⑲ **Octrooicentrum**
Nederland

⑪ **2024075**

⑫ B1 OCTROOI

㉑ Aanvraagnummer: **2024075**

㉒ Aanvraag ingediend: **22 oktober 2019**

(51) Int. Cl.:
G03F 1/62 (2020.01) **G03F 7/20** (2020.01)

㉚ Voorrang:
16 november 2018 EP 18206667.0
11 januari 2019 EP 19151377.9

㊶ Aanvraag ingeschreven:
20 mei 2020

㊸ Aanvraag gepubliceerd:
22 mei 2020

㊼ Octrooi verleend:
19 augustus 2020

㊺ Octrooischrift uitgegeven:
10 september 2020

(73) Octrooihouder(s):
ASML Netherlands B.V. te Veldhoven

(72) Uitvinder(s):
Pieter-Jan van Zwol te Veldhoven
Inci Donmez te Veldhoven
Adrianus Johannes Maria Giesbers
te Veldhoven
Zomer Silvester Houweling te Veldhoven
Alexander Ludwig Klein te Veldhoven
Johan Hendrik Klootwijk te Veldhoven
Evgenia Kurganova te Veldhoven
Arnoud Willem Notenboom te Veldhoven
Fai Tong Si te Veldhoven
Ties Wouter van der Woord te Veldhoven
Markus Gerardus Martinus Maria van Kraaij
te Veldhoven

(74) Gemachtigde:
ir. A.J.M. van Hoef te Veldhoven

(54) A PELLICLE FOR EUV LITHOGRAPHY

(57) A pellicle for EUV lithography comprising: a frame; and a membrane supported by the frame, wherein the membrane comprises: a metallic or semimetallic layer, wherein the membrane comprises pores at a density of at least 5 per μm^2. The membrane may have a substrate layer for supporting the metallic or semimetallic layer, the substrate layer comprising for example silicon obtained from silicon on insulator or polysilicon.

Dit octrooi is verleend ongeacht het bijgevoegde resultaat van het onderzoek naar de stand van de techniek en schriftelijke opinie. Het octrooischrift komt overeen met de oorspronkelijk ingediende stukken.

A PELLICLE FOR EUV LITHOGRAPHY

FIELD

[0001] The present invention relates to a pellicle, a membrane, a patterning device assembly and a dynamic gas lock assembly for EUV lithography.

BACKGROUND

[0002] A lithographic apparatus is a machine that applies a desired pattern onto a substrate, usually onto a target portion of the substrate. A lithographic apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In that instance, a patterning device, which is alternatively referred to as a mask or a reticle, may be used to generate a circuit pattern to be formed on an individual layer of the IC. This pattern can be transferred onto a target portion (e.g., comprising part of, one, or several dies) on a substrate (e.g., a silicon wafer). Transfer of the pattern is typically via imaging onto a layer of radiation-sensitive material (resist) provided on the substrate. In general, a single substrate will contain a network of adjacent target portions that are successively patterned.

[0003] Lithography is widely recognized as one of the key steps in the manufacture of ICs and other devices and/or structures. However, as the dimensions of features made using lithography become smaller, lithography is becoming a more critical factor for enabling miniature IC or other devices and/or structures to be manufactured.

[0004] A theoretical estimate of the limits of pattern printing can be given by the Rayleigh criterion for resolution as shown in equation (1):

$$CD = k_1 * \frac{\lambda}{NA} \qquad (1)$$

where λ is the wavelength of the radiation used, NA is the numerical aperture of the projection system used to print the pattern, k1 is a process-dependent adjustment factor, also called the Rayleigh constant, and CD is the feature size (or critical dimension) of the printed feature. It follows from equation (1) that reduction of the minimum printable size of features can be obtained in three ways: by shortening the exposure wavelength λ, by increasing the numerical aperture NA or by decreasing the value of k1.

[0005] In order to shorten the exposure wavelength and, thus, reduce the minimum printable size, it has been proposed to use an extreme ultraviolet (EUV) radiation source. EUV radiation is electromagnetic radiation having a wavelength within the range of 10-20 nm, for example within the range of 13-14 nm. It has further been proposed that EUV radiation with a wavelength of less than 10 nm could be used, for example within the range of 5-10 nm such as 6.7 nm or 6.8 nm. Such radiation is termed extreme ultraviolet radiation or soft x-ray radiation. Possible sources include, for example, laser-produced plasma sources, discharge plasma sources, or sources based on synchrotron radiation provided by an electron storage ring.

[0006] A lithographic apparatus includes a patterning device (e.g., a mask or a reticle). Radiation is provided through or reflected off the patterning device to form an image on a substrate. A membrane assembly may be provided to protect the patterning device from airborne particles and other forms of contamination. The membrane assembly for protecting the patterning device may be called a pellicle. Contamination on the surface of the patterning device can cause manufacturing defects on the substrate. The membrane assembly may comprise a frame and a membrane stretched across the frame.

[0007] In use the performance of the membrane can degrade over time, particularly at higher temperatures. At higher temperatures the membrane can give off a gas. It is desirable to keep the temperature of the pellicle relatively low. It is also desirable for the pellicle to transmit a high proportion of EUV radiation and to have low flare towards the substrate.

SUMMARY OF THE INVENTION

[0008] According to an aspect of the invention, there is provided a pellicle for EUV lithography comprising: a frame; and a membrane supported by the frame, wherein the membrane comprises: a metallic or semimetallic layer, wherein the membrane comprises pores at a density of at least 5 per μm^2

[0009] According to an aspect of the invention, there is provided a membrane for a pellicle for EUV lithography comprising: a non-gold metallic or semimetallic layer, wherein the membrane comprises pores at a density of at least 5 per μm^2.

[0010] According to an aspect of the invention, there is provided a method of manufacturing a pellicle for EUV lithography comprising: applying a first material on a second material for forming a frame of the pellicle; applying a third material for forming a metallic or semimetallic layer of a membrane of the pellicle on a substrate layer of the membrane; and forming pores in the substrate layer at a density of at least 5 per μm^2.

[0011] According to an aspect of the invention, there is provided a membrane for a pellicle for EUV lithography comprising a grating, the grating comprising a plurality of holes, pores or protrusions. The plurality of holes may e.g. comprise round, square, rounded squares or arbitrary shaped holes. The membrane can e.g. comprise a main film or main layer. The main film or layer thickness in the grating can e.g. range from 20 nm to 100nm. In an embodiment the main film or main layer may also be referred to as the core or membrane core. Preferably the grating pitch is less than 200nm to ensure a good thermal emissivity. The grating pitch may be defined as the distance between the centers of adjacent holes of the grating. In an embodiment the dominant grating pitch is preferably less than 100nm to ensure a low flare at the wafer level. A smaller grating pitch such as 30 nm or less can stop debris particles from falling on the reticle. The membrane for a pellicle for EUV lithography according to any embodiment may comprise a metal layer having a thickness between 4 and 15nm, or a semimetal of a thickness in the range from 20 to 80nm. The metal layer is preferably thicker if the membrane is more open. In an embodiment the membrane grating has substantially square openings (i.e. holes), a pitch from 30 to 200 nm, such as 100nm and a % of open area or an openness defined by the grating openings of from 50 to 90%, such as a 75% openness or open area. An emissive Ru layer of around 8nm thickness has a thermal emissivity >0.35. The material of the pellicle membrane may comprise for example SOI Si membrane core in combination with metal layers. In a further embodiment the membrane grating comprising SOI Si has a substantial circular or square shaped openings covering from 50 to 90% of the membrane area, a grating pitch of less than 100 nm and a metal layer having a thickness in the range from 5 to 15 nm which provides low flare at wafer level and a thermal emissivity > 0.2.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, and in which:

[0013] Figure 1 depicts a lithographic apparatus according to an embodiment of the invention;

[0014] Figure 2 is a more detailed view of the lithographic apparatus;

[0015] Figure 3 schematically depicts, in cross-section, part of a membrane assembly according to an embodiment of the invention;

[0016] Figure 4 is a graph showing the relationship between angle of incident radiation and emissivity for membranes having different fill factors;

[0017] Figure 5 is a graph showing the relationship between angle of incident radiation and emissivity for membranes having different distances between pores;

[0018] Figure 6 is a graph showing the relationship between angle of incident radiation and emissivity for membranes having different metallic layers;

[0019] Figure 7 is a cross-sectional view of a membrane of a pellicle according to an embodiment of the invention;

[0020] Figure 8 is a plan view of a membrane of a pellicle with circular pores according to an embodiment of the invention;

[0021] Figure 9 is a plan view of a membrane of a pellicle with square pores according to an embodiment of the invention;

[0022] Figures 10-13 schematically depict stages of a method of manufacturing a membrane of a pellicle according to an embodiment of the invention;

[0023] Figures 14-16 schematically depict different stages of an alternative method of manufacturing a membrane of a pellicle according to an embodiment of the invention;

[0024] Figures 17-20 schematically depict different stages of forming pores in a membrane of a pellicle according to an embodiment of the invention;

[0025] Figures 21-24 schematically depict different stages of an alternative way of forming pores in a membrane of a pellicle according to an embodiment of the invention;

[0026] Figure 25 is an image of metal islands used for forming pores in a membrane of a pellicle according to an embodiment of the invention;

[0027] Figure 26 is an image of a metallic layer of a membrane of a pellicle according to an embodiment of the invention; and

[0028] Figure 27 is an image of a honeycomb structure used for forming pores in a membrane of a pellicle according to an embodiment of the invention.

DETAILED DESCRIPTION

[0029] Figure 1 schematically depicts a lithographic apparatus 100 including a source collector module SO according to one embodiment of the invention. The apparatus 100 comprises:

- an illumination system (or illuminator) IL configured to condition a radiation beam B (e.g., EUV radiation).
- a support structure (e.g., a mask table) MT constructed to support a patterning device (e.g., a mask or a reticle) MA and connected to a first positioner PM configured to accurately position the patterning device;
- a substrate table (e.g., a wafer table) WT constructed to hold a substrate (e.g., a resist-coated wafer) W and connected to a second positioner PW configured to accurately position the substrate; and
- a projection system (e.g., a reflective projection system) PS configured to project a pattern imparted to the radiation beam B by patterning device MA onto a target portion C (e.g., comprising one or more dies) of the substrate W.

[0030] The illumination system IL may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, for directing, shaping, or controlling radiation.

[0031] The support structure MT holds the patterning device MA in a manner that depends on the orientation of the patterning device, the design of the lithographic apparatus, and other conditions, such as for example whether or not the patterning device is held in a vacuum environment. The support structure MT can use mechanical, vacuum, electrostatic or other clamping techniques to hold the patterning device MA. The support structure MT may be a frame or a table, for example, which may be fixed or movable as required. The support structure MT may ensure that the patterning device MA is at a desired position, for example with respect to the projection system PS.

[0032] The term “patterning device” should be broadly interpreted as referring to any device that can be used to impart a radiation beam B with a pattern in its cross-section such as to create a pattern in a target portion C of the substrate W. The pattern imparted to the radiation beam B may correspond to a particular functional layer in a device being created in the target portion C, such as an integrated circuit.

[0033] The patterning device MA may be transmissive or reflective. Examples of patterning devices include masks, programmable mirror arrays, and programmable liquid-crystal display (LCD) panels. Masks are well known in lithography, and include mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. An example of a programmable mirror array employs a matrix arrangement of small mirrors, each of which can be individually tilted so as to reflect an incoming radiation beam in different directions. The tilted mirrors impart a pattern in a radiation beam, which is reflected by the mirror matrix.

[0034] The projection system PS, like the illumination system IL, may include various types of optical components, such as refractive, reflective, magnetic, electromagnetic, electrostatic or other types of optical components, or any combination thereof, as appropriate for the exposure radiation being used, or for other factors such as the use of a vacuum. It may be desired to use a vacuum for EUV radiation since other gases may absorb too much radiation. A vacuum environment may therefore be provided to the whole beam path with the aid of a vacuum wall and vacuum pumps.

[0035] As here depicted, the lithographic apparatus 100 is of a reflective type (e.g., employing a reflective mask).

[0036] The lithographic apparatus 100 may be of a type having two (dual stage) or more substrate tables WT (and/or two or more support structures MT). In such a "multiple stage" lithographic apparatus the additional substrate tables WT (and/or the additional support structures MT) may be used in parallel, or preparatory steps may be carried out on one or more substrate tables WT (and/or one or more support structures MT) while one or more other substrate tables WT (and/or one or more other support structures MT) are being used for exposure.

[0037] Referring to Figure 1, the illumination system IL receives an extreme ultraviolet radiation beam from the source collector module SO. Methods to produce EUV light include, but are not necessarily limited to, converting a material into a plasma state that has at least one element, e.g., xenon, lithium or tin, with one or more emission lines in the EUV range. In one such method, often termed laser produced plasma ("LPP") the required plasma can be produced by irradiating a fuel, such as a droplet, stream or cluster of material having the required line-emitting element, with a laser beam. The source collector module SO may be part of an EUV radiation system including a laser, not shown in Figure 1, for providing the laser beam exciting the fuel. The resulting plasma emits output radiation, e.g., EUV radiation, which is collected using a radiation collector, disposed in the source collector module. The laser and the source collector module SO may be separate entities, for example when a CO_2 laser is used to provide the laser beam for fuel excitation.

[0038] In such cases, the laser is not considered to form part of the lithographic apparatus 100 and the radiation beam B is passed from the laser to the source collector module SO with the aid of a beam delivery system comprising, for example, suitable directing mirrors and/or a beam expander. In other cases the source may be an integral part of the source collector module SO, for example when the source is a discharge produced plasma EUV generator, often termed as a DPP source.

[0039] The illumination system IL may comprise an adjuster for adjusting the angular intensity distribution of the radiation beam. Generally, at least the outer and/or inner radial extent (commonly referred to as □-outer and □-inner, respectively) of the intensity distribution in a pupil plane of the illumination system IL can be adjusted. In addition, the illumination system IL may comprise various other components, such as facetted field and pupil mirror devices. The illumination system IL may be used to condition the radiation beam B, to have a desired uniformity and intensity distribution in its cross-section.

[0040] The radiation beam B is incident on the patterning device (e.g., mask) MA, which is held on the support structure (e.g., mask table) MT, and is patterned by the patterning device MA. After being reflected from the patterning device (e.g., mask) MA, the radiation beam B passes through the projection system PS, which focuses the radiation beam B onto a target portion C of the substrate W. With the aid of the second positioner PW and position sensor PS2 (e.g., an interferometric device, linear encoder or capacitive sensor), the substrate table WT can be moved accurately, e.g., so as to position different target portions C in the path of the radiation beam B. Similarly, the first positioner PM and another position sensor PS1 can be used to accurately position the patterning device (e.g., mask) MA with respect to the path of the radiation beam B. The patterning device (e.g., mask) MA and the substrate W may be aligned using mask alignment marks M1, M2 and substrate alignment marks P1, P2.

[0041] A controller 500 controls the overall operations of the lithographic apparatus 100 and in particular performs an operation process described further below. Controller 500 can be embodied as a suitably-programmed general purpose computer comprising a central processing unit, volatile and non-volatile storage means, one or more input and output devices such as a keyboard and screen, one or more network connections and one or more interfaces to the various parts of the lithographic apparatus 100. It will be appreciated that a one-to-one relationship between controlling computer and lithographic apparatus 100 is not necessary. In an embodiment of the invention one computer can control multiple lithographic apparatuses 100. In an embodiment of the invention, multiple networked computers can be used to control one lithographic apparatus 100. The controller 500 may also be configured to control one or more associated process devices and substrate handling devices in a lithocell or cluster of which the lithographic apparatus 100 forms a part. The controller 500 can also be configured to be subordinate to a supervisory control system of a lithocell or cluster and/or an overall control system of a fab.

[0042] Figure 2 shows the lithographic apparatus 100 in more detail, including the source collector module SO, the illumination system IL, and the projection system PS. An EUV radiation emitting plasma 210 may be formed by a plasma source. EUV radiation may be produced by a gas or vapor, for example Xe gas, Li vapor or Sn vapor in which the radiation emitting plasma 210 is created to emit radiation in the EUV range of the electromagnetic spectrum. In an embodiment, a plasma of excited tin (Sn) is provided to produce EUV radiation.

[0043] The radiation emitted by the radiation emitting plasma 210 is passed from a source chamber 211 into a collector chamber 212.

[0044] The collector chamber 212 may include a radiation collector CO. Radiation that traverses the radiation collector CO can be focused in a virtual source point IF. The virtual source point IF is commonly referred to as the intermediate focus, and the source collector module SO is arranged such that the virtual source point IF is located at or near an opening 221 in the enclosing structure 220. The virtual source point IF is an image of the radiation emitting plasma 210.

[0045] Subsequently the radiation traverses the illumination system IL, which may include a facetted field mirror device 22 and a facetted pupil mirror device 24 arranged to provide a desired angular distribution of the unpatterned beam 21, at the patterning device MA, as well as a desired uniformity of radiation intensity at the patterning device MA. Upon reflection of the unpatterned beam 21 at the patterning device MA, held by the support structure MT, a patterned beam 26 is formed and the patterned beam 26 is imaged by the projection system PS via reflective elements 28, 30 onto a substrate W held by the substrate table WT.

[0046] More elements than shown may generally be present in the illumination system IL and the projection system PS. Further, there may be more mirrors present than those shown in the Figures, for example there may be 1- 6 additional reflective elements present in the projection system PS than shown in Figure 2.

[0047] Alternatively, the source collector module SO may be part of an LPP radiation system.

[0048] As depicted in Figure 1, in an embodiment the lithographic apparatus 100 comprises an illumination system IL and a projection system PS. The illumination system IL is configured to emit a radiation beam B. The projection system PS is separated from the substrate table WT by an intervening space. The projection system PS is configured to project a pattern imparted to the radiation beam B onto the substrate W. The pattern is for EUV radiation of the radiation beam B.

[0049] The space intervening between the projection system PS and the substrate table WT can be at least partially evacuated. The intervening space may be delimited at the location of the projection system PS by a solid surface from which the employed radiation is directed toward the substrate table WT.

[0050] In an embodiment the lithographic apparatus 100 comprises a dynamic gas lock. The dynamic gas lock comprises a membrane assembly 80. In an embodiment the dynamic gas lock comprises a hollow part covered by a membrane assembly 80 located in the intervening space. The hollow part is situated around the path of the radiation. In an embodiment the lithographic apparatus

100 comprises a gas blower configured to flush the inside of the hollow part with a flow of gas. The radiation travels through the membrane assembly before impinging on the substrate W.

[0051] In an embodiment the lithographic apparatus 100 comprises a membrane assembly 80. As explained above, in an embodiment the membrane assembly 80 is for a dynamic gas lock. In this case the membrane assembly 80 functions as a filter for filtering DUV radiation. Additionally or alternatively, in an embodiment the membrane assembly 80 is pellicle for the patterning device MA for EUV lithography. The membrane assembly 80 of the present invention can be used for a dynamic gas lock or for a pellicle or for another purpose such as a spectral purity filter. In an embodiment the membrane assembly 80 comprises a membrane 40, which may also be called a membrane stack. In an embodiment the membrane is configured to transmit at least 80% of incident EUV radiation.

[0052] In an embodiment the membrane assembly 80 is configured to seal off the patterning device MA to protect the patterning device MA from airborne particles and other forms of contamination. Contamination on the surface of the patterning device MA can cause manufacturing defects on the substrate W. For example, in an embodiment the pellicle is configured to reduce the likelihood that particles might migrate into a stepping field of the patterning device MA in the lithographic apparatus 100.

[0053] If the patterning device MA is left unprotected, the contamination can require the patterning device MA to be cleaned or discarded. Cleaning the patterning device MA interrupts valuable manufacturing time and discarding the patterning device MA is costly. Replacing the patterning device MA also interrupts valuable manufacturing time.

[0054] Figure 3 schematically depicts, in cross-section, part of a membrane assembly 80 according to an embodiment of the invention. The membrane assembly 80 is for EUV lithography. The membrane assembly 80 comprises a membrane 40. The membrane 40 is emissive for EUV radiation. Of course the membrane 40 may not have 100% emissivity for EUV radiation. However, the membrane may have, for example, at least 20% emissivity. As shown in Figure 3, in an embodiment the membrane 40 is substantially planar. In an embodiment the plane of the membrane 40 is substantially parallel to the plane of the patterning device MA.

[0055] The membrane assembly 80 has a shape such as a square, a circle or a rectangle, for example. The shape of the membrane assembly 80 is not particularly limited. The size of the membrane assembly 80 is not particularly limited. For example, in an embodiment the membrane assembly 80 has a diameter in the range of from about 100 mm to about 500 mm, for example about 200 mm.

