two adjacent septa walls (131) of the stack are frictionally and/or positively and/or materially connected to each other.

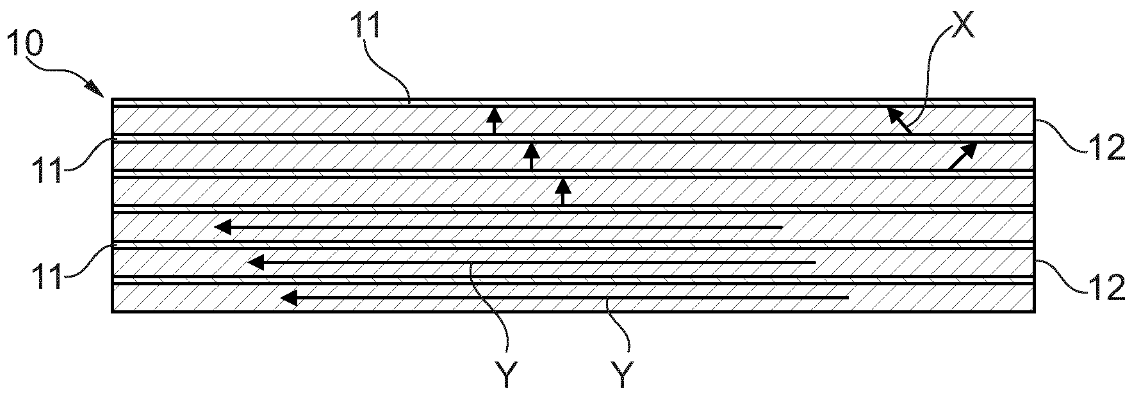


Fig. 1A
(Prior Art)

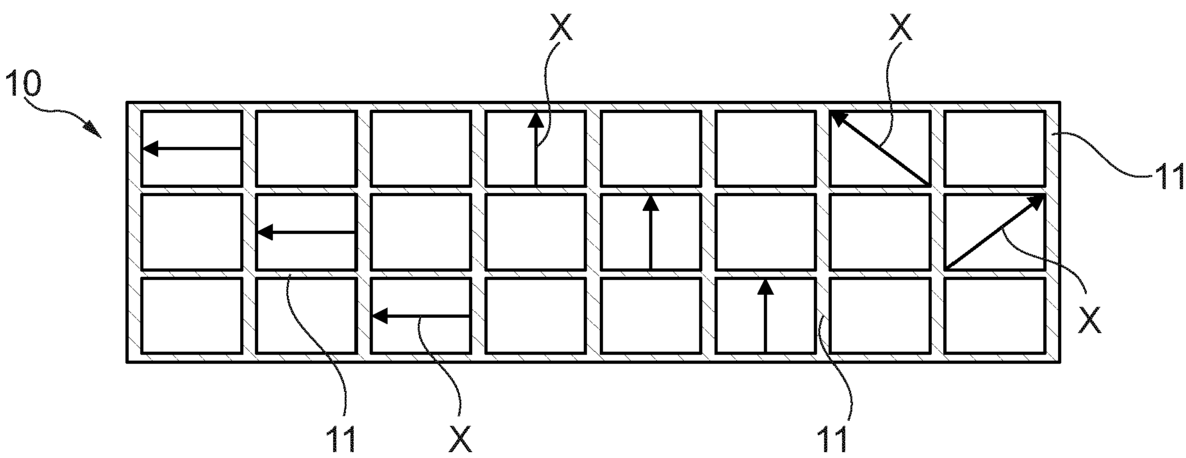


Fig. 1B
(Prior Art)