[0056] As depicted in Figure 3, in an embodiment the membrane assembly 80 comprises a frame 81. The frame 81 is configured to hold the membrane 40. The frame 81 provides mechanical stability to the membrane 40. The frame 81 is configured to reduce the possibility of the membrane 40 being deformed away from its planar shape. In an embodiment, a pre-tension is applied to the membrane 40 during its manufacture. The frame 81 is configured to maintain the tension in the membrane 40 so that the membrane 40 does not have an undulating shape during use of the lithographic apparatus 100. In an embodiment the frame 81 extends along the perimeter of the membrane 40. The outer periphery of the membrane 40 is positioned on top of the frame 81 (according to the view of Figure 3).

[0057] As depicted in Figure 3, in an embodiment the frame 81 comprises a border portion directly connected to the membrane 40. The border portion of the frame 81 is formed by the second material 74 described later in this disclosure. As shown in Figure 3, in an embodiment the frame 81 further comprises an extension portion that makes it easier for the membrane assembly 80 to be fixed relative to the patterning device MA. The border portion and the extension portion of the frame 81 may be adhered to each other.

[0058] As depicted in Figure 3, in an embodiment the membrane assembly 80 comprises a fixture 50. The fixture 50 is arranged to be removably coupled to studs 60 fixed relative to the pattern device MA. Additional details of the assembly are described in WO 2016079051 A2, in particular in Figure 11 and Figures 28 to 31 and the associated description.

[0059] The performance of the membrane 40 can degrade over time. Degradation of the membrane 40 can result in undesirable reticle imprints on the pellicle. The problem of degradation of the membrane 40 can be worse when relatively high power EUV radiation is incident on the membrane 40. At high temperatures the membrane 40 can undesirably give off a gas (i.e. outgas). For example, the membrane 40 may give off gasses comprising oxides. Outgassing of oxides can be accelerated by photoinduced etching. It is desirable to keep the temperature of the pellicle low so as to reduce the possibility of outgassing.

[0060] As explained above, in an embodiment the pellicle comprises a frame 81 and a membrane 40. The membrane 40 is supported by the frame 81. The membrane 40 comprises a metallic or semimetallic layer 72.

[0061] Figure 7 shows a cross-section of a membrane 40 according to an embodiment of the invention. As shown in Figure 7, in an embodiment the membrane 40 comprises a substrate layer 71. The substrate layer 71 is for supporting the metallic or semimetallic layer 72. As shown in Figure 7, in an embodiment the substrate layer 71 is thicker than the metallic or semimetallic layer 72. The substrate layer 71 is configured to provide structural stability to the membrane 40.

[0062] In an embodiment, the membrane 40 comprises an interlayer between the substrate layer 71 and the metallic or semimetallic layer 72. The interlayer is configured to reduce the possibility of the metallic or semimetallic layer 72 rupturing. Such rupturing is a greater possibility at higher temperatures. In an embodiment, the interlayer comprises Mo. In an embodiment, the interlayer has a thickness in the range of from about 1nm to about 2nm. In an embodiment, the interlayer is formed of a different material from the metallic or semimetallic layer 72. In an embodiment, the interlayer is thinner than the metallic or semimetallic layer 72.

[0063] In an embodiment, the substrate layer 71 comprises single crystalline Si as obtained from the release from a silicon on insulator (SOI) wafer. In an alternative embodiment the substrate layer 71 comprises a polysilicon (a polycrystalline silicon) .

[0064] However, it is not necessary for the membrane 40 to comprise such a substrate layer 71. For example, in an alternative embodiment the metallic or semimetallic layer 72 provides its own structural stability. For example, in an embodiment the same metallic layer 72 forms at least 90% of the total thickness of the membrane 40.

[0065] Figure 8 shows a plan view of a membrane 40 according to an embodiment of the invention. As shown in Figure 8, in an embodiment the membrane 40 comprises pores 73. The pores 73 extend through the thickness of the membrane 40. The membrane 40 is not continuous. By providing that the membrane 40 comprises pores 73, the membrane 40 can transmit a higher proportion of the EUV radiation that is incident on it. This reduces the amount of EUV radiation that can undesirably heat up the membrane 40.

[0066] Although Figure 8 shows a regular distribution of pores 73 across the membrane 40, the arrangement of pores 73 is not particularly limited. The pores 73 can be regularly, semi-regularly or randomly distributed across the membrane 40.

[0067] It is desirable for the pores 73 to be positioned relatively closely together. In an embodiment, the pores are at a density of at least 5 per μm^2. The distance between the centers of adjacent pores 73 is known as the pitch p. The pitch p is shown in Figure 8. In general, a greater density of pores 73 corresponds to a smaller pitch p. For pores 73 that are not regularly distributed, there may in effect be different pitches at different positions in the membrane 40. However, a dominant pitch can be determined by considering the average distance between pores 73 over an area of membrane 40 having a size of at least1 μm^2. A density of 5 pores 73 per μm^2 corresponds to a pitch p of approximately 450 nm.

[0068] By providing that the density of pores 73 is of at least 5 per μm^2, the dominant pitch p of the pores 73 is less than 1 μm. The pitch p is smaller than the wavelength of radiation (i.e. infrared radiation) that is emitted by the membrane 40. The inventors have found that this helps to increase the emissivity E of the membrane 40.

[0069] By providing that the density of pores 73 is of at least 5 per μm^2, the emissivity E of the membrane 40 can remain relatively high. In general, the pores 73 cause the emissivity E of the membrane 40 to reduce relative to a continuous membrane 40 (i.e. a membrane that has no pores). A higher density of pores 73 (corresponding to a smaller pitch p) is preferred for higher emissivity E.

[0070] Figure 5 is a graph showing the relationship between angle θ of incident radiation and the emissivity E of the membrane 40. The angle θ is the angle of EUV radiation relative to the normal to plane of the membrane 40. Line 91 is for a membrane 40 that has a lateral pitch of 200 nm (corresponding to a density of that 25 pores per μm^2). Line 92 is for a membrane 40 having the same characteristics except for having a lateral pitch p of 2000 nm (corresponding to a density of about 0.25

pores per µm^2). Line 93 is for a membrane 40 with similar characteristics except for having a lateral pitch p of 20000 nm (corresponding to a pore density of about 0.0025 pores per µm^2). The other main characteristics of the membrane 40 are that 75% of its area is formed by the pores 73, and that the metallic layer 72 is formed of Ru with a thickness of 4 nm.

[0071] As shown in Figure 5, the emissivity E of the membrane 40 increases for decreasing lateral pitch p. A higher emissivity E is desirable so that membrane 40 radiates more of the energy that it absorbs, so as to keep the temperature of the membrane 40 down. An embodiment of the invention is expected to achieve a reduced temperature of the membrane 40 during use.

[0072] In an embodiment, the density of pores 73 is at least 20 per µm^2. This corresponds to a lateral pitch of approximately 220 nm. As shown in Figure 5, this increases the emissivity E of the membrane 40. In turn this helps to keep the membrane 40 cooler during use.

[0073] In an embodiment, the density of pores is at least 100 per µm^2. This corresponds to a lateral pitch p of about 100 nm. By providing that the density of pores is at least 100 per µm^2 (i.e. a lateral pitch p of at most 100 nm), the flare from the membrane 40 to the substrate W can be reduced. The flare relates to the proportion of energy of EUV incident of the membrane 40 that is scattered onto the substrate W. In an embodiment, the membrane 40 is configured such the flare to the substrate W is at most 0.25%. This helps to provide good quality imaging. If the flare is too high, then this can undesirably affect the imaging at the level of the substrate W.

[0074] The inventors have found that the membrane 40 with pores 73 acts as a diffraction grating. When the lateral pitch p is at most 150 nm, there is substantially zero flare for normal incidence illumination. The inventors have found that in practice a lower maximum lateral pitch p of about 100 nm provides substantially zero flare to the substrate W at any illumination mode.

[0075] The table below shows examples of flare values for membranes 40 having different lateral pitch p and different metallic and semimetallic layers 72. The material and thickness of the metallic or semi metallic layer 72 is shown in the top of the each column of the table. The values in the table are the percentage of flare towards to substrate W.

[0076]

Pitch / nm	8nm Ru	4nm Ru	4nm Zr	8nm Zr	8nm Zr and 8nm SiO^2
100	0	0	0	0	0
150	0	0	0	0	0
160	00.53	0.15	0.032	0.09	0.23
180	1.1	0.31	0.063	0.18	0.47
300			0.065	0.19	
400			0.12	0.35	
600			0.16	0.46	

[0077] As shown in the table, the flare tends to be higher for an Ru metallic layer than for a Zr metallic layer. This is because Ru is optically stronger than Zr. The other characteristics of the membrane 40 on which the calculations in the table are based are that it has a substrate layer 71 of 50 nm thickness of silicon and a 75 % open area (i.e. 75% of the area of the membrane 40 is formed by the pores 73).

[0078] In an embodiment, the metallic layer 72 has a thickness of at least 4 nm. this helps to increase the emissivity E of the membrane 40. Figure 6 is graph showing the relationship between the angle θ of incident radiation and the emissivity E of the membrane 40. There are three lines corresponding to different types of membrane 40. For all of the membranes 40, the pores 73 have a lateral pitch p of about 200 nm. The pores 73 form about 75% of the area of the membrane 40. Line 61 is for a membrane 40 that has a metallic layer 72 formed of Ru at a thickness of 8 nm. Line 62 is for a membrane 40 with a metallic layer 72 formed of Ru at a thickness of 4 nm. Line 63 is for a membrane 40 with a metallic layer 72 formed of Zr in a thickness of 8 nm.

[0079] As shown in Figure 6, in general a thicker metallic or semi metallic layer 72 increases the emissivity E of the membrane 40. By providing that the metallic layer 72 has a thickness of at least 4 nm, the emissivity E can be kept relatively high even with the pores 73 forming a relatively high percentage of the overall area of the membrane 40.

[0080] In an embodiment, the metallic layer 72 has a thickness of at least 8 nm. As shown in Figure 6, this further increases the emissivity E of the membrane 40. Of course, there is a trade-off that a thicker metallic layer 72 can result in greater absorption of the incident radiation. It is desirable to provide a good balance between the proportion of EUV radiation that is transmitted by the membrane 40 and the emissivity of the membrane 40.

[0081] For example in an embodiment the pellicle satisfies $\frac{\mathrm{E}}{1-T} \geq 4$, where E is the emissivity for incident EUV radiation and T is the proportion of incident EUV radiation transmitted through the membrane 40. For example, in an embodiment the emissivity E may be about 0.2 and the EUV transmission T may be about 95%. This would provide a ratio of E:(1-T) of 4. In an embodiment, this ratio is at least 5, at least 6, at least 7, at least 8, at least 9 or at least 10.

[0082] As mentioned above, instead of a metallic layer, there may be a semimetallic layer 72. When a semi metallic layer is provided rather than a metallic layer, it is desirable for the thickness of the semi metallic layer 72 to be greater. For example, in an embodiment the semi metallic layer has a thickness of at least 10 nm.

[0083] As further explained above, when a semimetallic layer 72 is provided it may not be necessary to provide a separate substrate layer 71. However, when no additional substrate layer 71 is provided, it is desirable for the semi metallic layer 72 to be thicker. For example, in an embodiment the semi metallic layer 72 has a thickness of at least 20 nm.

[0084] In an embodiment, the pores 73 form at least 50% of the total area of the membrane 40. Figure 4 is a graph showing the relationship between angle θ of incident radiation and emissivity E of the membrane 40. The different lines 41 to 45 are for different membranes 40 which are similar except for having different levels of openness. Line 41 is for continuous membrane with no pores. Line 42 is for a porous membrane 42 that is 9% open (i.e. the pores 73 form 9% of the total area of the membrane 40). Line 43 is for a membrane 40 that is 36% open. Line 44 is for a membrane 40 that is 64% open. Line 45 is for a membrane 40 that is 81% open.

[0085] As shown in Figure 4, increasing levels of openness of the membrane 40 decrease the emissivity E. However, increasing levels of openness increase the EUV transmission T of the membrane 40. An embodiment of the invention is expected to increase the proportion of EUV radiation transmitted by the membrane 40.

[0086] In an embodiment the pores form at least 75% of the total area of the membrane 40. This may reduce the proportion of EUV radiation that is not transmitted by the membrane 40 by a factor of about 5. As a result, even though the emissivity E is reduced by a factor of about 2, there is still a significant overall benefit. The amount of energy that heats up the membrane 40 is overall reduced.

[0087] As shown in Figure 8, in an embodiment the pores 73 are circular. The pores 73 have a diameter d. the diameter d can be selected so as to provide the desired fill factor of the membrane 40.

[0088] However, it is not necessary for the pores 73 to be circular. Figure 9 shows an alternative embodiment in which the pores 73 are square. The pores 73 have a dimension d. The dimension d can be selected so as to provide the desired fill factor for the membrane 40.

[0089] The shape of the pores 73 is not particularly limited. In an embodiment, the pores 73 do not have nay regular shape.

[0090] An embodiment of the invention is expected to reduce the amount of EUV radiation absorbed in the membrane 40. A greater proportion of incident EUV radiation is transmitted by the membrane 40. However, not all of the extra transmitted EUV radiation is transmitted to the substrate W. In particular the pores 73 diffract the radiation such that the transmitted EUV radiation reaches other areas outside of the substrate W. This means that the imaging at the level of the substrate W can remain of high quality.

[0091] In an embodiment, the membrane 40 is configured to have at least 80% specular EUV transmission. In an embodiment, the membrane 40 is configured to have at most 0.25% non-specular EUV transmission that reaches the substrate W (e.g. with an angle of less than 4.7 degrees relative to the normal to the plane of the membrane 40). In an embodiment, the membrane 40 is configured to have at most 10% EUV absorption in the membrane 40. In an embodiment the membrane 40 is configured to have at most 10% non-specular EUV transmission that does not go into the projection optics or to the substrate W. Specular EUV transmission, non-specular EUV transmission and absorption add up to 100%.

[0092] The metal of the metallic layer 72 is not particularly limited. Some metals can oxide in use. In an embodiment an oxidation protection layer is provided. For example, an oxidation protection layer formed of boron can be provided. The oxidation protection layer is of reducing oxidation of the metallic layer 72. The oxidation protection layer can be coated on the metallic layer 72.

[0093] In an embodiment, the metal of the metallic layer 72 is not gold. In an embodiment the metal is a transition metal. In an embodiment, the metal is transition metal of groups 3 to 10. In an embodiment, the metal is a transition metal of periods 4 to 5.

[0094] In an embodiment the metal is a transition metal. The particular transition metal is not particularly limited but may be Zr, Y, Mo, Cr, Hf, Ir, Mn, Nb, Os, Pd, Pt, Re, Rh, Ru, Ta, Ti, V or W, for example.

[0095] In an embodiment the membrane assembly 80 is applied as a pellicle or as part of a dynamic gas lock. Alternatively, the membrane assembly 80 can be applied in other filtration areas such as identification, or for beam splitters. In an embodiment the dynamic gas lock is configured to block debris within the lithographic apparatus 100. In an embodiment the dynamic gas lock is positioned between the projection system PS and the substrate W. The dynamic gas lock reduces the possibility of particles from the substrate W or from near the substrate W reaching optical components in or around the projection system PS. Similarly, the dynamic gas lock can protect the illumination system IL. In an alternative embodiment the dynamic gas lock is positioned at the virtual source point IF. For example, the dynamic gas lock may be positioned between the source collector module SO and the illumination system IL.

[0096] According to an embodiment, there is provided a method of manufacturing a pellicle for EUV lithography. Figures 10 to 13 schematically depict different stages of a method of manufacturing a pellicle according to an embodiment of the invention.

[0097] As shown in Figure 10, in an embodiment the method comprises applying a first material on a second material 74. The second material 74 is for forming part of the frame 81 of the membrane assembly 80. The invention will be described for an embodiment in which the first material is for forming the substrate layer 71. However, as will be described in more detail later, the first material may alternatively form a sacrificial layer on which the substrate layer 71 is formed.

[0098] As shown in Figure 10, in an embodiment the first material that forms the substrate layer 71 is applied to all sides (in cross-section) of the second material 74. The method of depositing the first material onto the second material 74 is not particularly limited.

[0099] As shown in Figure 11, in an embodiment the method comprises patterning the first material at the backside of the second material 74. The backside is the opposite side from the side that forms the membrane 40 of the membrane assembly 80. The first material is patterned so as to form a mask for later etching the second material 74.

[00100] As shown in Figure 11, in an embodiment the method comprises applying a third material to form a metallic or semi-metallic layer 72 of the membrane 40 on the substrate layer 71. The third material is a metal or a semi-metal, e.g. Ru or Zr as mentioned above. The method of applying the third material on the substrate layer 71 is not particularly limited. In an embodiment the third material is deposited via physical vapor deposition.

[00101] As shown in Figure 12, in an embodiment the method comprises forming pores 73 in the substrate layer 71. The pores 73 may be formed at a density of at least 5 μm^2. As shown in Figure 12, in an embodiment the pores 73 are opened on the combined stack of the metallic or semi-metallic layer 72 and the substrate layer 71. As shown in the progression from Figure 11 to Figure 12, in an embodiment the third material (which forms the metallic or semi-metallic layer 72) is applied on the substrate layer 71 before the pores 73 are formed. This allows the pores 73 to be formed in both the metallic or semi-metallic layer 72 and the substrate layer 71 in substantially the same process step. This helps to provide a good uniformity of the shape of the pores 73 in the metallic or semi-metallic layer 72 and the substrate layer 71. There are various methods for forming the pores 73 in the substrate layer 71, as will be described in more detail below.

[00102] In an embodiment the method comprises applying a sacrificial layer 75 on the stack of the metallic or semi-metallic layer 72 and the substrate layer 71. In an embodiment the method comprises applying a mechanical support layer 76 on the sacrificial layer 75 and on the sides of the membrane assembly 80. In a subsequent step the method comprises etching the second material 74 so as to expose the backside of the membrane 40 (the membrane 40 being formed by the metallic or semi-metallic layer 72 on the substrate layer 71).

[00103] The method of etching the second material 74 so as to expose the membrane 40 is not particularly limited. In an embodiment, the second material 74 is etched by performing wet anisotropic etching. The mechanical support layer 76 is for providing mechanical support to the membrane assembly 80 during the step of etching the second material 74. This reduces the possibility of the membrane 40 being damaged (e.g. rupturing) during the etching step. The mechanical support layer 76 is configured to protect the top side of the stack from the etching agent that removes the second material 74.

[00104] In an embodiment the second material comprises silicon. As described above, in an embodiment the second material can be etched away by performing wet etching. As an alternative, the second material can be etched away using a dry etching process.

[00105] As shown in Figure 13, in an embodiment the method comprises removing the mechanical support layer 76. The method for removing the mechanical support layer 76 is not particularly limited. As shown in Figure 13, in an embodiment the method comprises removing the sacrificial layer 75. The sacrificial layer 75 is for protecting the topside of the membrane 40 when the mechanical support layer 76 is being removed. For example, the sacrificial layer 75 may protect the topside of the membrane 40 from any agent that is used for removing mechanical support layer 76. The method for removing the sacrificial layer 75 is not particularly limited.

[00106] The sacrificial layer 75 acts as a protection layer to prevent oxidation of the substrate layer 71 and/or the metallic or semi-metallic layer 72. The process of removing the sacrificial layer 75 can be performed without damaging or oxidizing the substrate layer 71 or the metallic or semi-metallic layer 72.

[00107] As shown in Figure 13, by removing the mechanical support layer 76 and the sacrificial layer 75, the membrane 40 formed by the metallic or semi-metallic layer 72 on the substrate layer 71 is formed. The membrane 40 stretches across the border portion of the frame 81 formed by the second material.

[00108] Modifications of the process described above with reference to Figures 10 to 13 will now be described.

[00109] In an embodiment the first material that forms the substrate layer 71 is a low stress nitride such as a silicone nitride. Low stress nitride is resistant to the wet etching. This means that the substrate layer 71 does not require an additional sacrificial layer to protect it during the wet etching step (i.e. when the bulk of the second material 74 is etched away). The low stress nitride is also suitable for forming the hard etch mask on the backside of the assembly, as shown in Figure 11.