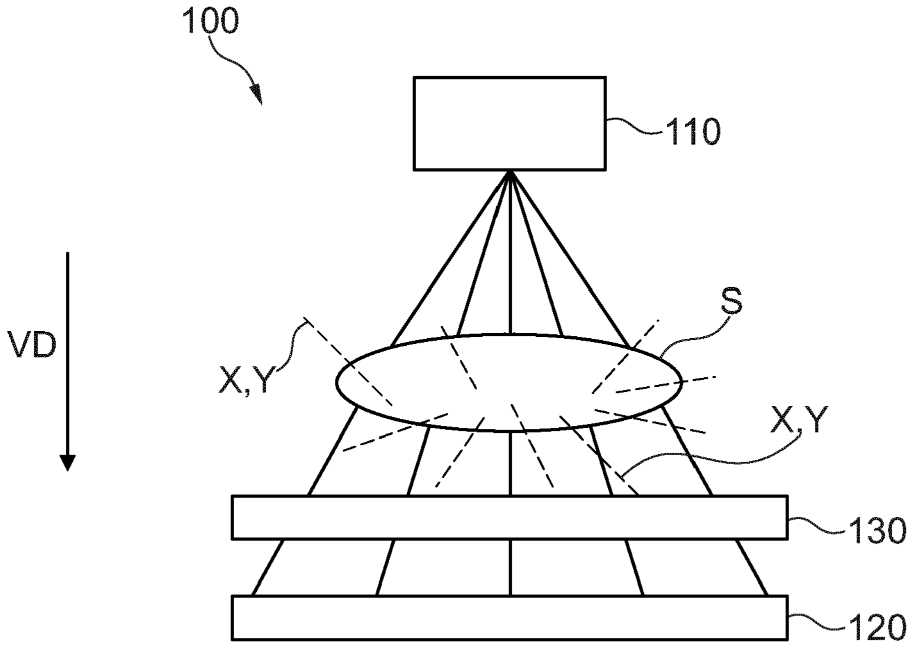


Fig. 2

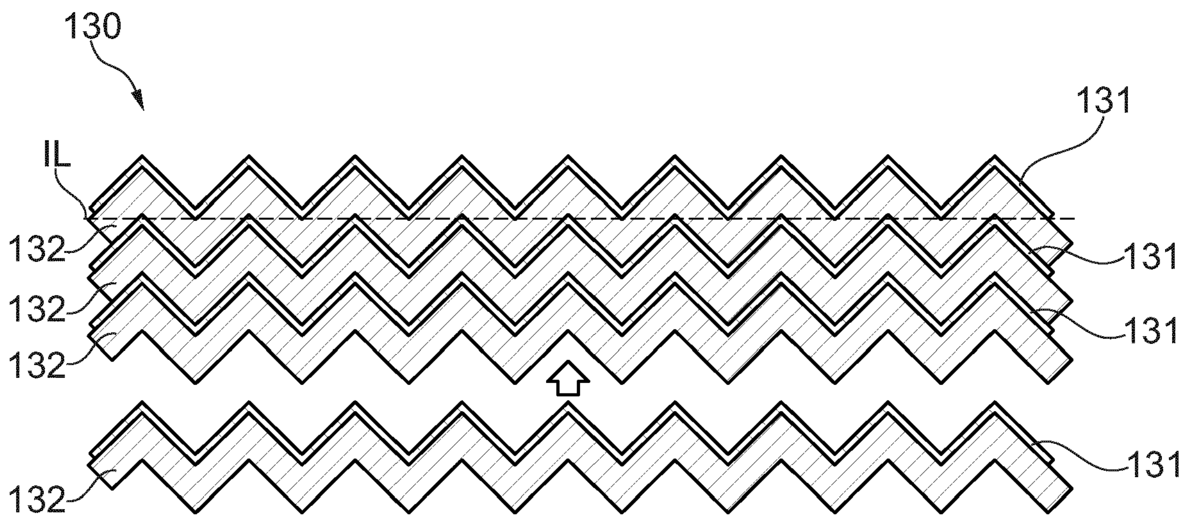
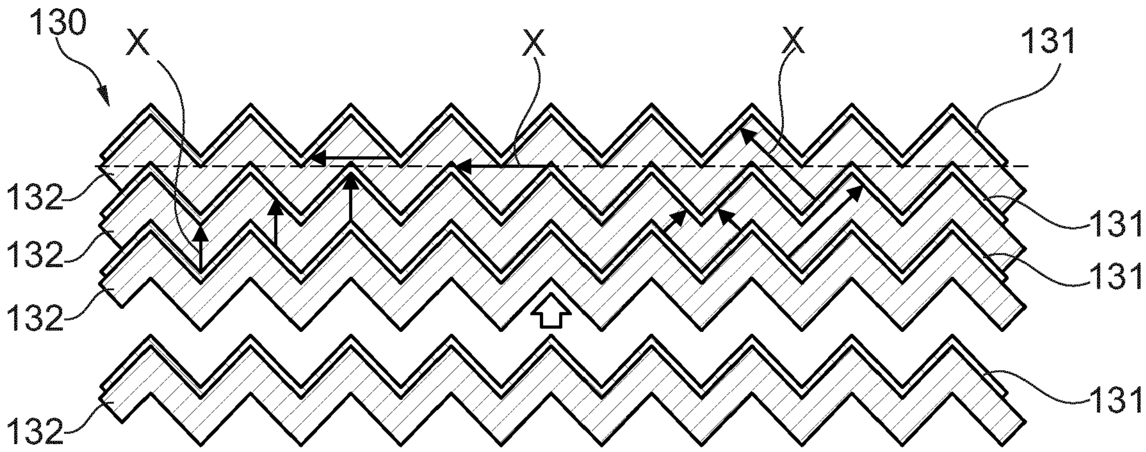