[00110] However, in an embodiment the substrate layer 71 comprises a polysilicon. When the substrate layer 71 is to be formed by polysilicon, then the first material does not form the substrate layer. Instead, the first material acts as a sacrificial layer to protect the polysilicon substrate layer when the second material 74 is etched. Hence, the method may comprise the step of applying polysilicon (or other material that is to form the substrate layer of the membrane 40) on the first material before the step of etching the second material 74. When the first material is used as a sacrificial layer to protect the substrate layer, the first material may comprise SiO_2.

[00111] In the process described above, the third material is applied on the substrate layer 71 before the pores 73 are formed. However, this is not necessarily the case. Figures 14 to 16 show different stages of an alternative method in which the third material is applied on the substrate layer 71 after the pores 73 are formed.

[00112] In this alternative embodiment, the first material is applied on the second material 74 as shown in Figure 10. However, as shown in Figure 14, the backside of the first material is patterned to form a hard mask without depositing the metallic or semi-metallic layer 72 on the topside.

[00113] As shown in Figure 15, the pores 73 are formed in the substrate layer 71. This step is performed before the metallic or semi-metallic layer 72 is provided. Accordingly, the pores 73 are not simultaneously formed in the metallic or semi-metallic layer 72.

[00114] The sacrificial layer 75 and the mechanical support layer 76 are then applied around the substrate layer 71. This allows the second material to be etched away.

[00115] As shown in Figure 16, the mechanical support layer 76 and the sacrificial layer 75 can then be removed, in the same manner as described above. As shown in Figure 16, this leaves the substrate layer 71 extending across the border portion of the frame 81 formed by the second material 74.

[00116] The third material can then be applied to form the metallic or semi-metallic layer 72 of the membrane 40 on the substrate layer 71. This results in the assembly shown in Figure 13.

[00117] Various methods for forming the pores 73 are described below.

[00118] Figures 17 to 20 schematically depict different stages of a process for forming the pores 73. In particular, Figures 17 to 20 depict stages of a process of nanoimprint lithography.

[00119] As shown in Figure 17, in an embodiment the process of forming the pores 73 comprises pressing a mold 77 onto a mask material 79 covering the substrate layer 71. The mold 77 is a substantially flat plate comprising dimples 78. The dimples 78 are arranged in a pattern that corresponds to the desired pore positions (i.e. the positions where the pores 73 are intended to be in the membrane 40). In an embodiment the mold 77 is flexible. In an embodiment, the mold 77 is made of a material that is substantially transparent to UV radiation. This allows the mask material79 to be irradiated with UV radiation when the mold 77 is being applied to the mask material 79.

[00120] The type of mask material is not particularly limited. In an embodiment the mask material is a photoresist. Alternatively, the mask material may be a sol-gel.

[00121] As shown in Figure 18, by pressing the mold 77 onto the mask material 79, a pattern of imprints is formed in the mask material 79 corresponding to the pore positions. The application of the mold 77 results in the mask material 79 having contrasting thicknesses. In particular, the mask material 79 has pillars 82 and depressions 83. The mold 77 is pressed into the mask material 79 and then cured through UV-radiation to harden/cure the mask material 79. The mold 77 is then removed to expose the now cured (solid) and patterned layer.

[00122] As shown in Figure 19, in an embodiment the process of forming the pores 73 comprises etching the mask material 79 to form gaps corresponding to the pore positions. In an embodiment, reactive-ion etching is used to etch the mask material 79. The reactive-ion etching process is substantially homogenous. The etching process results in the depressions 83 being etched away so as to expose the underlying substrate layer 71 at gaps corresponding to the pore positions. The pillars 82 are also etched away but continue to cover the substrate layer 71, thereby acting as a mask.

[00123] As shown in Figure 20, in an embodiment the process of forming the pores 73 comprises etching the substrate layer 71 through the gaps to form the pores 73. The pillars 82 of the mask material 79 protect some areas of the substrate layer 71 from being etched away. Where the substrate layer 71 is exposed, it is etched away so as to form the pores 73. The pores 73 are formed at positions corresponding to the dimples 78 of the mold 77. The mold 77 can be designed so as to provide a desired pattern of pores 73 in the substrate layer 71 of the membrane 40.

[00124] The process of nanoimprint lithography makes it possible to finely tune the periodicity of the pores 73 and the fill factor of the pellicle. This can be done by appropriately designing the mold 77. The mold 77 can be reused. This helps to keep down the costs of manufacture.

[00125] Figures 21 to 24 schematically depict different stages of an alternative process for forming the pores 73. As shown in Figure 21, in an embodiment the process of forming the pores 73 comprises depositing spheres 84 on the substrate layer 71. The spheres 84 are deposited in a pattern corresponding to the desired pore positions. In particular, the centre of each sphere 84 is positioned at a location corresponding to the centre of a pore 73. The process shown in Figures 21 to 24 may be called nanosphere lithography. The nanosphere lithography technique is an alternative to nanoimprint lithography. The nanosphere lithography technique shown in Figures 21 to 24 can replace the steps shown in Figure 12 and Figure 15 above.

[00126] The material of the spheres 84 is not particularly limited. In an embodiment these spheres are made of polystyrene. In an embodiment the spheres 84 are arranged in an hexagonal close packed layer. In an embodiment, the layer of spheres 84 is a monolayer.

[00127] As shown in the transition from Figure 21 to Figure 22, in an embodiment the process comprises reducing the size of the spheres 84. For example, the size of the spheres 84 may be reduced by etching the spheres 84. For example, plasma etching may be used. The step of reducing the size of the spheres is optional. For example, if the spheres 84 applied to the substrate layer 71 are already of the appropriate size, then it may not be necessary to reduce their size.

[00128] As shown in Figure 22, in an embodiment the process of forming the pores 73 comprises applying the third material on the spheres 84 and the substrate layer 71. The third material is for forming the metallic or semi-metallic layer 72 of the membrane 40. As shown in Figure 22, the third material covers the tops of the spheres 84 and covers the sections of the substrate layer 71 between the spheres 84. The pattern of the pores 73 formed in the membrane 40 can be controlled by controlling the size and arrangement of the spheres 84 on the substrate layer 71.

[00129] As shown in Figure 23, in an embodiment the process of forming the pores 73 comprises removing the spheres 84. This forms exposed sections of the substrate layer 71 corresponding to the pore positions. This results in the third material forming a mask protecting appropriate portions of the substrate layer 71. The third material acts as a mask in addition to forming the metallic or semi-metallic layer 72.

[00130] As shown in Figure 24, in an embodiment the process of forming the pores 73 comprises etching the exposed sections of the substrate layer 71 to form the pores 73. Merely as an example, a process of plasma etching may be used to etch away the appropriate sections of the substrate layer 71.

[00131] The dimensions for the spheres 84 can be selected so as provide pores 73 of the appropriate dimensions and arrangement. In general, the size of the sphere 84 corresponds to the size of the pore 73. In an embodiment, the size of the spheres 84 is at least 100 nm and at most 10 µm.

[00132] Figure 25 is an image of a layer of metal used in an alternative process for forming the pores 73. In this alternative process for forming the pores 73 a metal is applied on the substrate layer 71. For example, the metal may be silver or gold. Other metals suitable for use in a metal-assisted chemical etching process can be used. In an embodiment, the metal is initially applied as a substantially uniform layer (i.e. having uniform thickness) across the substrate layer 71.

[00133] In an embodiment, the process of forming the pores 73 comprises annealing the metal to form metal islands 85 on the substrate layer 71. The metal islands 85 can be seen in Figure 25. The metal islands 85 are separated from each other. The annealing process results in complete dewetting of the metal. In particular, the annealing process results in rupturing of the layer of metal. As the annealing process continues, the ruptures connect together to form a network, leaving individual metal islands 85 as seen in Figure 25. When the metal is annealed to a sufficiently high temperature, the metal particles move to an energetically more favourable configuration. This results in the formation of the metal islands 85.

[00134] In an embodiment, the process of forming the pores 73 comprises performing metal-assisted chemical etching to etch sections of the substrate layer 71 under the metal islands 85 to form the pores 73. The metal islands 85 function as a catalyst to etch the substrate layer 71 under each metal island 85 (i.e. metal droplet).

[00135] Figure 26 is an image of a metallic or semi-metallic layer 72 used in an alternative process of forming the pores 73. In an embodiment, the third material, which forms the metallic or semi-metallic layer 72 is applied on the substrate layer 71. In an embodiment the process of forming the pores 73 comprises annealing the third material to form gaps in the metallic or semi-metallic layer 72. These gaps can be seen in the image of Figure 26. The conditions (e.g. temperature, time) of the annealing process can be selected so that the gaps are formed as shown in Figure 26, without the gaps connecting together to form a network separating metal islands as shown in Figure 25. Figure 26 shows the results of a partial dewetting (rather than the complete dewetting shown in Figure 25) of the third material.

[00136] The resulting metallic or semi-metallic lattice shown in Figure 26 can be used as an etching mask for etching the substrate layer 71. In an embodiment the process of forming the pores 73 comprises etching the substrate layer 71 through the gaps to form the pores 73. The metallic or semi-metallic lattice can then be retained as the metallic or semi-metallic layer 72 so as to improve the emissivity of the membrane 40.

[00137] In an embodiment, the annealing and etching steps may be performed in place of the steps shown in Figure 12. Alternatively, the annealing and etching steps may be performed at the end of the method of manufacturing the pellicle. For example, the pellicle may be formed with a membrane which has a continuous surface (i.e. without the pores 73). The annealing and etching steps could then be performed so as to create the pores 73. Hence, the steps of annealing and etching could be performed after the release of a continuous film membrane.

[00138] Figure 27 is an image of a honeycomb structure 86 used in an alternative process for forming the pores 73. In an embodiment, the process for forming the pores 73 comprises providing the honeycomb structure 86 as an etching mask. For example, the honeycomb structure 86 can be positioned above the substrate layer 71.

[00139] In an embodiment the honeycomb structure 86 comprises highly ordered and homogenous nanopores. For example, in an embodiment the honeycomb structure comprises porous anodic aluminum oxide.

[00140] In an embodiment the process for forming the pores 73 comprises etching the substrate layer 71 through the honeycomb structure 86 to form the pores 73. The honeycomb structure 86 is then removed.

[00141] The process of providing the honeycomb structure and etching can be performed in place of the steps shown in Figures 12 and 15, for example.

[00142] In an embodiment the honeycomb structure 86 is applied to the stack via an adhesion layer. Alternatively, the honeycomb structure 86 can be produced during the manufacturing process.

[00143] According to an aspect of the invention, there is provided a membrane for a pellicle for EUV lithography comprising a grating, the grating comprising a plurality of holes, pores or protrusions. The plurality of holes may e.g. comprise round, square, rounded squares or arbitrary shaped holes. The membrane can e.g. comprise a main film or main layer. The main film or layer thickness in the grating can e.g. range from 20 nm to 100nm. In an embodiment the main film or main layer may also be referred to as the core or membrane core. Preferably the grating pitch is less than 200nm to ensure a good thermal emissivity. The grating pitch may be defined as the distance between the centers of adjacent holes of the grating. In an embodiment the dominant grating pitch is preferably less than 100nm to ensure a low flare at the wafer level. A smaller grating pitch such as 30 nm or less can stop debris particles from falling on the reticle. The membrane for a pellicle for EUV lithography according to any embodiment may comprise a metal layer having a thickness between 4 and 15nm, or a semimetal of a thickness in the range from 20 to 80nm. The metal layer is preferably thicker if the membrane is more open. In an embodiment the membrane grating has substantially square openings (i.e. holes), a pitch from 30 to 200 nm, such as 100nm and a % of open area or an openness defined by the grating openings of from 50 to 90%, such as a 75% openness or open area. An emissive Ru layer of around 8nm thickness has a thermal emissivity >0.35. The material of the pellicle membrane may comprise for example SOI Si membrane core in combination with metal layers. In a further embodiment the membrane grating comprising SOI Si has a substantial circular or square shaped openings covering from 50 to 90% of the membrane area, a grating pitch of less than 100 nm and a metal layer having a thickness in the range from 5 to 15 nm which provides low flare at wafer level and a thermal emissivity > 0.2.

Although specific reference may be made in this text to the use of lithographic apparatus in the manufacture of ICs, it should be understood that the lithographic apparatus described herein may have other applications, such as the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, flat-panel displays, LCDs, thin-film magnetic heads, etc.. The substrate referred to herein may be processed, before or after exposure, in for example a track (a tool that typically applies a layer of resist to a substrate and develops the exposed resist), a metrology tool and/or an inspection tool. Where applicable, the disclosure herein may be applied to such and other substrate processing tools. Further, the substrate may be processed more than once, for example in order to create a multi-layer IC, so that the term substrate used herein may also refer to a substrate that already contains multiple processed layers.

[00144] While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. For example, the various photo resist layers may be replaced by non-photo resist layers that perform the same function.

[00145] The descriptions above are intended to be illustrative, not limiting. Thus it will be apparent to one skilled in the art that modifications may be made to the invention as described without departing from the scope of the claims set out below.

Conclusies

1. Vlies voor EUV-lithografie, omvattend:
een frame; en
een membraan dat ondersteund wordt door het frame, waarbij het membraan omvat:
een metalen of semi-metalen laag,
waarbij het membraan poriën omvat met een dichtheid van ten minste 5 per μm^2.

2. Vlies volgens conclusie 1, waarbij de dichtheid van poriën ten minste 20 per μm^2 is.

3. Vlies volgens conclusie 1, waarbij de dichtheid van poriën ten minste 100 per μm^2 is.

4. Vlies volgens een van de voorgaande conclusies, waarbij het membraan omvat:
een substraatlaag voor het ondersteunen van de metalen of semi-metalen laag.

5. Vlies volgens conclusie 4, waarbij de substraatlaag silicium omvat dat verkregen is uit silicium op isolator of polysilicium.

6. Vlies volgens een van de voorgaande conclusies, waarbij de metalen laag een dikte heeft van ten minste 4nm.

7. Vlies volgens een van de voorgaande conclusies, waarbij de metalen laag een dikte heeft van ten minste 8nm.

8. Vlies volgens een van de voorgaande conclusies, waarbij de semi-metalen laag een dikte heeft van ten minste 10nm.

9. Vlies volgens een van de voorgaande conclusies, waarbij de semi-metalen laag ten minste 90% van een totale dikte van het membraan vormt.

10. Vlies volgens een van de voorgaande conclusies, waarbij de semi-metalen laag een dikte heeft van ten minste 20nm.

11. Vlies volgens een van de voorgaande conclusies, waarbij de poriën ten minste 50% van een totaal gebied van het membraan vormen.

12. Vlies volgens een van de voorgaande conclusies, waarbij de poriën ten minste 75% van een totaal gebied van het membraan vormen.

13. Vlies volgens een van de voorgaande conclusies, waarbij het metaal een transitiemetaal is van groepen 3 tot en met 10.

14. Vlies volgens een van de voorgaande conclusies, waarbij het metaal een transitiemetaal is van periodes 4 tot en met 5.

15. Vlies volgens een van de voorgaande conclusies, waarbij het metaal geselecteerd is uit de groep die bestaat uit Zr, Y, Mo, Cr, Hf, Ir, Mn, Nb, Os, Pd, Pt, Re, Rh, Ru, Ta, Ti, V en W.

16. Vlies volgens een van de voorgaande conclusies, waarbij de poriën cirkelvormig of vierkant zijn.

17. Vlies volgens een van de voorgaande conclusies, dat voldoet aan $\frac{E}{1-T} \geq 4$, waarbij E staat voor emissiviteit voor invallende EUV-straling en T staat voor een gedeelte van invallende EUV-straling die door het membraan doorgegeven wordt.

18. Vlies volgens een van de voorgaande conclusies, met een emissiviteit van ten minste 0,2 voor invallende EUV-straling.

19. Vlies volgens een van de voorgaande conclusies, ingericht om ten minste 95% van invallende EUV-straling door te geven.

20. Membraan voor een vlies voor EUV-lithografie, omvattend:
een niet-gouden metalen of semi-metalen laag,
waarbij het membraan poriën omvat met een dichtheid van ten minste 5 per μm^2.

21. Vlies voor EUV-lithografie, omvattend:
een frame; en
het membraan volgens conclusie 20 ondersteund door het frame.

22. Patroneerinrichtingssamenstel voor EUV-lithografie dat het vlies volgens een van de conclusies 1 tot en met 19 of 21 omvat.

23. Dynamisch gasvergrendelingssamenstel voor EUV-lithografie dat het vlies volgens een van de conclusies 1 tot en met 19 of 21 omvat.

24. Werkwijze voor het produceren van een vlies voor EUV-lithografie, omvattende:
het aanbrengen van een eerste materiaal op een tweede materiaal voor het vormen van een frame van het vlies;
het aanbrengen van een derde materiaal voor het vormen van een metalen of semi-metalen laag van een membraan van het vlies op een substraatlaag van het membraan; en
het vormen van poriën in de substraatlaag met een dichtheid van ten minste 5 per μm^2.

25. Werkwijze volgens conclusie 24, waarbij het eerste materiaal de substraatlaag vormt.

26. Werkwijze volgens conclusie 24 of 25, waarbij het derde materiaal aangebracht wordt op de substraatlaag voordat de poriën gevormd worden.

27. Werkwijze volgens conclusie 24 of 25, waarbij het derde materiaal aangebracht wordt op de substraatlaag nadat de poriën gevormd zijn.

28. Werkwijze volgens een van de conclusies 24 tot en met 27, waarbij het vormen van de poriën omvat:
het drukken van een mal op een maskermateriaal dat de substraatlaag bedekt teneinde een patroon van afdrukken in het maskermateriaal te vormen dat overeenkomt met porieposities;
het etsen van het maskermateriaal om openingen te vinden die horen bij de porieposities; en
het etsen van de substraatlaag door de openingen om de poriën te vormen.

29. Werkwijze volgens een van de conclusies 24 tot en met 27, waarbij het vormen van de poriën omvat:
het deponeren van bollen op de substraatlaag in een patroon dat overeenkomt met porieposities;
het aanbrengen van het derde materiaal op de bollen en de substraatlaag;
het verwijderen van de bollen teneinde blootgestelde secties van de substraatlaag te vormen die overeenkomen met de porieposities; en
het etsen van de blootgestelde secties van de substraatlaag om de poriën te vormen.

30. Werkwijze volgens een van de conclusies 24 tot en met 27, waarbij het vormen van de poriën omvat:
het aanbrengen van een metaal op de substraatlaag;
het gloeien van het metaal om metalen eilandjes te vormen op de substraatlaag; en
het uitvoeren van metaalondersteund chemisch etsen om secties van de substraatlaag onder de metalen eilandjes te etsen teneinde de poriën te vormen.

31. Werkwijze volgens een van de conclusies 24 tot en met 27, waarbij het vormen van de poriën omvat:
het gloeien van het derde materiaal om openingen te vormen in de metalen of semi-metalen laag; en
het etsen van de substraatlaag door de openingen om de poriën te vormen.

32. Werkwijze volgens een van de conclusies 24 tot en met 27, waarbij het vormen van de poriën omvat:
het verschaffen van een honingraatstructuur als een etsmasker;
het etsen van de substraatlaag om de poriën te vormen; en
het verwijderen van de honingraatstructuur.

33. Werkwijze volgens conclusie 32, waarbij de honingraatstructuur poreus anodisch aluminiumoxide omvat.

34. Membraan voor een vlies voor EUV-lithografie, waarbij het membraan een rooster omvat dat een veelvoud van gaten omvat.

35. Membraan volgens conclusie 34, waarbij het rooster een roosterpitch heeft van < 200 nm, bij voorkeur < 100 nm, meer bij voorkeur < 30 nm.

36. Membraan volgens conclusie 34 of 35, waarbij het rooster een kern omvat, met een dikte tussen 20 nm en 100 nm.

37. Membraan volgens een van de conclusies 34 tot en met 36, waarbij het rooster een metaal of semi-metaal omvat.

38. Membraan volgens een van de conclusies 34 tot en met 37, waarbij het rooster een SOI Si-membraankern omvat.

39. Membraan volgens conclusie 38, waarbij het rooster verder een of meer metalen lagen omvat.

40. Membraan volgens conclusie 38 of 39, waarbij het rooster in hoofdzaak cirkelvormige of vierkante openingen en een open gebied tussen 50% en 90% omvat, bij voorkeur tussen 70% en 80%.