Fig. 3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131

Fig. 4

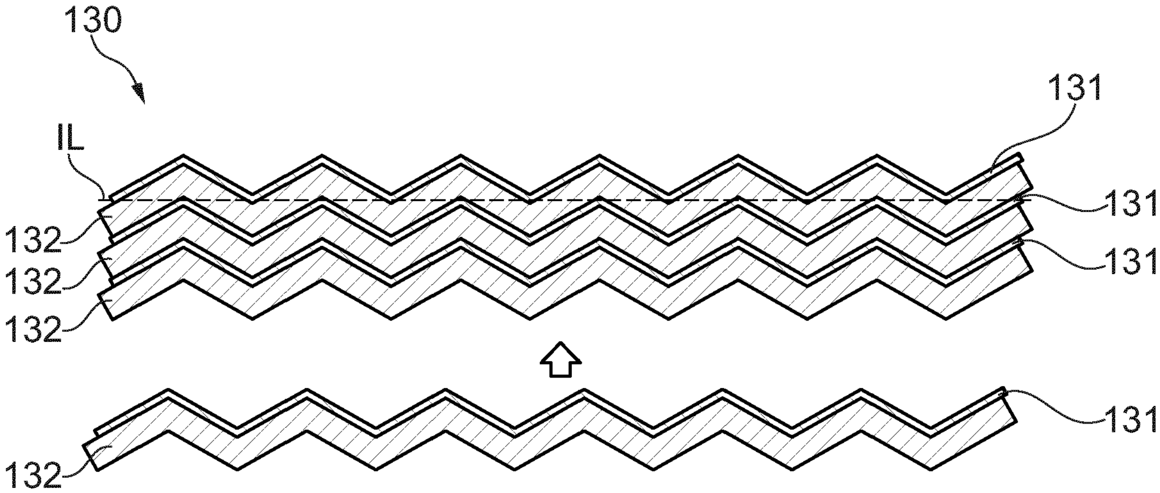
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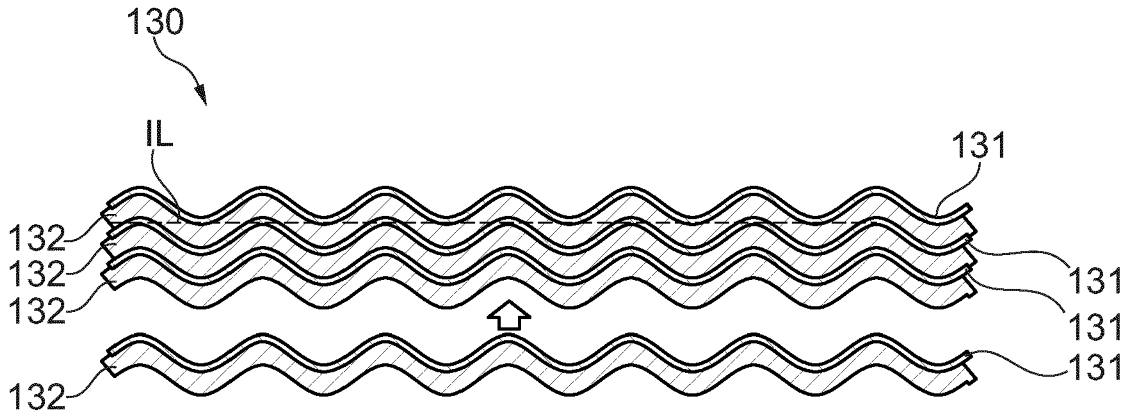
Fig. 5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131