Fig. 1

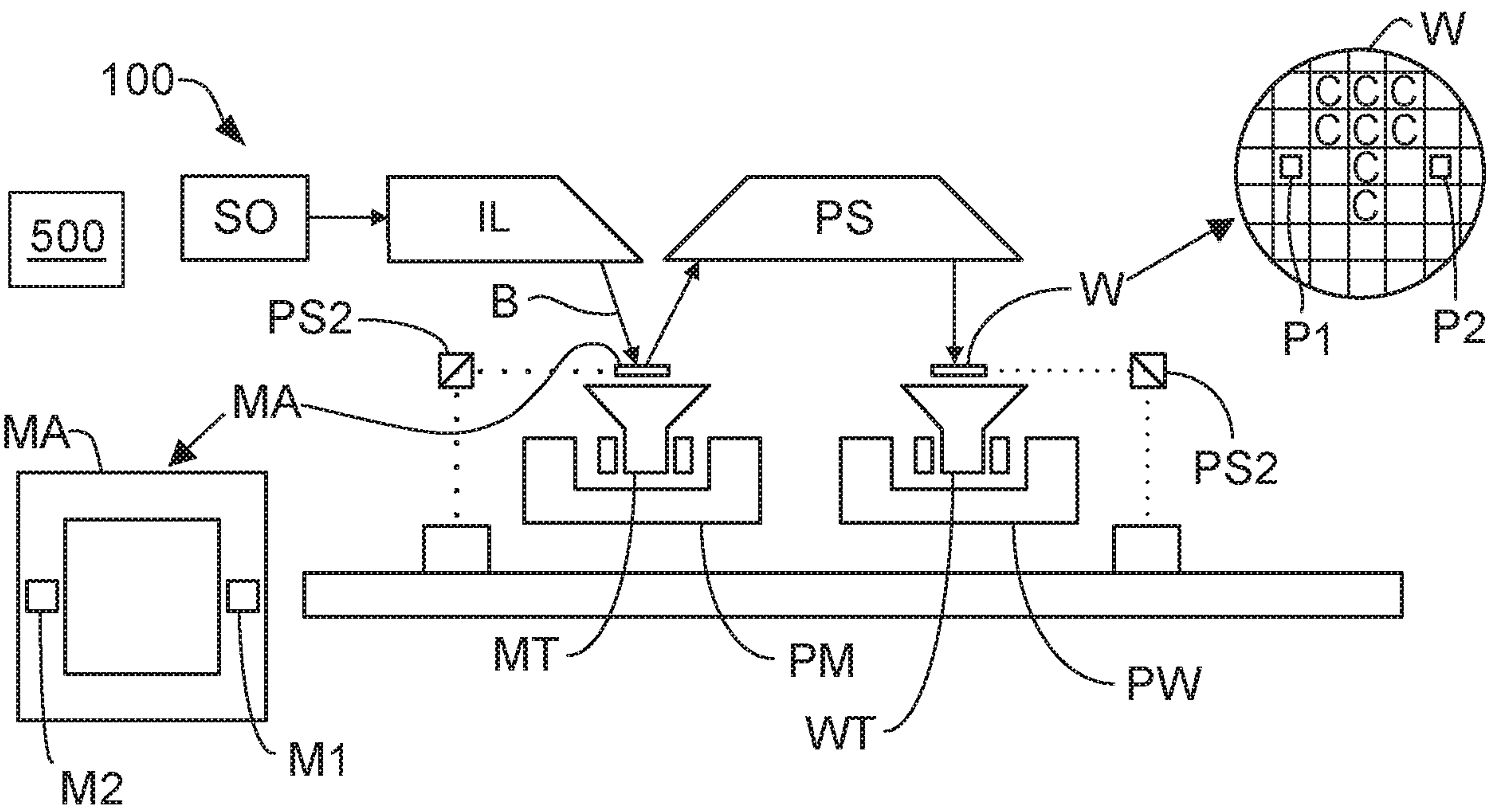

100
500
SO
IL
PS
B
PS2
MA
MA
W
W
C C C
C C C
C
C
P1
P2
PS2
MT
PM
WT
PW
M2
M1

Fig. 2

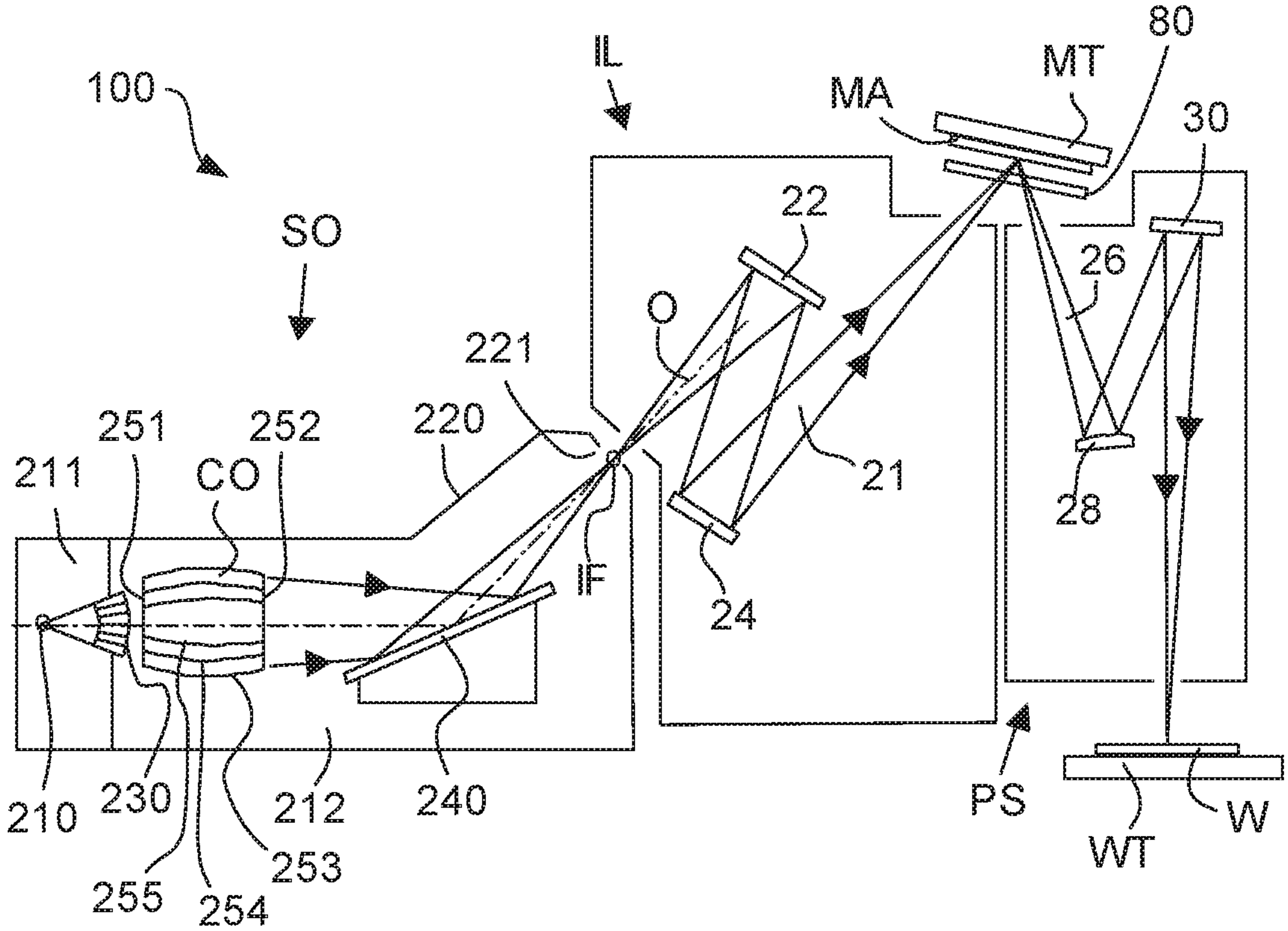

100
SO
IL
MA
MT
80
30
22
O
26
221
220
21
251
252
211
CO
IF
24
28
210
230
212
240
PS
WT
W
255
254
253

Fig. 3

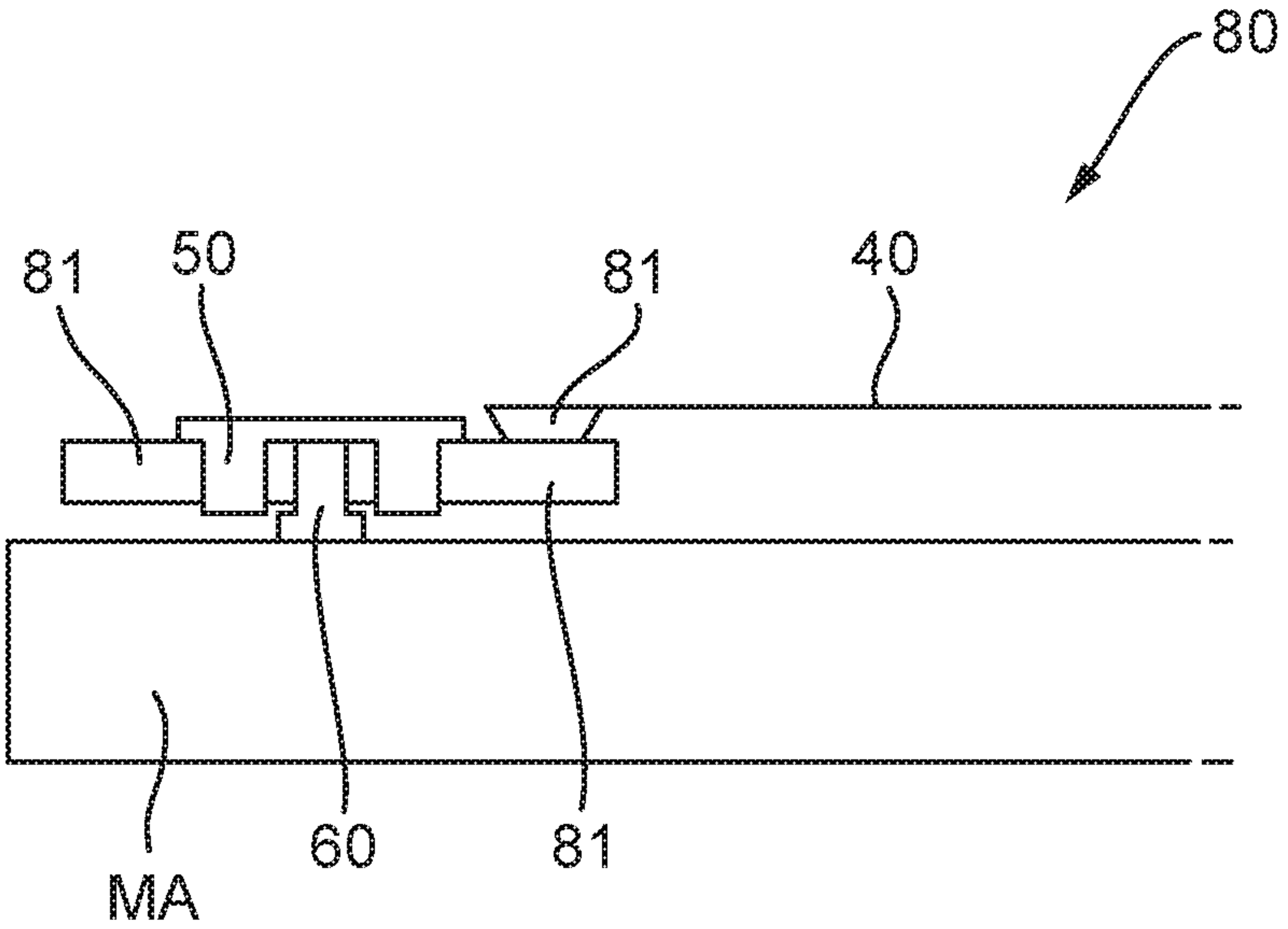


Fig. 4

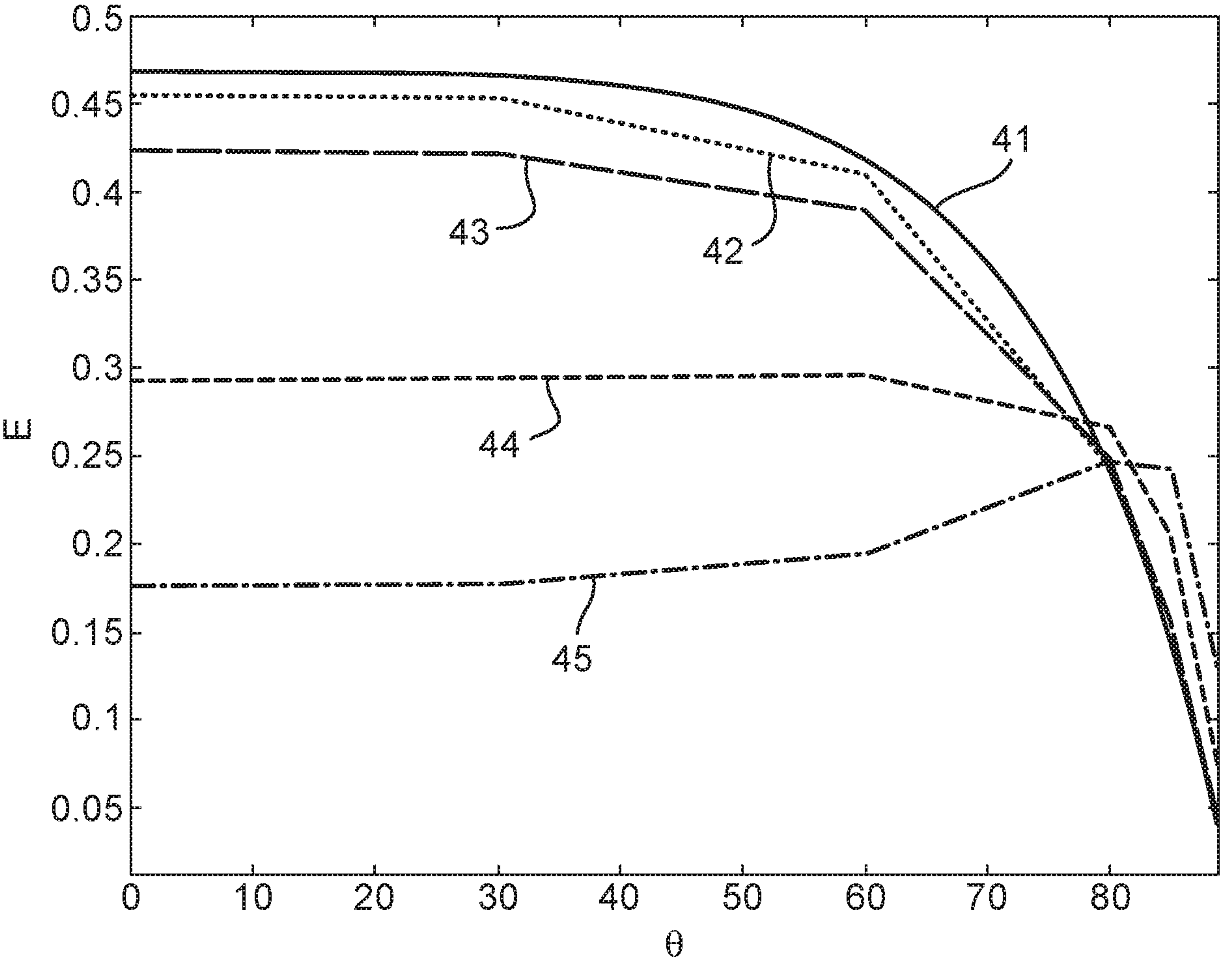

0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
E
0
10
20
30
40
50
60
70
80
θ
41
42
43
44
45

Fig. 5

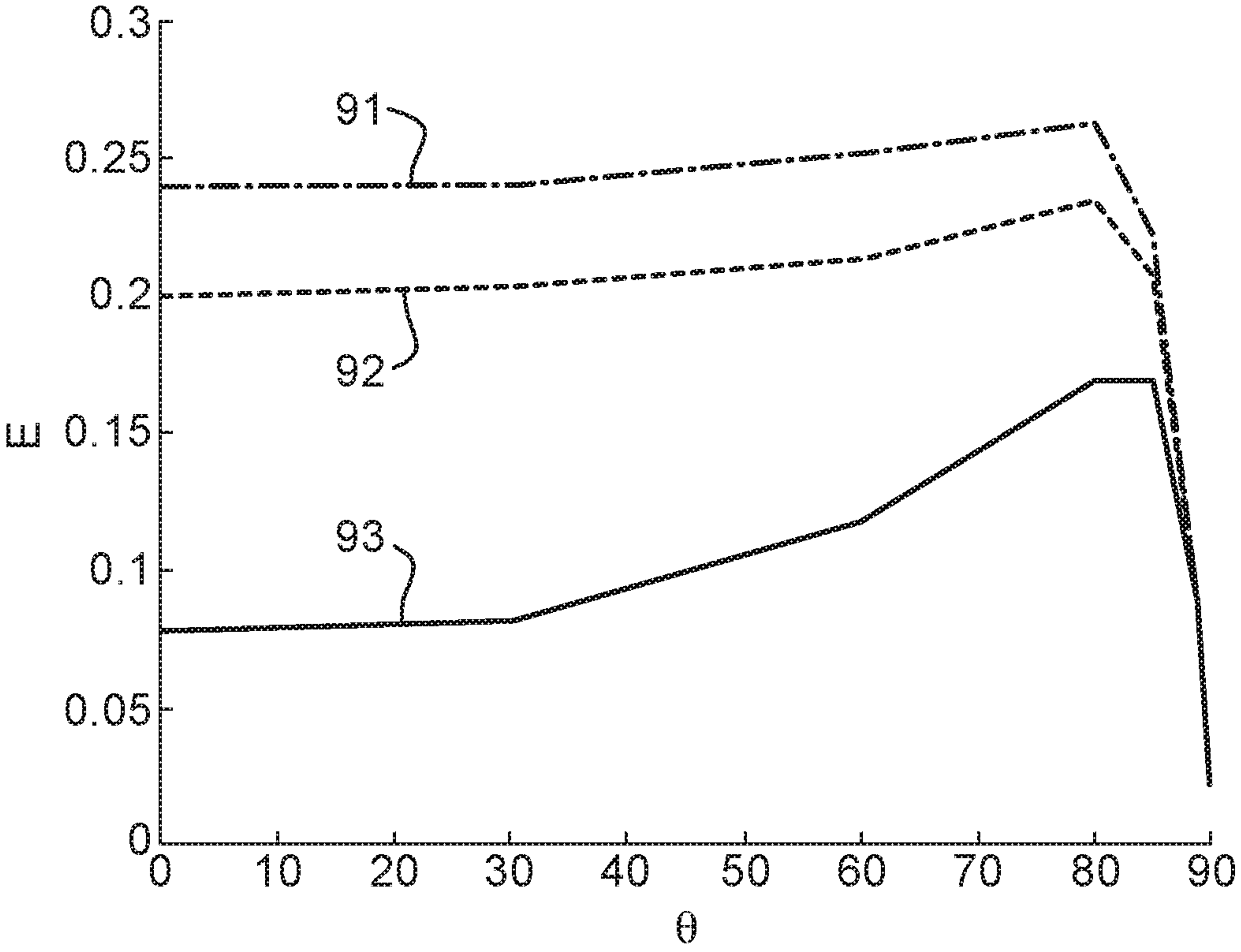

0.3
0.25
0.2
0.15
0.1
0.05
0
E
91
92
93
0
10
20
30
40
50
60
70
80
90
θ

Fig. 6

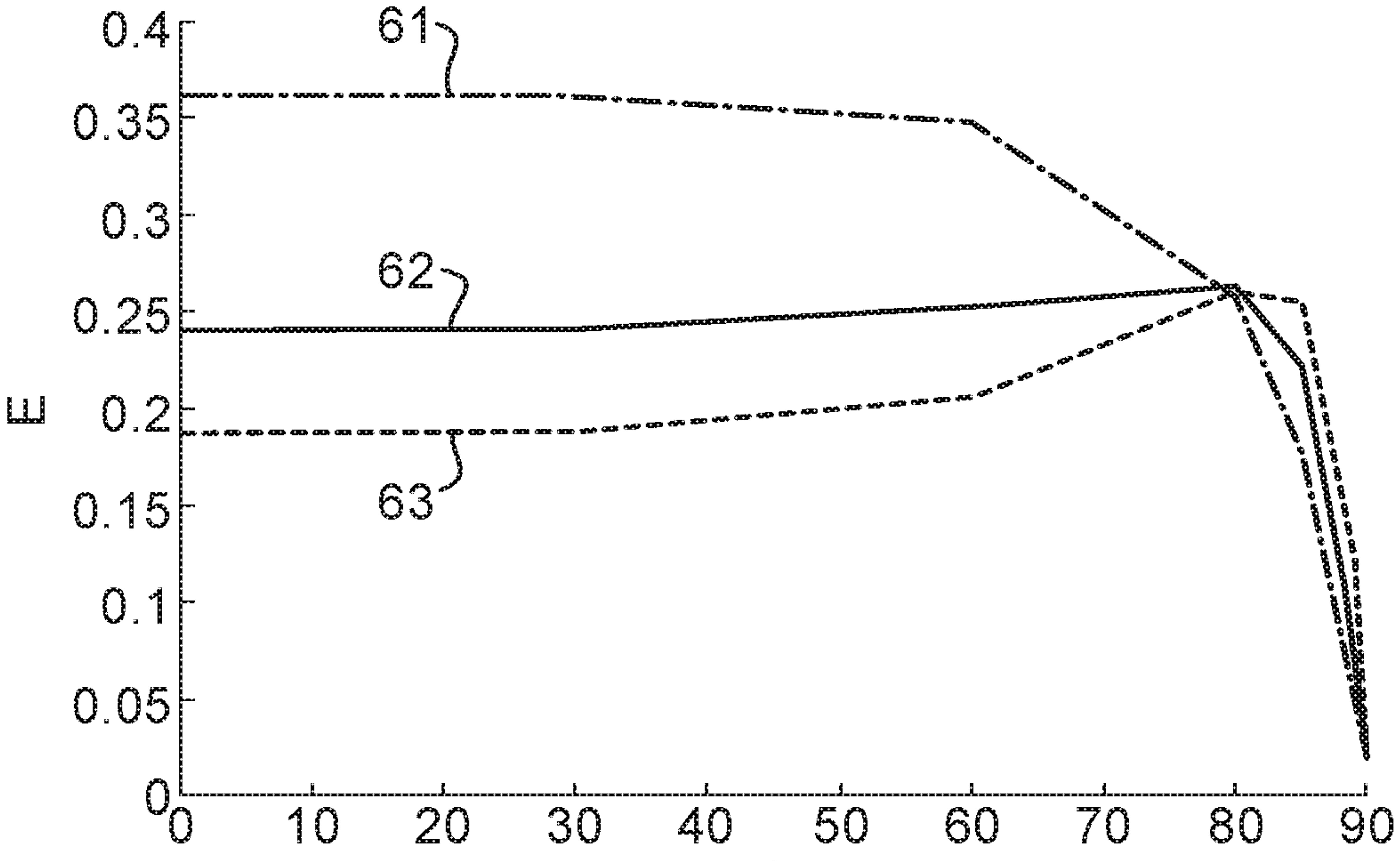

0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
E
61
62
63
0
10
20
30
40
50
60
70
80
90
θ