Fig. 6

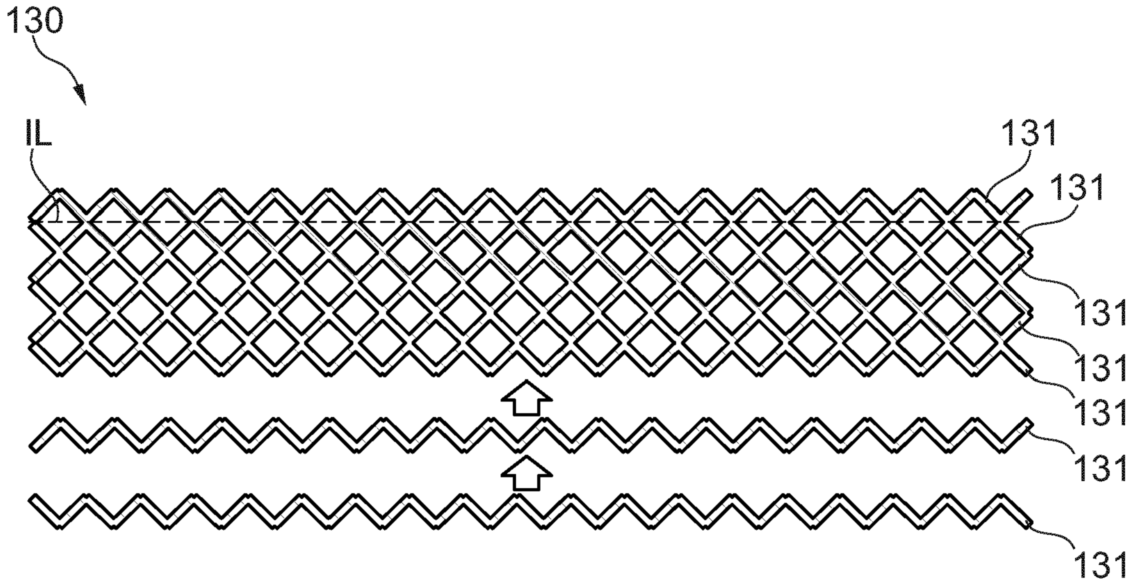
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Fig. 7

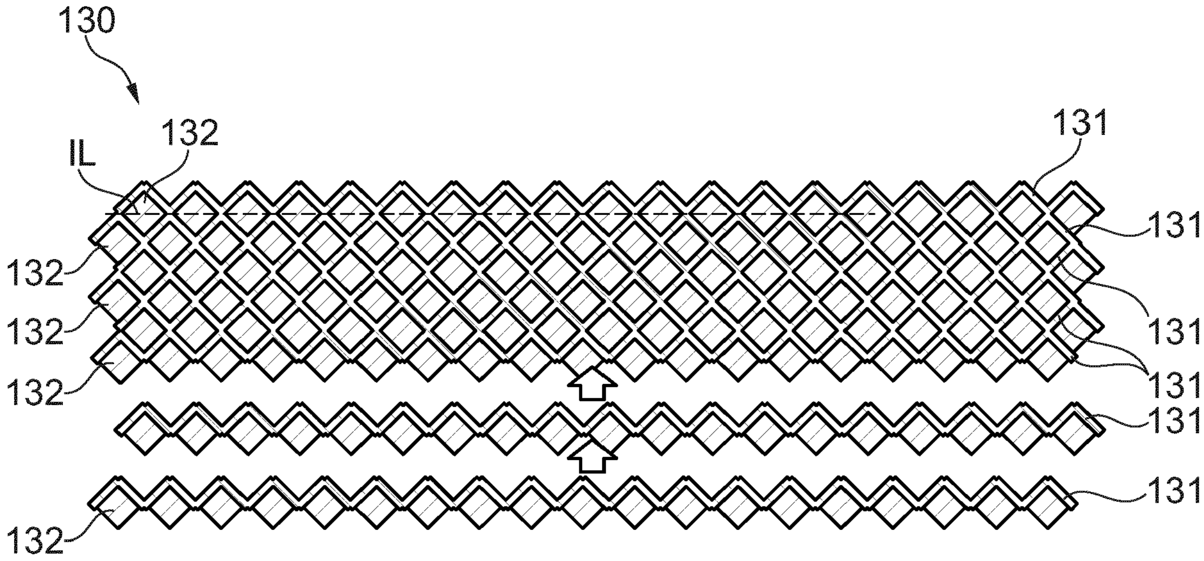
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Fig. 8