Fig. 7

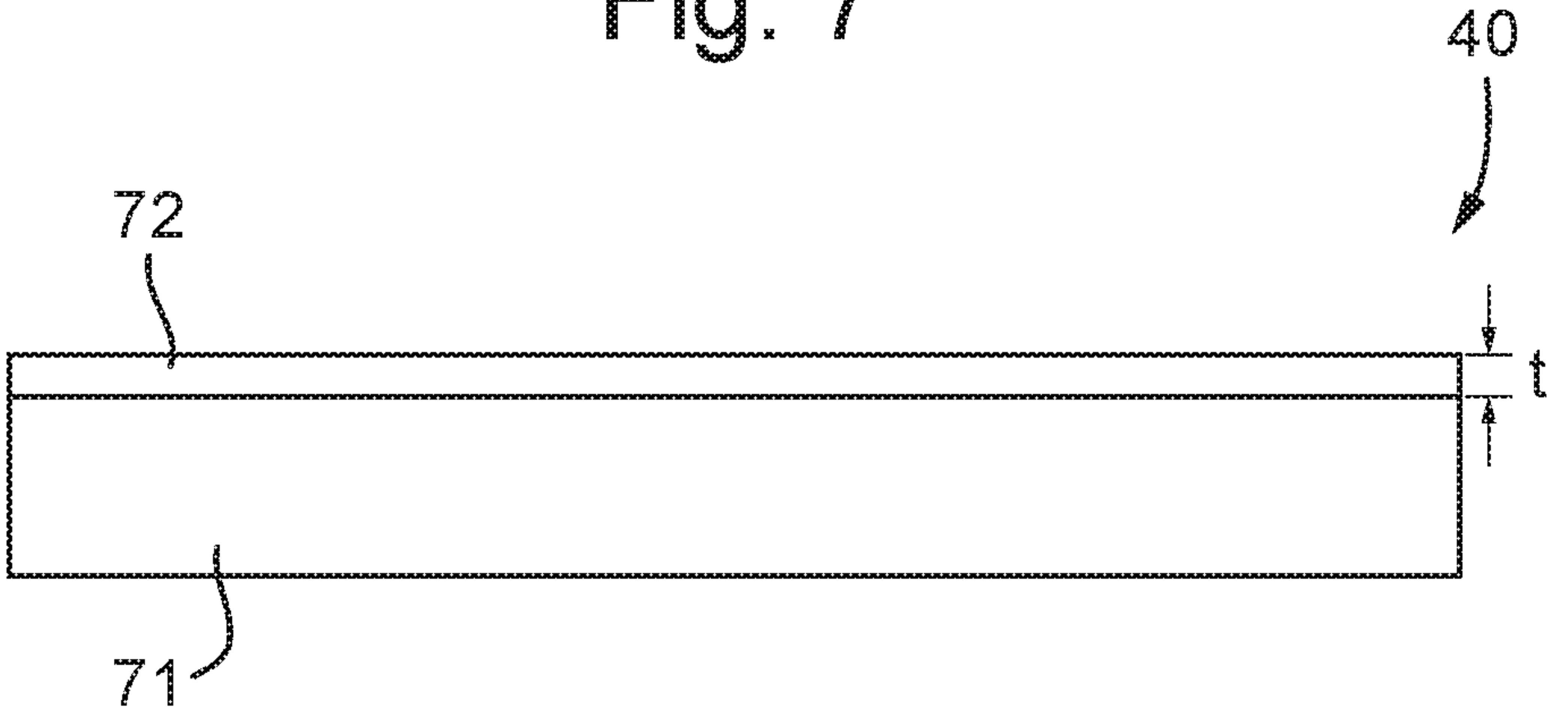


Fig. 8

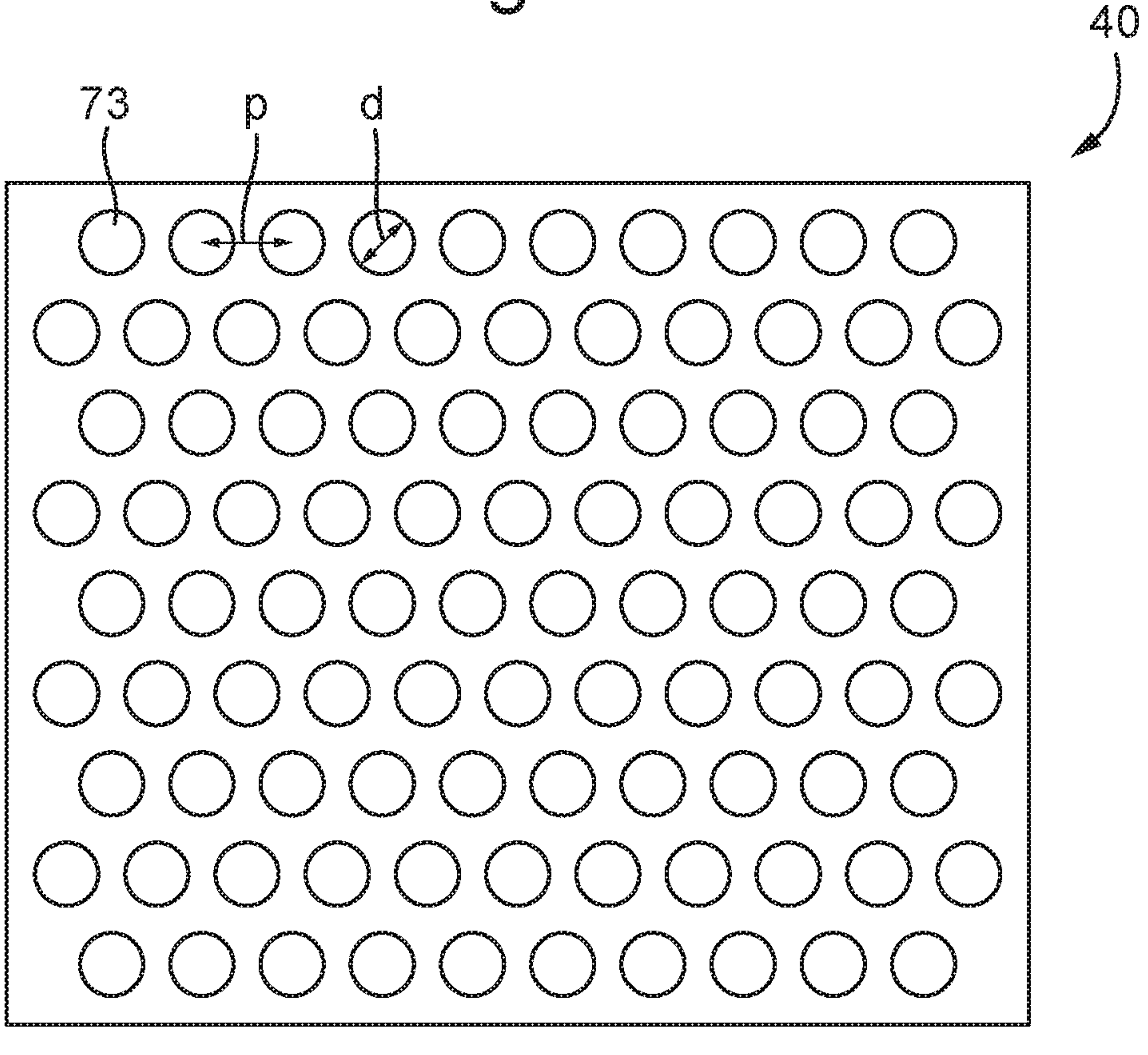


Fig. 9

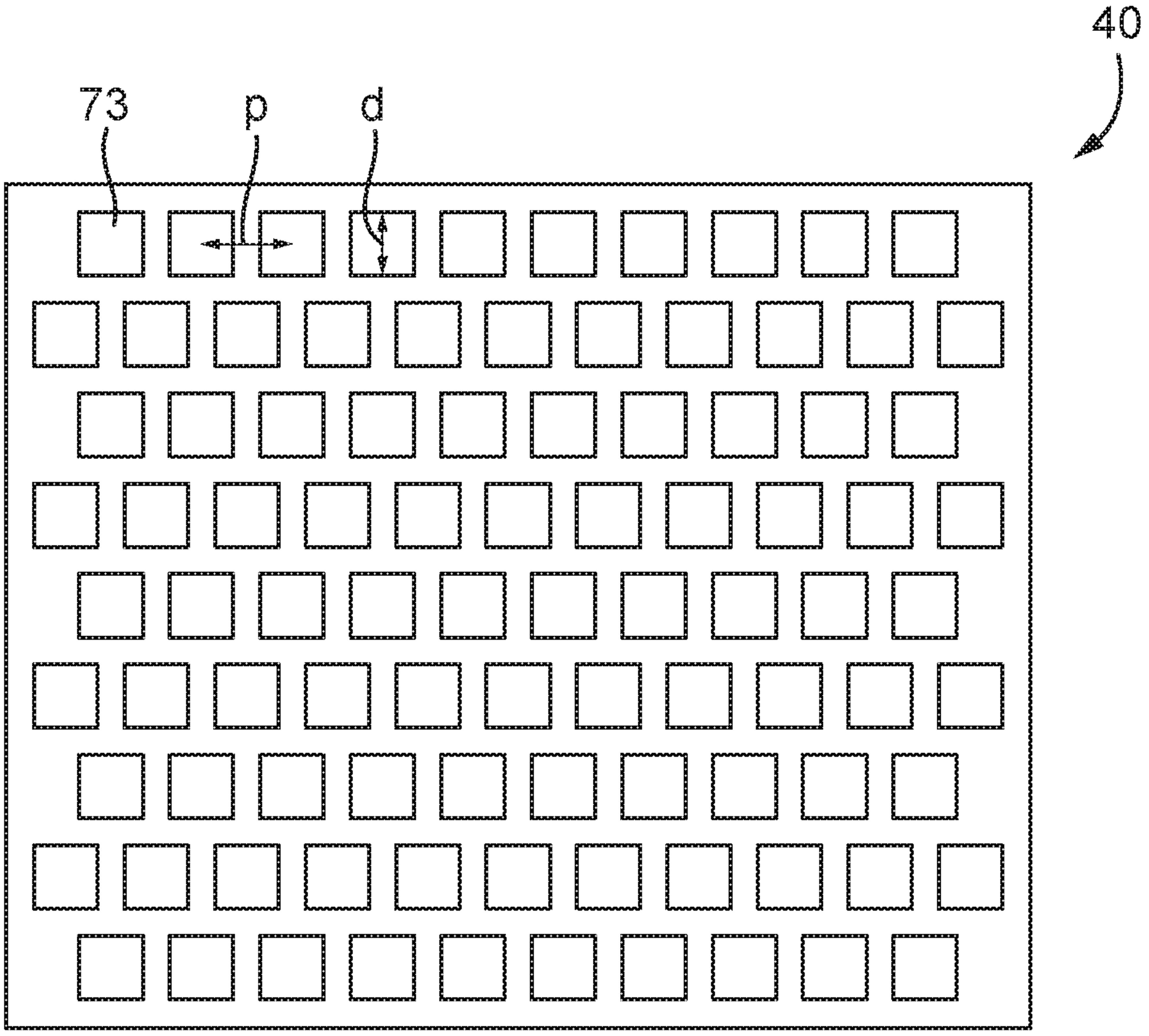


Fig. 10

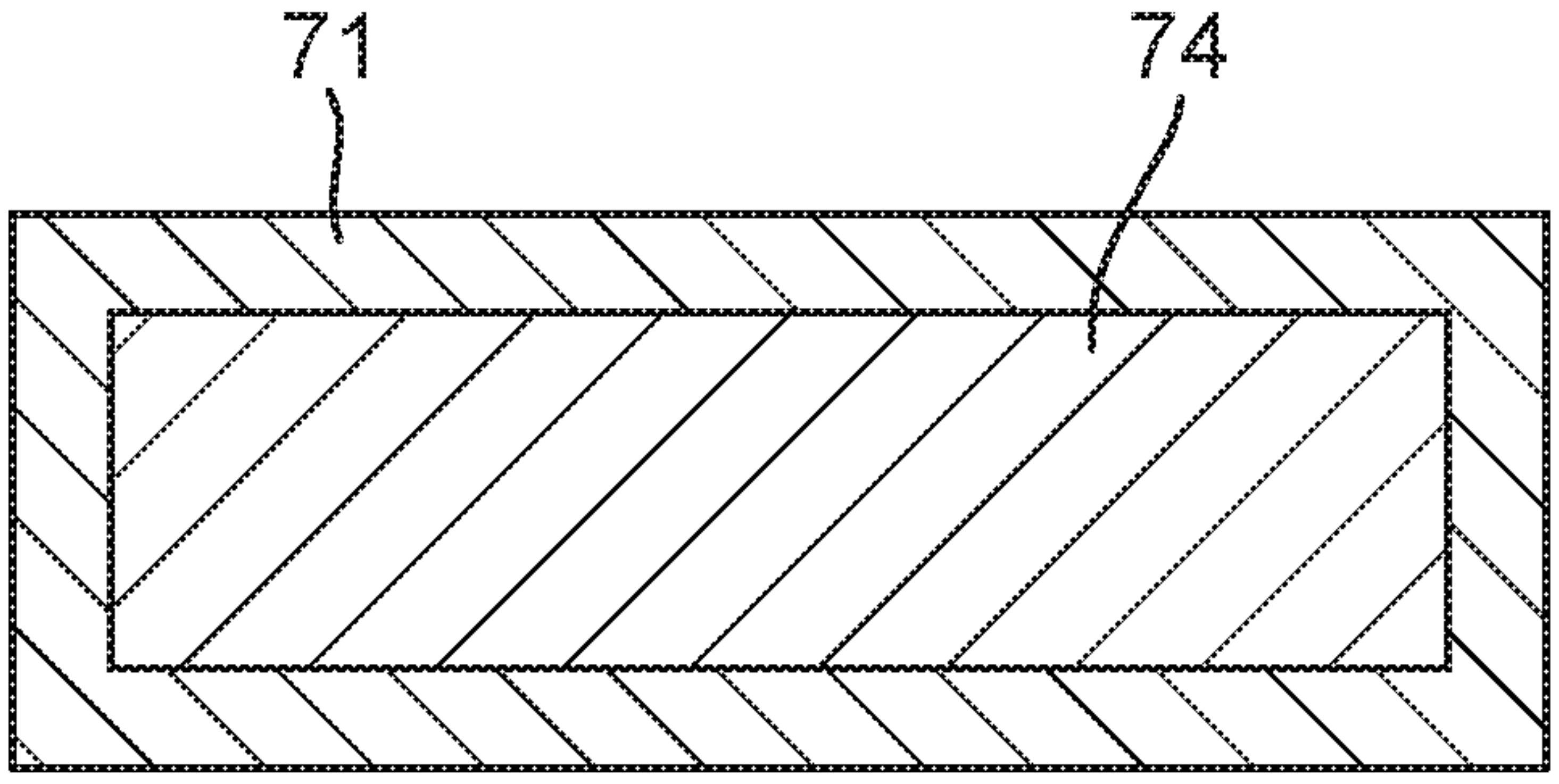


Fig. 11

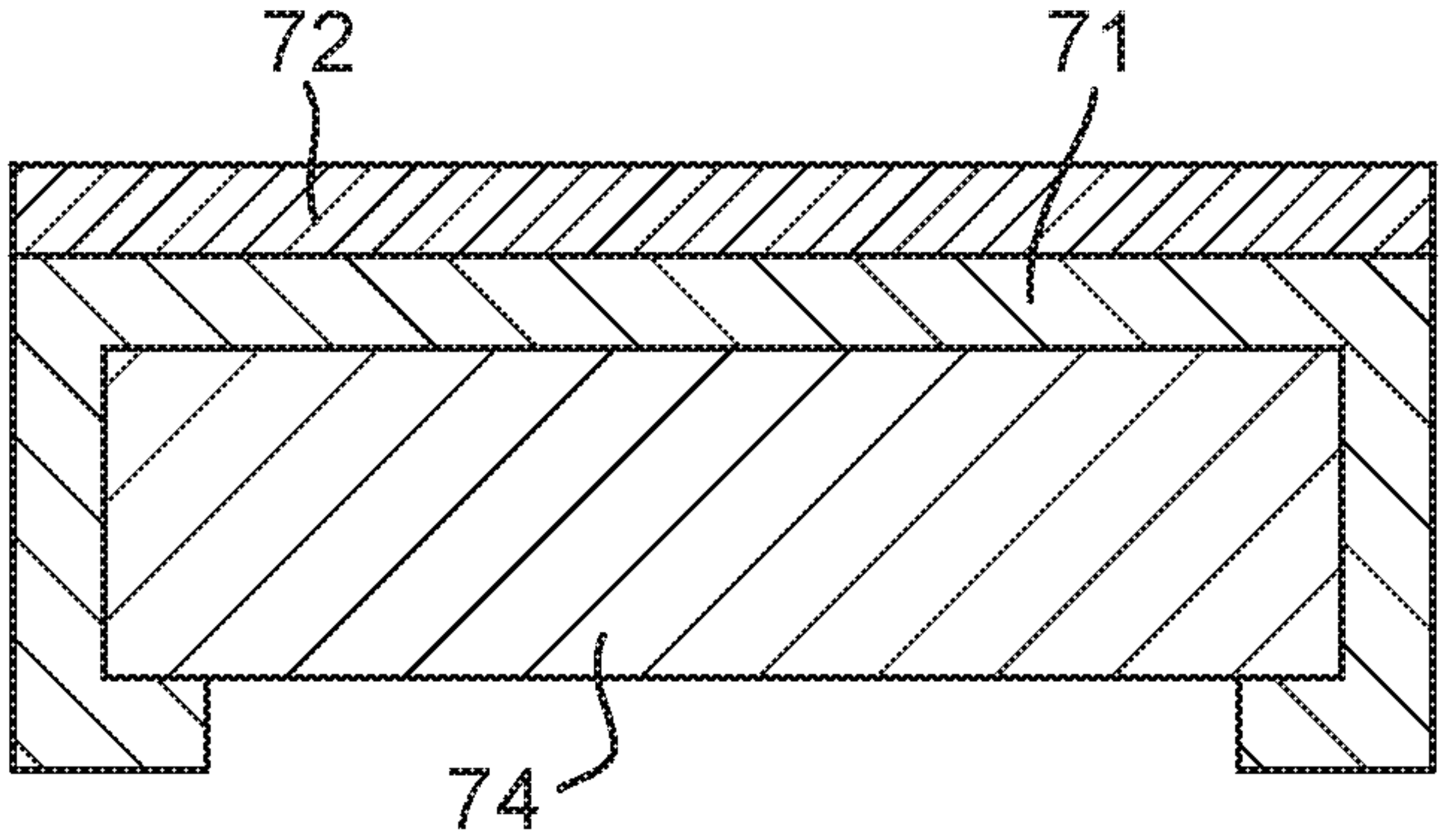


Fig. 12

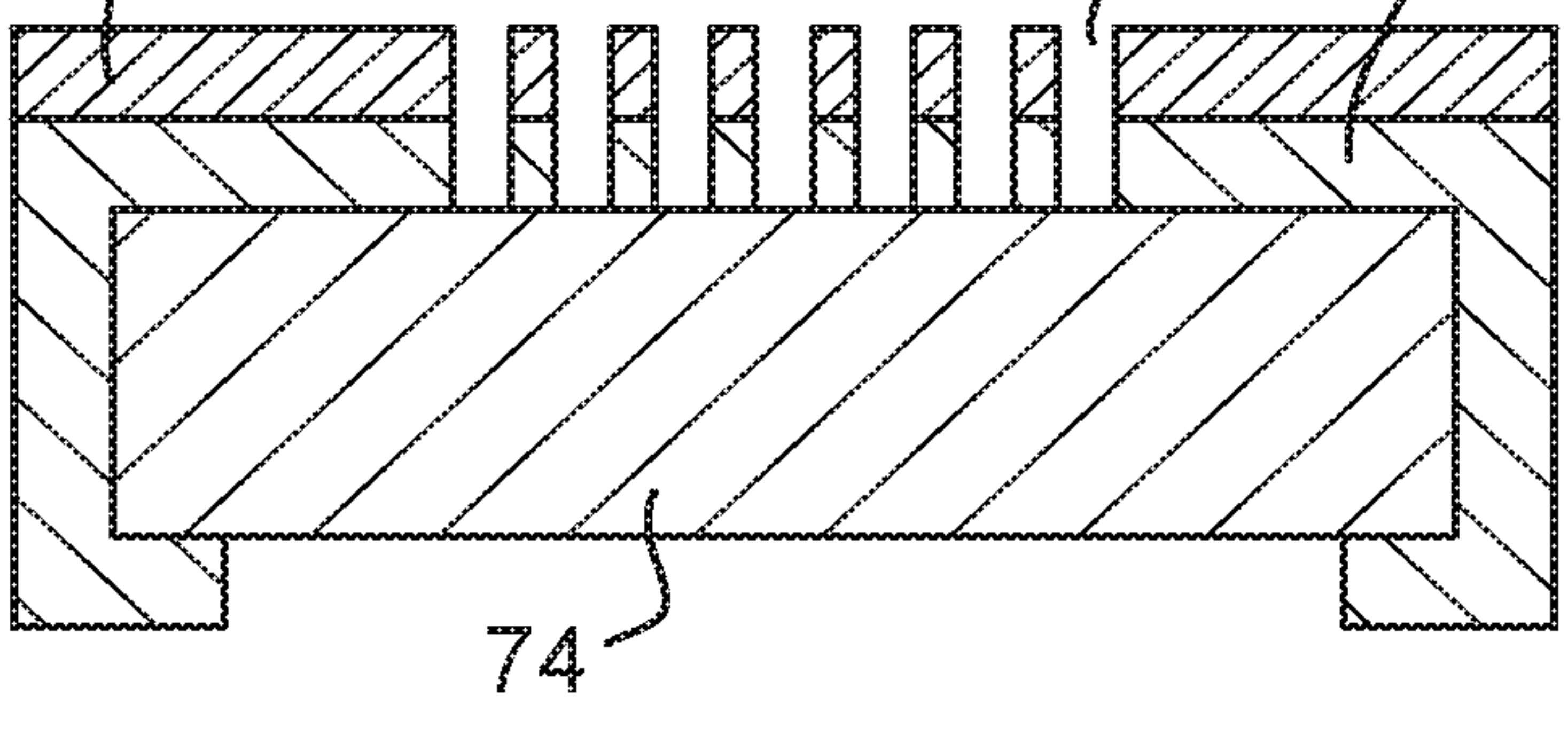


Fig. 13

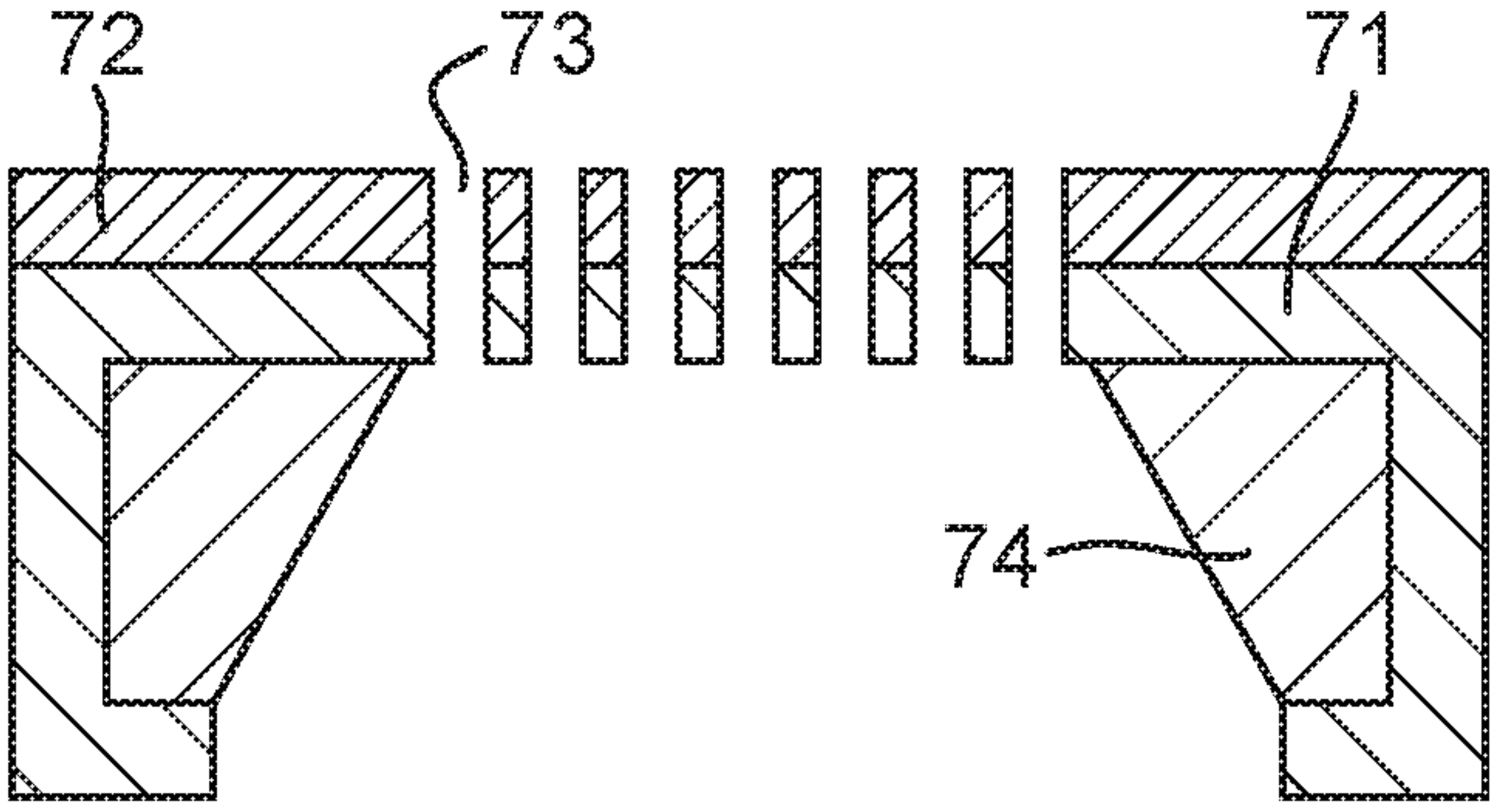


Fig. 14

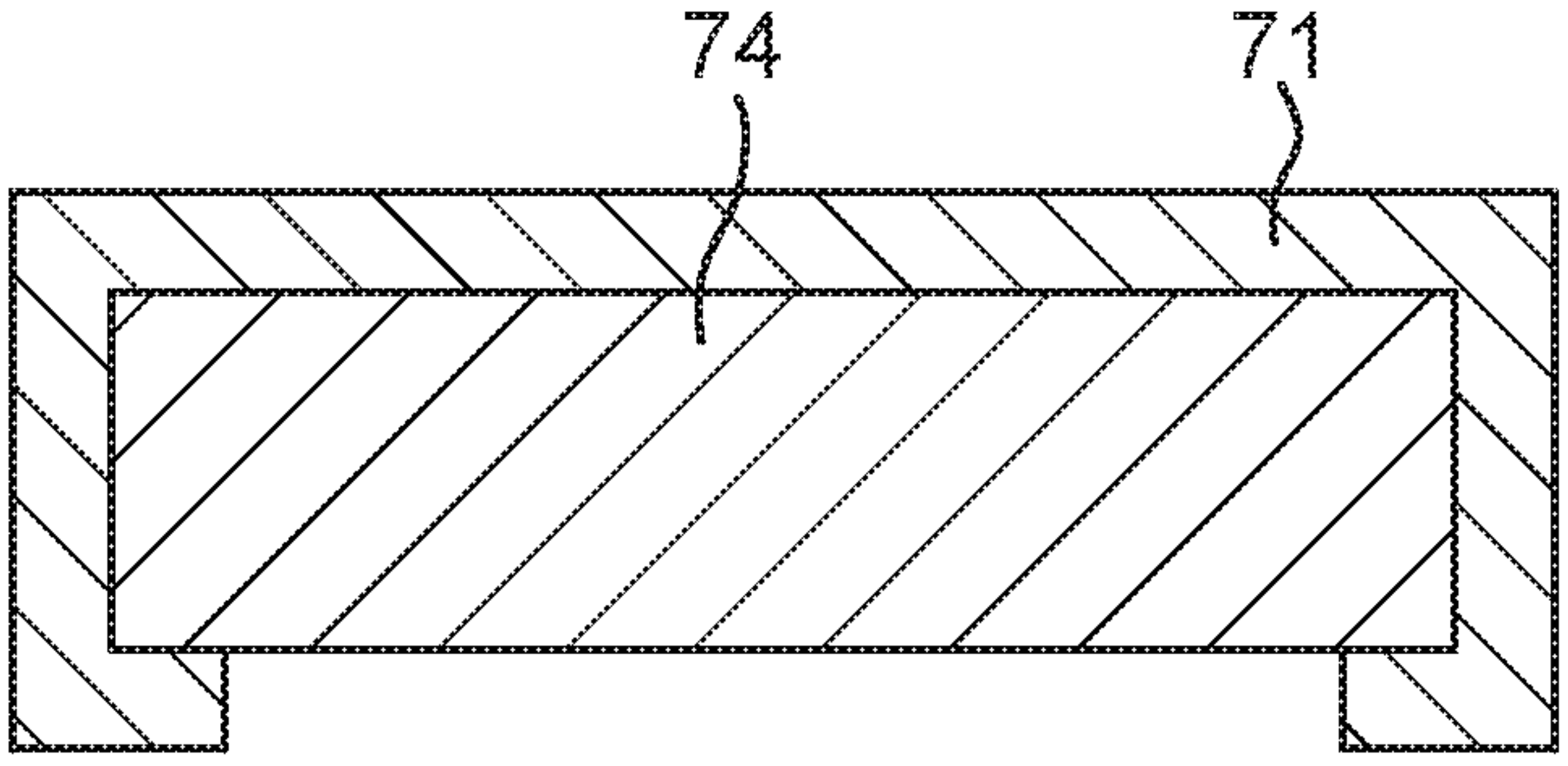


Fig. 15

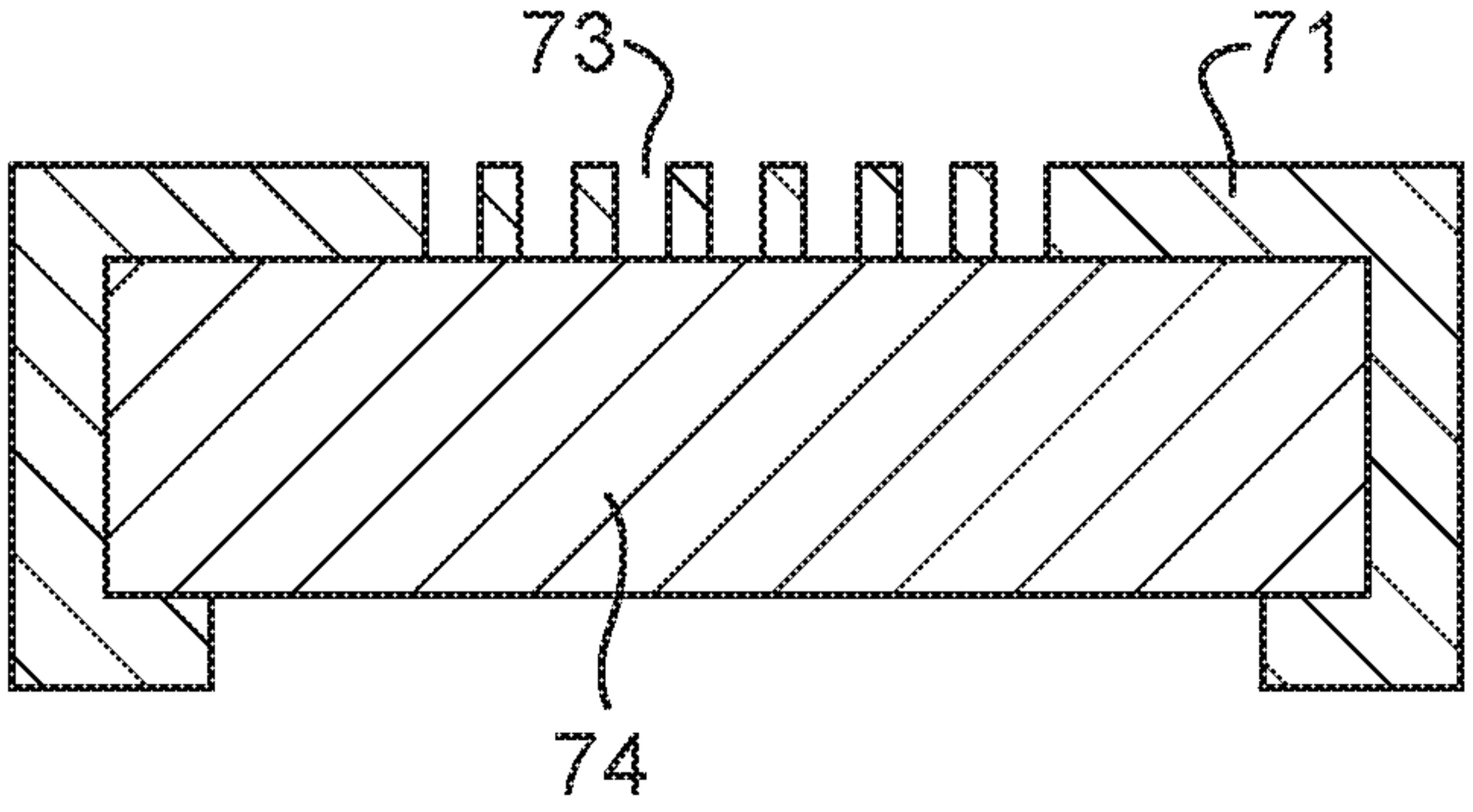


Fig. 16

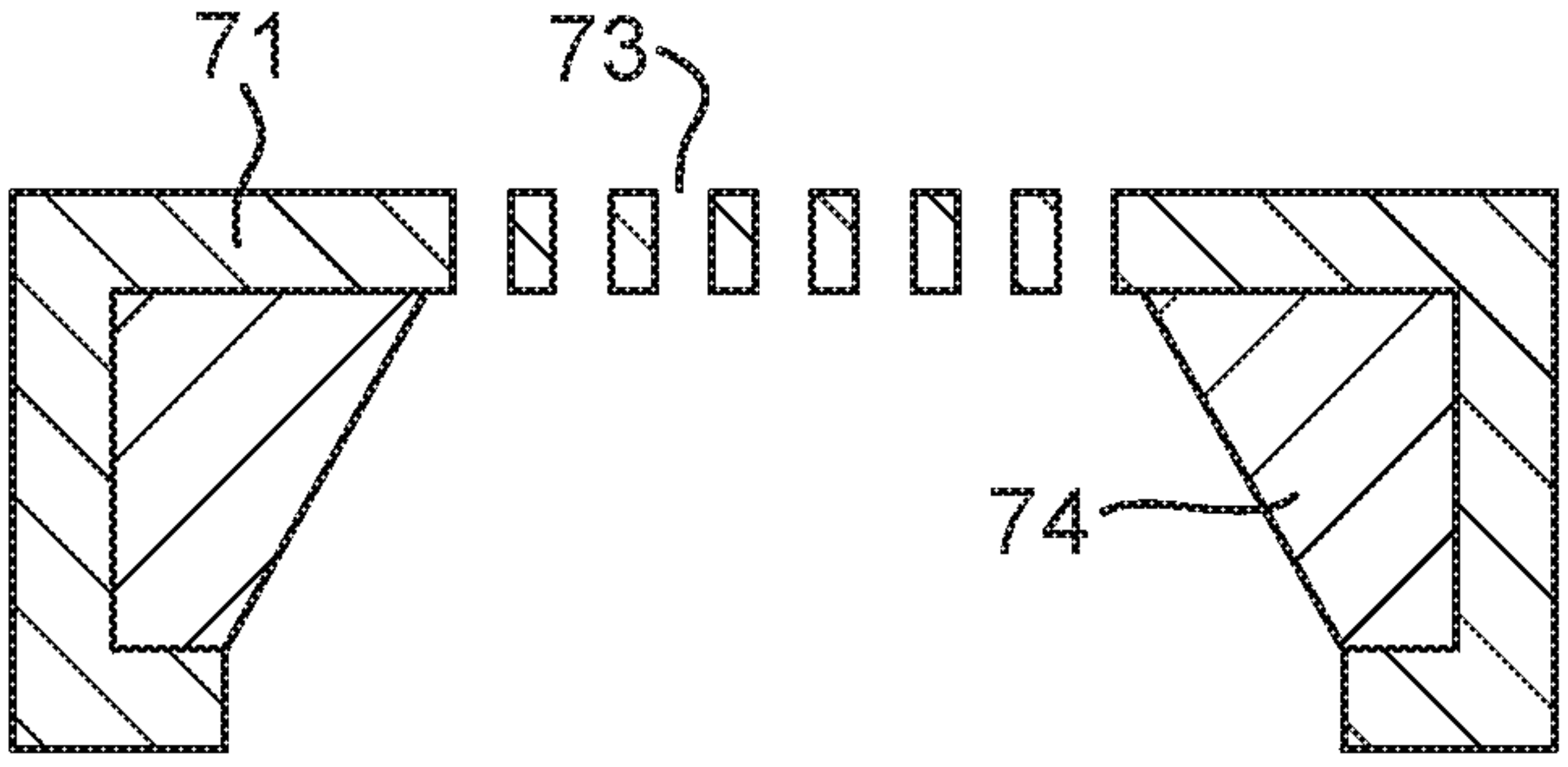


Fig. 17

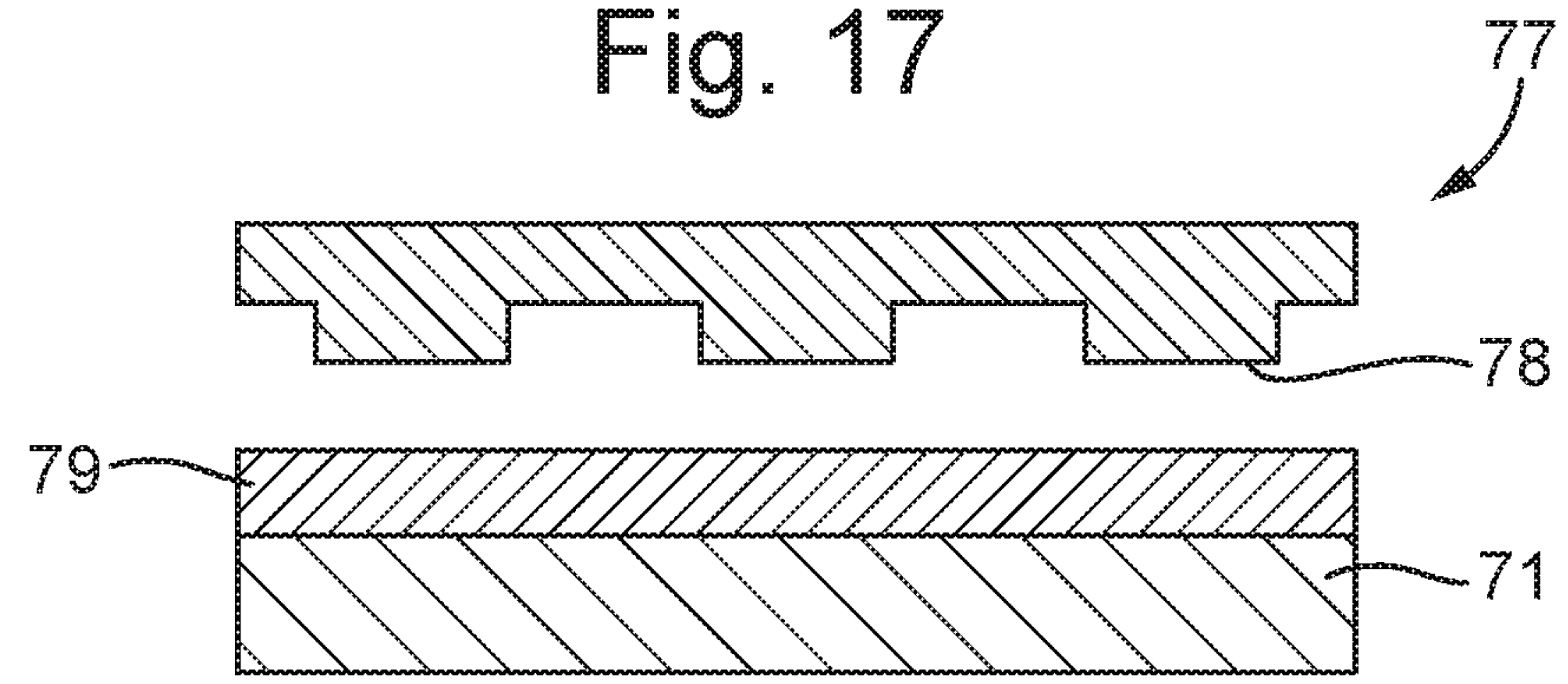


Fig. 18

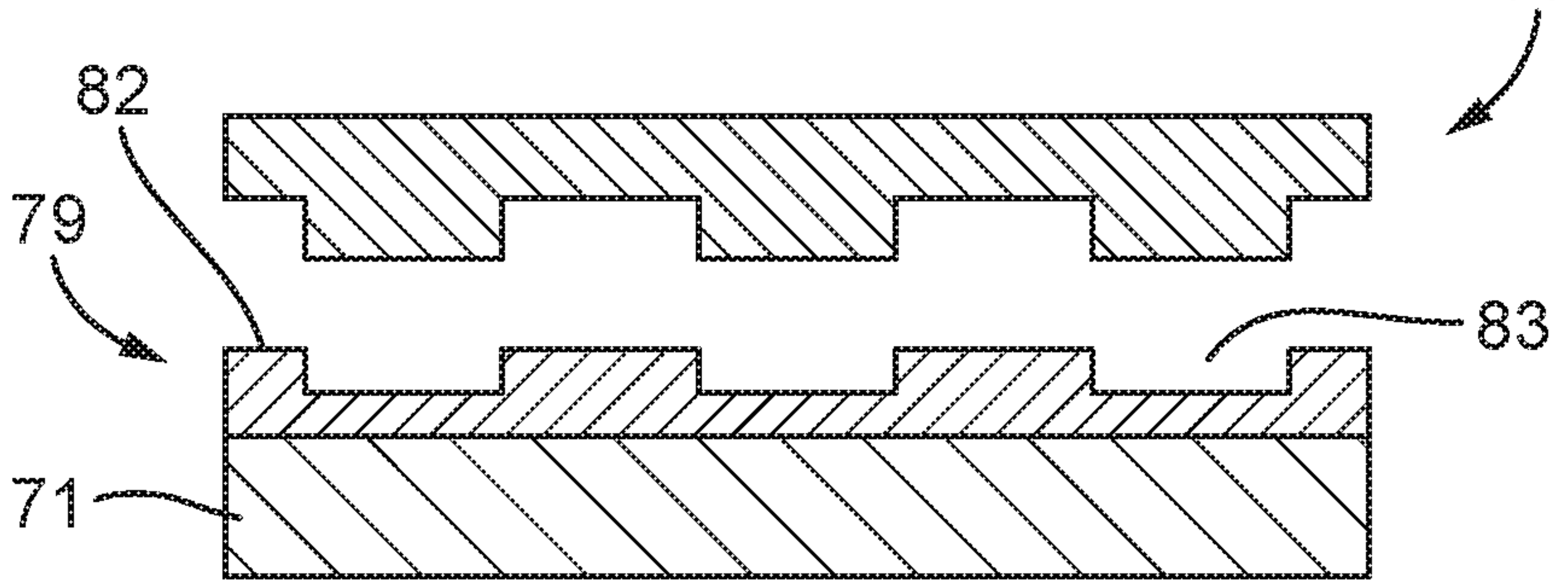


Fig. 19

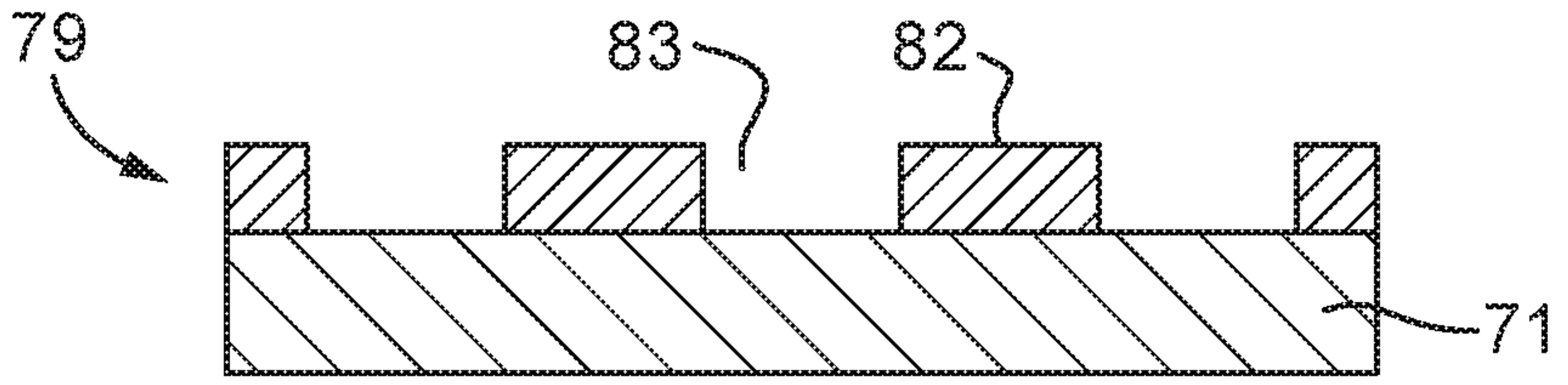


Fig. 20

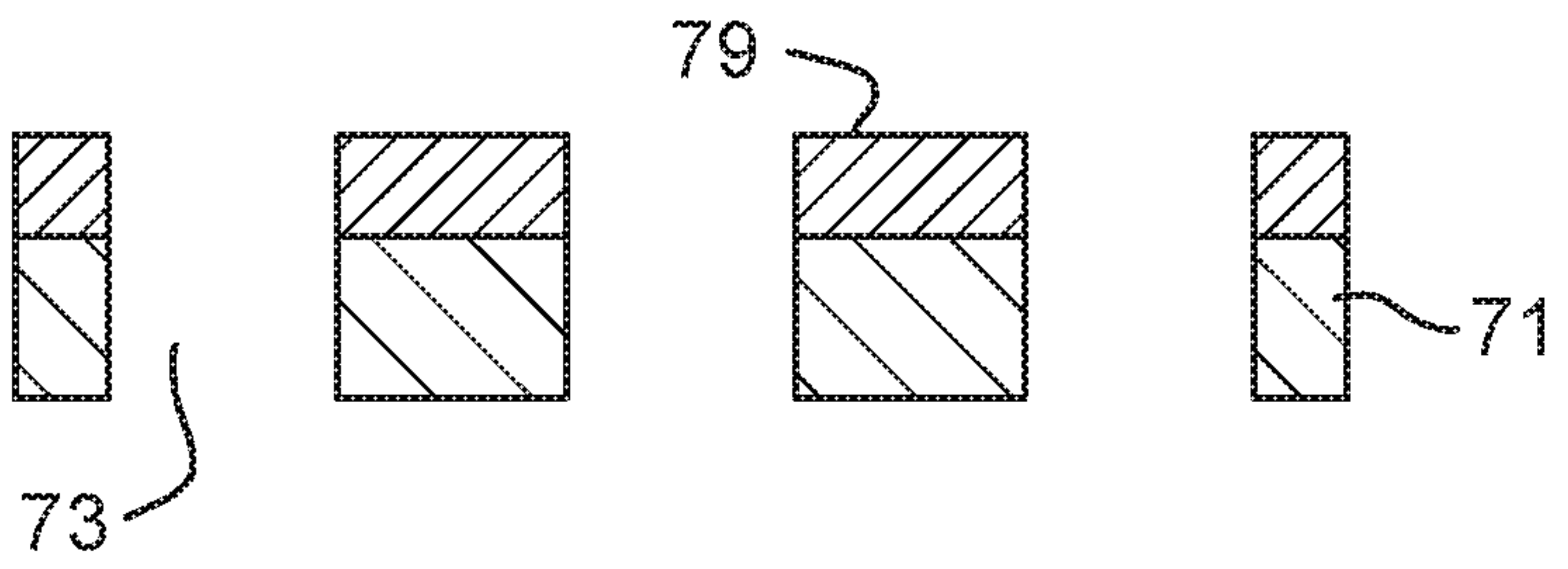


Fig. 21

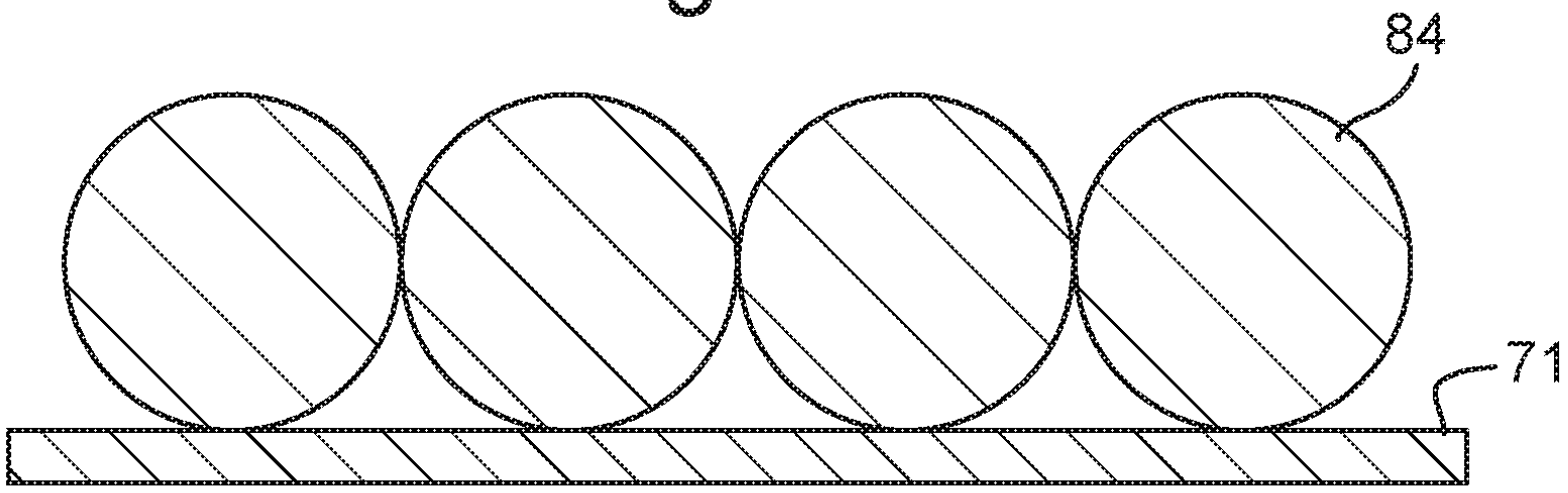


Fig. 22

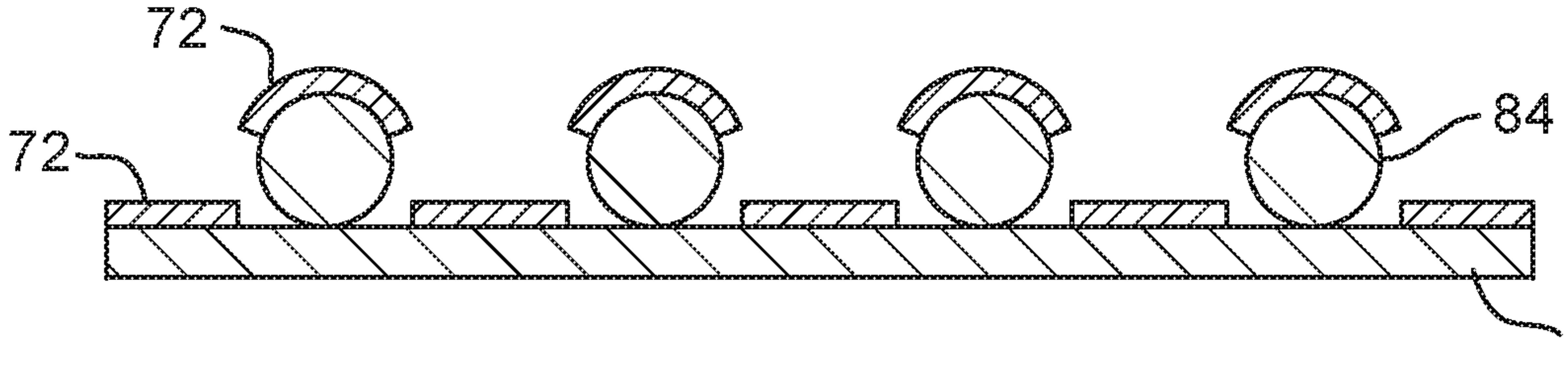


Fig. 23

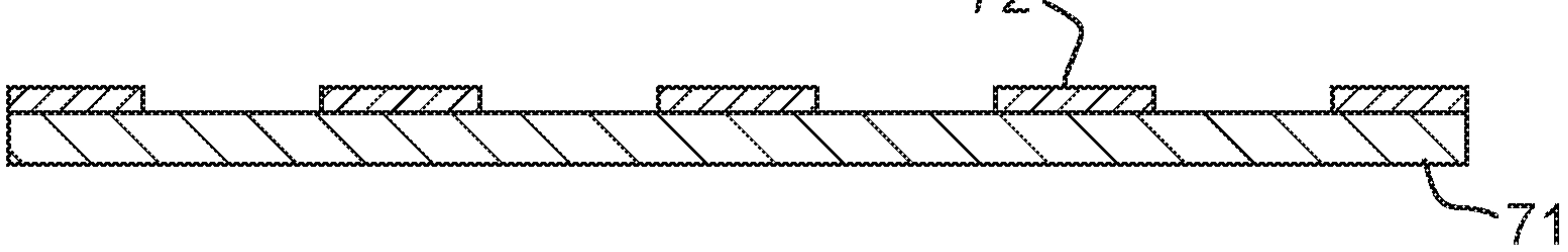


Fig. 24

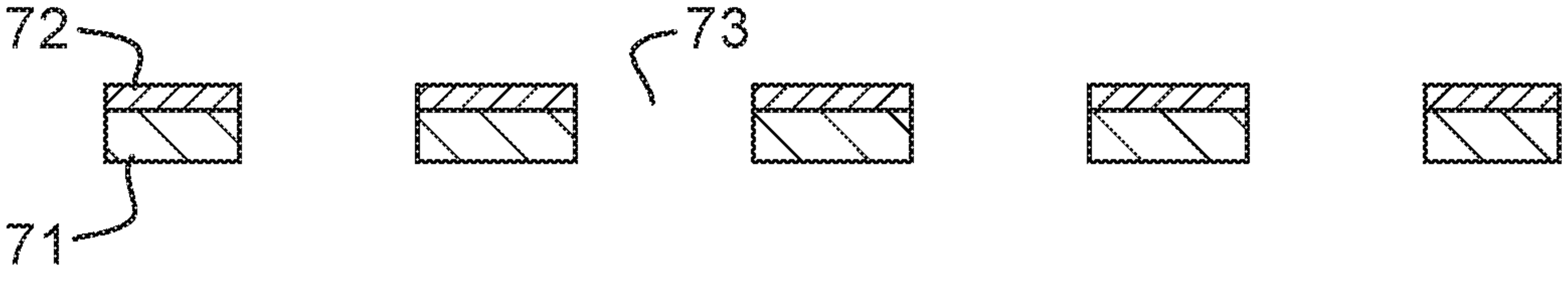


Fig. 25

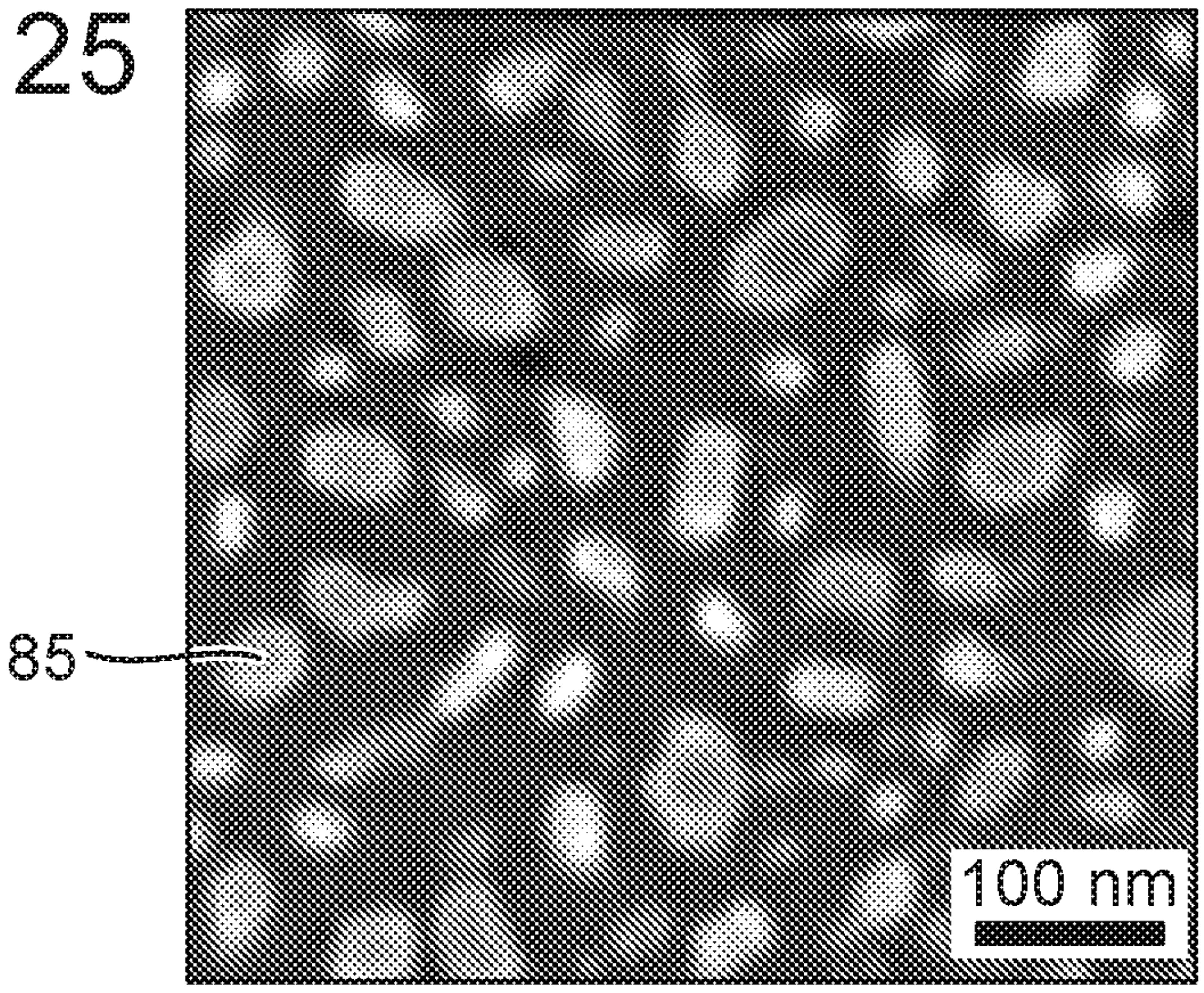


Fig. 26

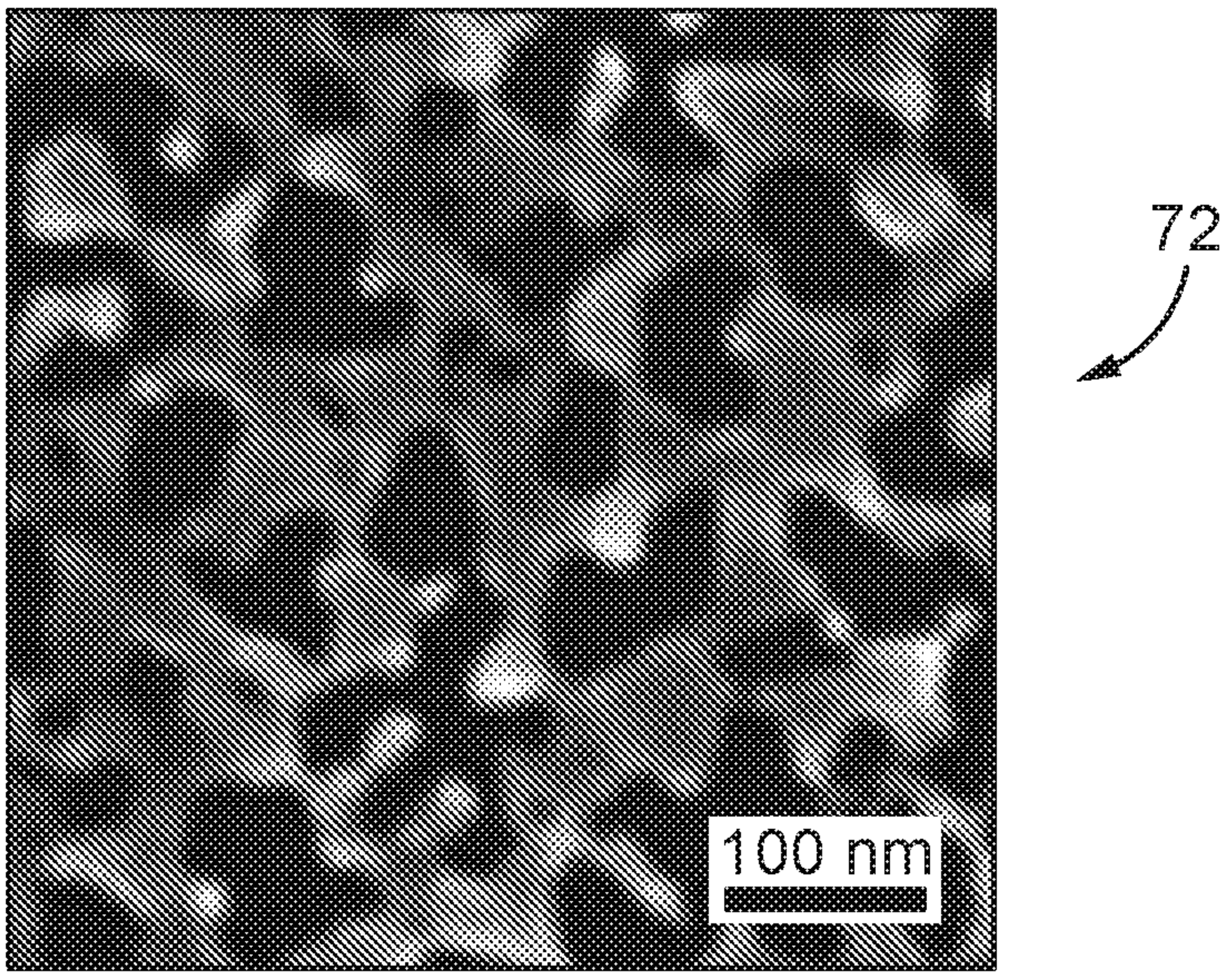
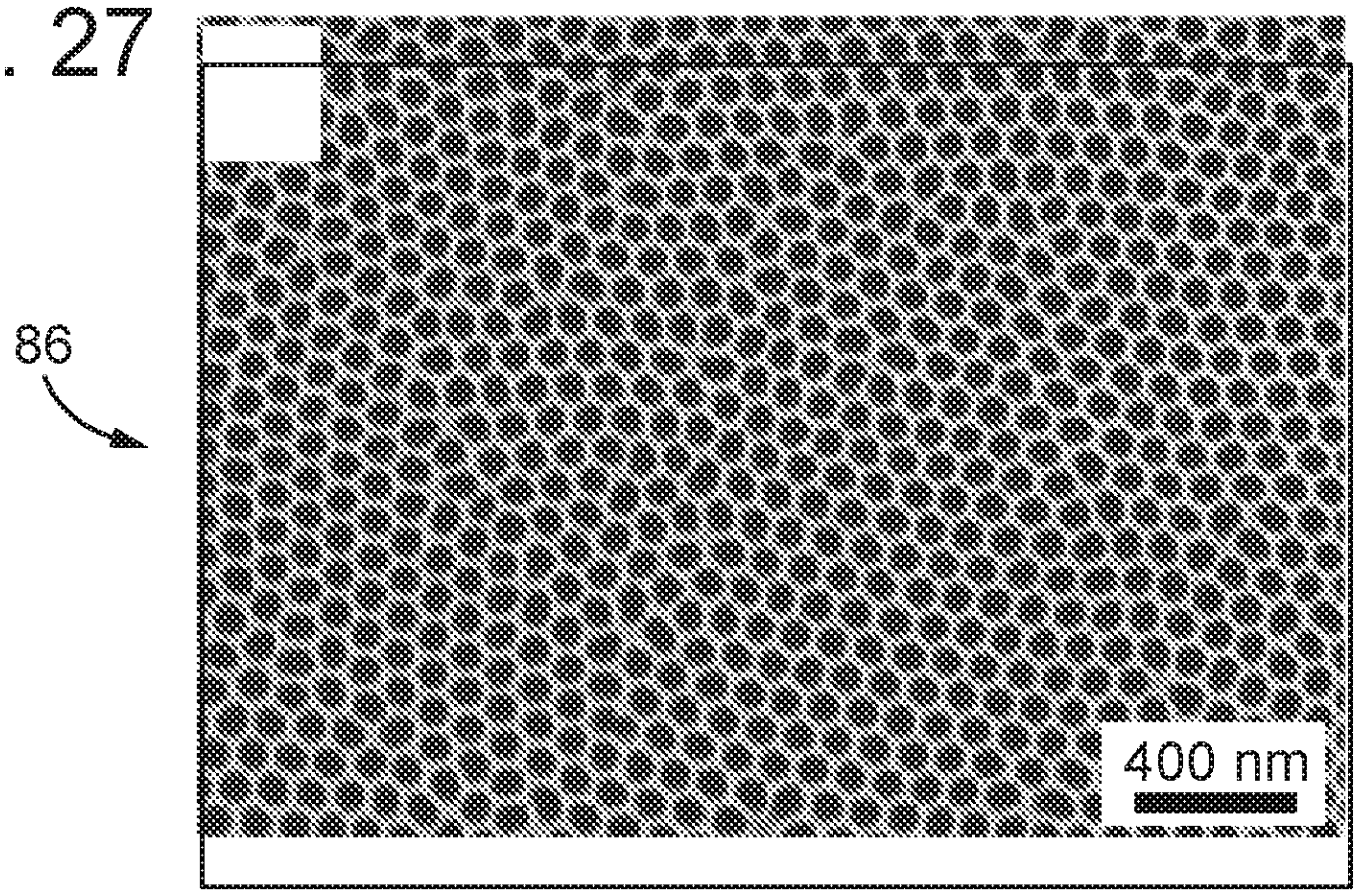


Fig. 27



Rijksdienst voor Ondernemend
Nederland

OCTROOIAANVRAAG NR.:
NO 140520
NL 2024075

ONDERZOEKSRAPPORT

BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK

RELEVANTE LITERATUUR

Categorie[1]	Literatuur met, voor zover nodig, aanduiding van speciaal van belang zijnde tekstgedeelten of figuren.	Van belang voor conclusie(s) nr:	Classificatie (IPC)
X A	KR 101 900 720 B1 (S&S TECH CO LTD [KR]) 20 september 2018 (2018-09-20) * alineas [0024], [0025], [0031], [0035] - [0039], [0054], [0055]; conclusies 17,23; figuren 1-5 * -----	1-7,20, 21,24-27 8-19, 28-40	INV. G03F1/62 G03F7/20
X	US 2018/329289 A1 (GALLAGHER EMILY [US] ET AL) 15 november 2018 (2018-11-15) * alineas [0006], [0025] - [0028], [0033], [0035], [0087], [0088], [0110] - [0113]; figuren 1,2,4 * -----	1-4,20, 21,34	
X A	US 2017/038676 A1 (JUNG YONG-SEOK [KR] ET AL) 9 februari 2017 (2017-02-09) * alineas [0007] - [0010], [0016], [0067] - [0075], [0157] - [0165]; figuren 1-2D,12A-12D * -----	1-3,34 4-33, 35-40	
A	US 2017/038675 A1 (AHN JINHO [KR] ET AL) 9 februari 2017 (2017-02-09) * alineas [0019] - [0022], [0031] - [0038], [0131] - [0164]; figuren 4-10 * -----	1-40	Onderzochte gebieden van de techniek
A	US 2013/004711 A1 (DOI SEITARO [JP] ET AL) 3 januari 2013 (2013-01-03) * alineas [0001], [0050] - [0053], [0059], [0060], [0104] - [0106]; figuren 1,6-9 * -----	1-40	G03F
A	US 2015/160569 A1 (OSORIO OLIVEROS EDGAR ALBERTO [NL]) 11 juni 2015 (2015-06-11) * alineas [0128] - [0136]; figuren 10-12 * -----	1-40	

Indien gewijzigde conclusies zijn ingediend, heeft dit rapport betrekking op de conclusies ingediend op:

Plaats van onderzoek:	Datum waarop het onderzoek werd voltooid:	Bevoegd ambtenaar:
München	29 april 2020	Roesch, Guillaume