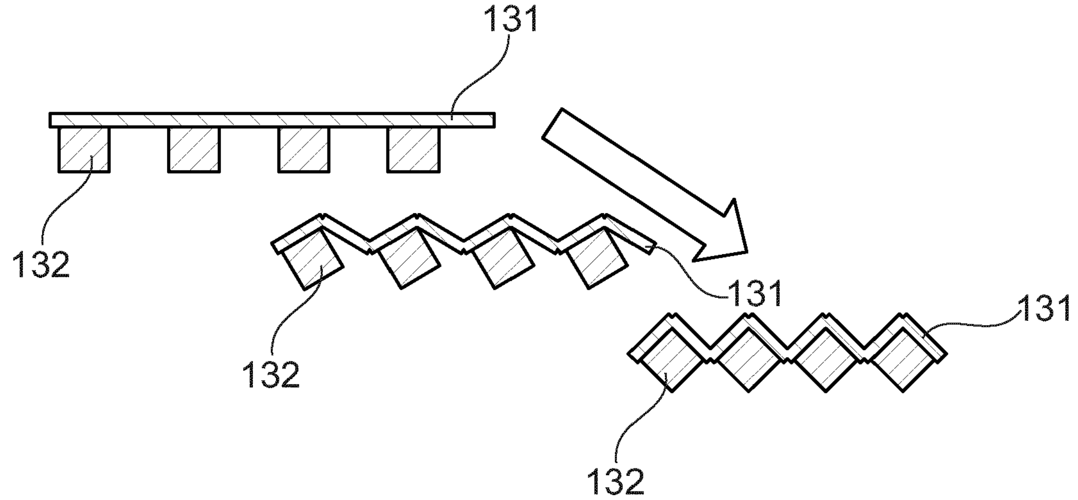
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Fig. 9

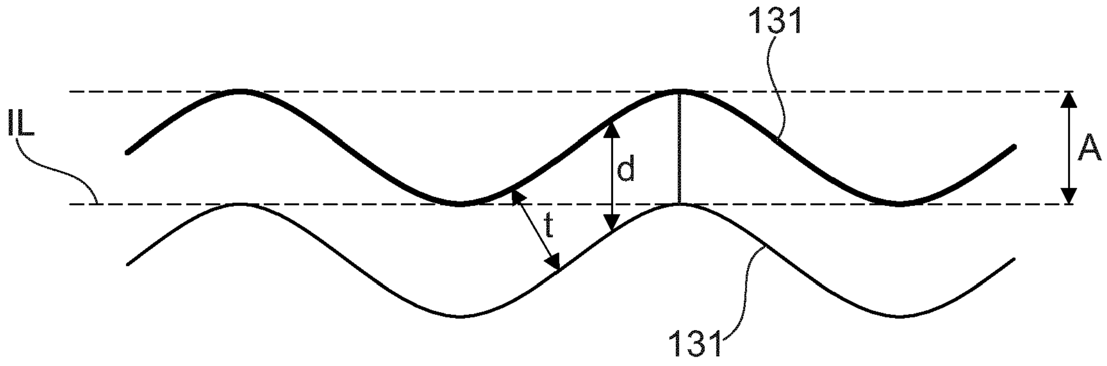


Fig. 10

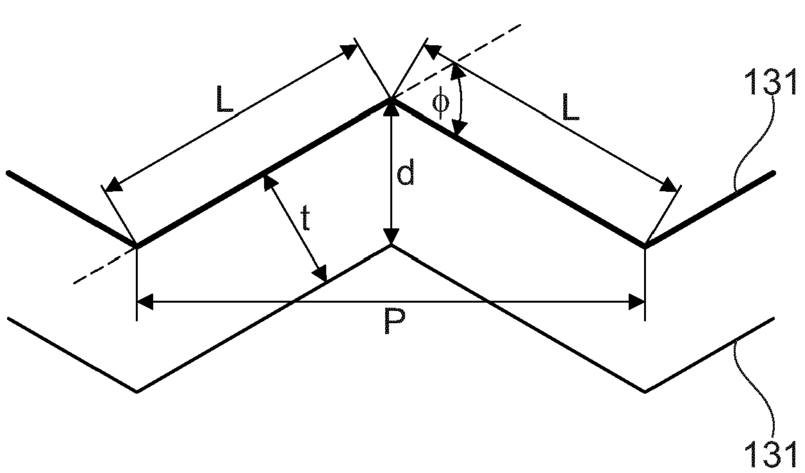


Fig. 11

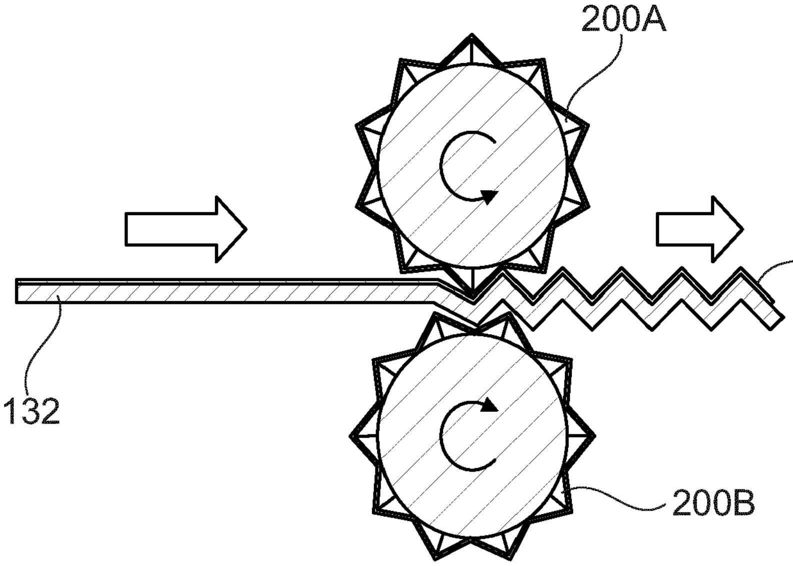


Fig. 12

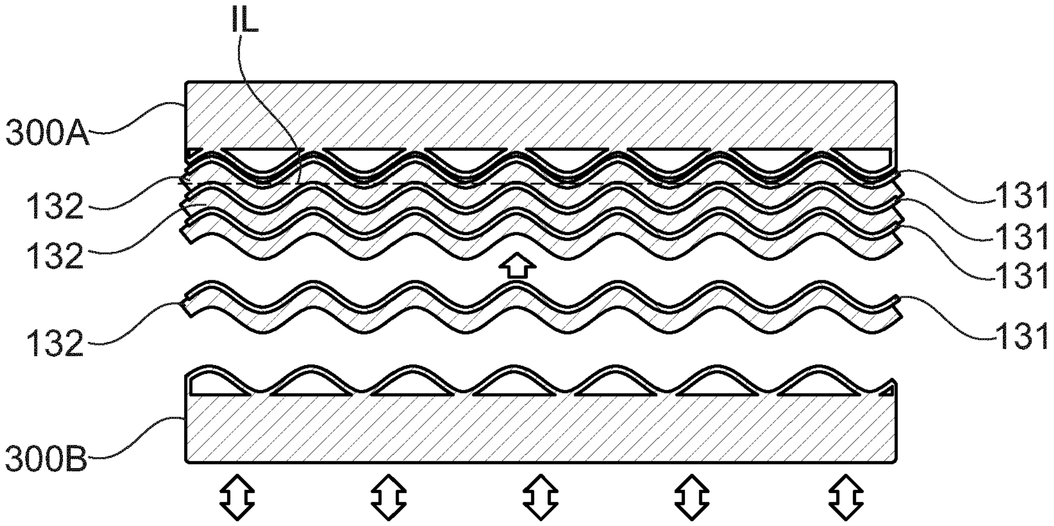
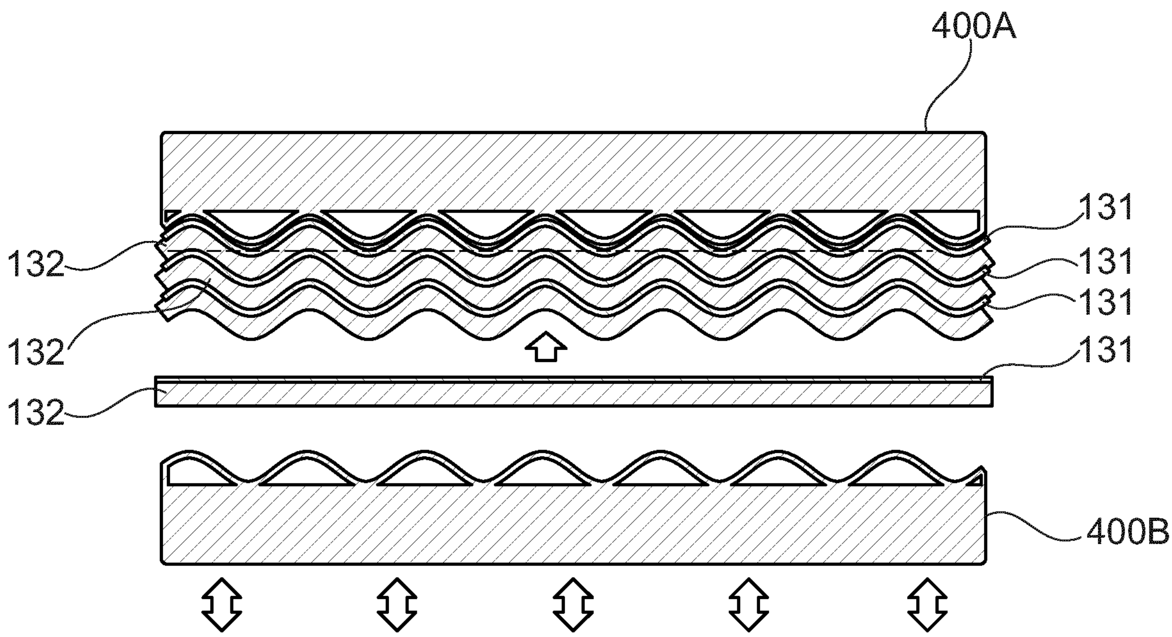