[1] CATEGORIE VAN DE VERMELDE LITERATUUR

X: de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur
Y: de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht
A: niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft
O: niet-schriftelijke stand van de techniek
P: tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur
T: na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding
E: eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven
D: in de octrooiaanvrage vermeld
L: om andere redenen vermelde literatuur
&: lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

AANHANGSEL BEHORENDE BIJ HET RAPPORT BETREFFENDE HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK, UITGEVOERD IN DE OCTROOIAANVRAGE NR.

NO 140520
NL 2024075

Het aanhangsel bevat een opgave van elders gepubliceerde octrooiaanvragen of octrooien (zogenaamde leden van dezelfde octrooifamilie), die overeenkomen met octrooischriften genoemd in het rapport.
De opgave is samengesteld aan de hand van gegevens uit het computerbestand van het Europees Octrooibureau per
De juistheid en volledigheid van deze opgave wordt noch door het Europees Octrooibureau, noch door het Bureau voor de Industriële eigendom gegarandeerd; de gegevens worden verstrekt voor informatiedoeleinden.

29-04-2020

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
KR 101900720 B1	20-09-2018	CN 109765752 A	17-05-2019
		EP 3483656 A1	15-05-2019
		JP 2019091001 A	13-06-2019
		KR 101900720 B1	20-09-2018
		TW 201918372 A	16-05-2019
		US 2019146324 A1	16-05-2019
US 2018329289 A1	15-11-2018	CN 108873596 A	23-11-2018
		EP 3404487 A1	21-11-2018
		JP 2018194840 A	06-12-2018
		US 2018329289 A1	15-11-2018
US 2017038676 A1	09-02-2017	CN 106406021 A	15-02-2017
		KR 20170016159 A	13-02-2017
		TW 201719274 A	01-06-2017
		US 2017038676 A1	09-02-2017
US 2017038675 A1	09-02-2017	CN 106233202 A	14-12-2016
		US 2017038675 A1	09-02-2017
		WO 2015160185 A1	22-10-2015
US 2013004711 A1	03-01-2013	CN 102859397 A	02-01-2013
		CN 104597531 A	06-05-2015
		EP 2560048 A1	20-02-2013
		JP 5827217 B2	02-12-2015
		JP 6009018 B2	19-10-2016
		JP 2015110806 A	18-06-2015
		JP WO2011129378 A1	18-07-2013
		KR 20120139797 A	27-12-2012
		KR 20150008917 A	23-01-2015
		TW 201210828 A	16-03-2012
		TW 201716479 A	16-05-2017
		US 2013004711 A1	03-01-2013
		US 2016334699 A1	17-11-2016
		WO 2011129378 A1	20-10-2011
US 2015160569 A1	11-06-2015	JP 6253641 B2	27-12-2017
		JP 2015523714 A	13-08-2015
		KR 20150021061 A	27-02-2015
		NL 2010777 A	25-11-2013
		US 2015160569 A1	11-06-2015
		WO 2013174656 A2	28-11-2013

SCHRIFTELIJKE OPINIE

DOSSIER NUMMER NO140520	INDIENINGSDATUM 22.10.2019	VOORRANGSDATUM 16.11.2018	AANVRAAGNUMMER NL2024075

CLASSIFICATIE
INV. G03F1/62 G03F7/20

AANVRAGER
ASML Netherlands B.V.

Deze schriftelijke opinie bevat een toelichting op de volgende onderdelen:

- ☒ Onderdeel I Basis van de schriftelijke opinie
- ☐ Onderdeel II Voorrang
- ☐ Onderdeel III Vaststelling nieuwheid, inventiviteit en industriële toepasbaarheid niet mogelijk
- ☐ Onderdeel IV De aanvraag heeft betrekking op meer dan één uitvinding
- ☒ Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid
- ☐ Onderdeel VI Andere geciteerde documenten
- ☒ Onderdeel VII Overige gebreken
- ☒ Onderdeel VIII Overige opmerkingen

DE BEVOEGDE AMBTENAAR

Roesch, Guillaume

Aanvraag nr.:

SCHRIFTELIJKE OPINIE

NL2024075

Onderdeel I Basis van de Schriftelijke Opinie

1. Deze schriftelijke opinie is opgesteld op basis van de meest recente conclusies ingediend voor aanvang van het onderzoek.

2. Met betrekking tot **nucleotide en/of aminozuur sequenties** die genoemd worden in de aanvraag en relevant zijn voor de uitvinding zoals beschreven in de conclusies, is dit onderzoek gedaan op basis van:

   a. type materiaal:

   ☐ sequentie opsomming

   ☐ tabel met betrekking tot de sequentie lijst

   b. vorm van het materiaal:

   ☐ op papier

   ☐ in elektronische vorm

   c. moment van indiening/aanlevering:

   ☐ opgenomen in de aanvraag zoals ingediend

   ☐ samen met de aanvraag elektronisch ingediend

   ☐ later aangeleverd voor het onderzoek

3. ☐ In geval er meer dan één versie of kopie van een sequentie opsomming of tabel met betrekking op een sequentie is ingediend of aangeleverd, zijn de benodigde verklaringen ingediend dat de informatie in de latere of additionele kopieën identiek is aan de aanvraag zoals ingediend of niet meer informatie bevatten dan de aanvraag zoals oorspronkelijk werd ingediend.

4. Overige opmerkingen:

Aanvraag nr.:

SCHRIFTELIJKE OPINIE

NL2024075

Onderdeel V Gemotiveerde verklaring ten aanzien van nieuwheid, inventiviteit en industriële toepasbaarheid

1. Verklaring

Nieuwheid	Ja:	Conclusies	8-19, 22, 23, 28-33, 35-40
	Nee:	Conclusies	1-7, 20, 21, 24-27, 34
Inventiviteit	Ja:	Conclusies	8-19, 22, 23, 28-33, 35-40
	Nee:	Conclusies	1-7, 20, 21, 24-27, 34
Industriële toepasbaarheid	Ja:	Conclusies	1-40
	Nee:	Conclusies	

2. Citaties en toelichting:

Zie aparte bladzijde

Onderdeel VII Overige gebreken

De volgende gebreken in de vorm of inhoud van de aanvraag zijn opgemerkt:

Zie aparte bladzijde

Onderdeel VIII Overige opmerkingen

De volgende opmerkingen met betrekking tot de duidelijkheid van de conclusies, beschrijving, en figuren, of met betrekking tot de vraag of de conclusies nawerkbaar zijn, worden gemaakt:

Zie aparte bladzijde

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following documents:

D1	KR 101 900 720 B1 (S&S TECH CO LTD [KR]) 20 September 2018 (2018-09-20)
D2	US 2018/329289 A1 (GALLAGHER EMILY [US] ET AL) 15 November 2018 (2018-11-15)
D3	US 2017/038676 A1 (JUNG YONG-SEOK [KR] ET AL) 9 February 2017 (2017-02-09)