Fig. 13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131
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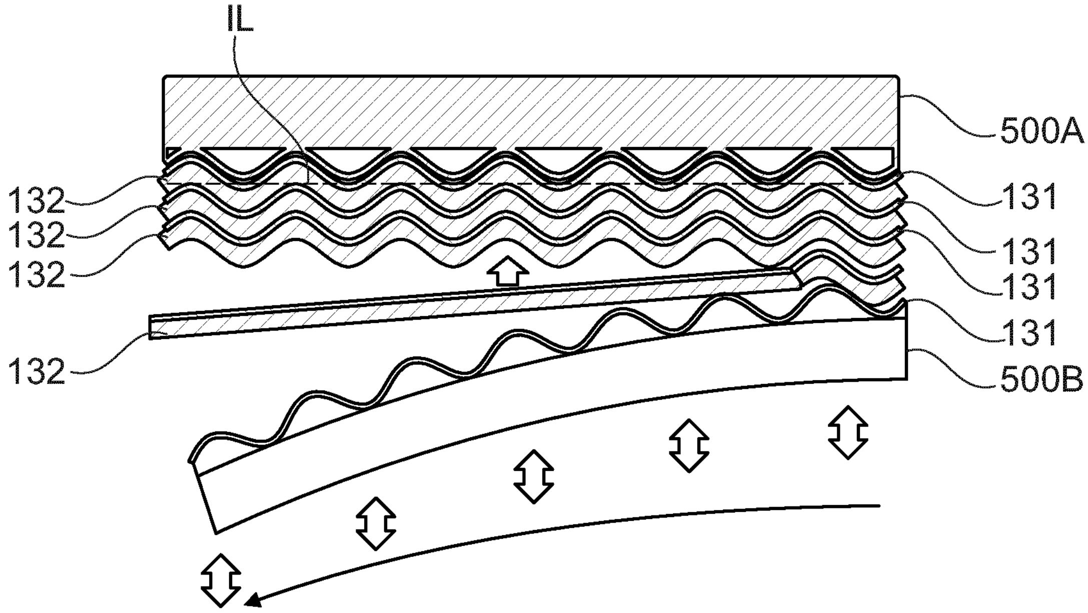
400B

Fig. 14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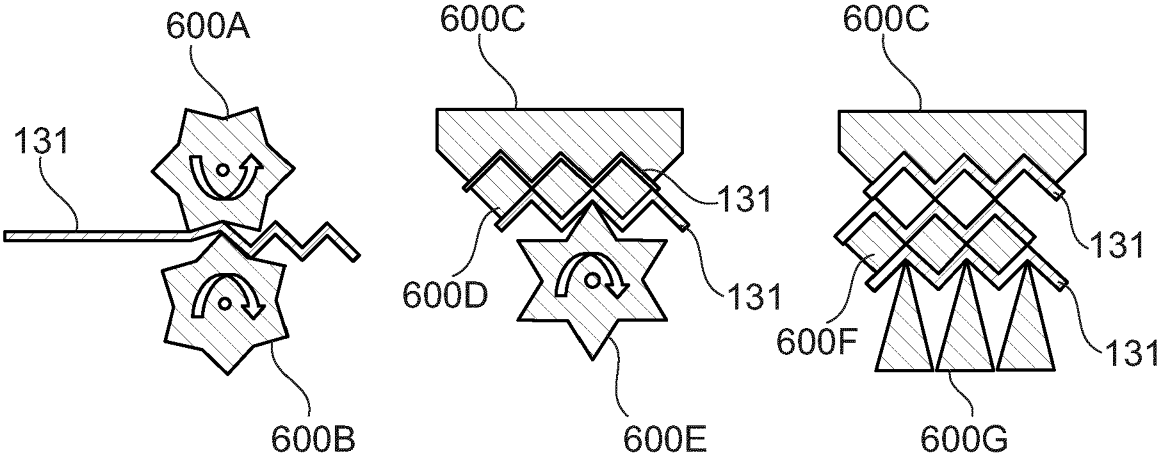
500B

Fig. 15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600B
600C
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600D
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600E
600C
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600F
131
600G

Fig. 16

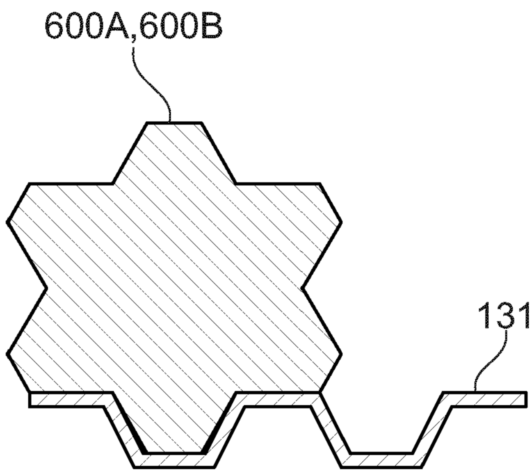
600A,600B
131

Fig. 17

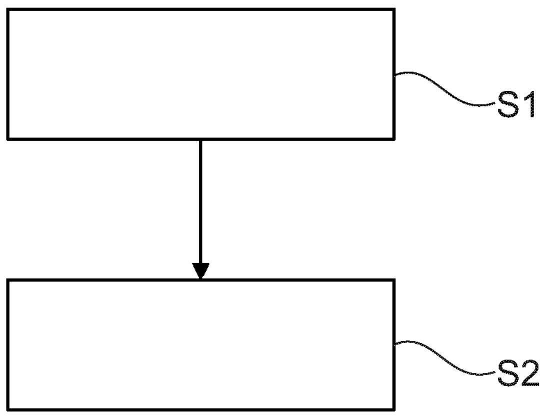

Fig. 18

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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 5856

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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X	US 9 048 002 B2 (BECK THOMAS J [US]; TURTLE BAY PARTNERS LLC [US]) 2 June 2015 (2015-06-02) * figures 8,11-14,15 * * column 1, lines 64-67 * * column 11, line 58 - column 15, line 30 * * column 15, line 47 - column 16, line 3 * -----	1-4,6,9, 11,12,14	
X	US 5 550 678 A (MORBY DEREK J [US]) 27 August 1996 (1996-08-27) * figures 2-6 * * column 1, lines 9-12 * * column 2, line 30 - column 3, line 41 * -----	1,3,5, 7-9, 11-13,15	TECHNICAL FIELDS SEARCHED (IPC)
X	US 4 054 800 A (LEASK JOHN WILSON) 18 October 1977 (1977-10-18) * figures 2-6 * * column 1, line 17 - column 2, line 48 * * column 3, line 23 - column 4, line 44 * -----	1,3,5, 7-13,15	G21K
X	US 2009/001273 A1 (HAWMAN ERIC GRANT [US]) 1 January 2009 (2009-01-01) * figures 1,3,4 * * paragraphs [0031], [0042] - [0050] * -----	1,3,5, 7-9, 11-13,15	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	26 September 2022	Giovanardi, Chiara

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

page 1 of 2

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EUROPEAN SEARCH REPORT

Application Number
EP 22 16 5856

DOCUMENTS CONSIDERED TO BE RELEVANT

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TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	26 September 2022	Giovanardi, Chiara

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CATEGORY OF CITED DOCUMENTS

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

EP 22 16 5856

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26-09-2022

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