D4	US 2017/038675 A1 (AHN JINHO [KR] ET AL) 9 February 2017 (2017-02-09)
D5	US 2013/004711 A1 (DOI SEITARO [JP] ET AL) 3 January 2013 (2013-01-03)

1 The subject-matter of claim 1 is not new.

1.1 D1 discloses in paragraphs 24, 25, 31, 35-39, 54, 55, claims 17 and 23 and figures 1-5 a pellicle for EUV lithography (paragraph 31) comprising a frame (figure 1, parts 110 and 130a); and a membrane (120) supported by the frame, wherein the membrane comprises a metallic or semimetallic layer (claim 23: the center layer comprises Y, Zr, Nb, or Mo; paragraph 35: the reinforcing layer are made of Mo or Ru),
wherein the membrane comprises pores at a density of at least 5 per square micron (this is considered an intrinsic property of the porosity and roughness disclosed D1 in view of the roughness lower than 10 nm in paragraph 55 for uniformity and in view of the surface increase in paragraph 38 to increase heat radiation).

1.2 D2 discloses in paragraphs 6, 25-28, 33, 35, 87, 88, 110-113 and figures 1, 2, 4 a pellicle for EUV lithography comprising a frame (402 in figure 4); and a membrane (102, 202) supported by the frame, wherein the membrane comprises a metallic or semimetallic layer (paragraphs 25-28: the nanotubes are coated with Mo or Ru), wherein the membrane comprises pores at a density of at least 5 per square micron by construction (the pores defined by the fibers form a high number in view of the geometric properties disclosed in paragraph 110: gaps smaller than 100 nm and fiber diameters smaller the 30nm).

1.3 D3 discloses (paragraphs 7-10, 16 and figures 1-2D) a pellicle for EUV lithography comprising a frame (150, 160 in figure 1); and a membrane supported by the frame, wherein the membrane comprises a metallic or semimetallic layer (paragraph 16), wherein the membrane comprises pores at a density of at least 5 per square micron (intrinsic property of a nanowire mesh).

2 The subject-matter of claim 20 is not new.

The membranes in D1, D2 do not contain gold and have the properties of claim 20 (see above).

3 The subject-matter of claim 21 is not new.

D1 and D2 disclose the pellicles for EUV lithography comprising frames and the membranes above (D1 paragraph 31, D2 figure 4).

4 The subject-matter of claim 24 is not new.

4.1 D1 discloses see the passages cited above) a method of manufacturing a pellicle for EUV lithography comprising applying a first material on a second material for forming a frame of the pellicle; applying a third material for forming a metallic or semimetallic layer of a membrane of the pellicle on a substrate layer of the membrane (see the stack of layers in the figures); and
forming pores in the substrate layer at a density of at least 5 per square micron (in D1, this is done by etching, as disclosed in paragraphs 26 or 39).

5 The subject-matter of claim 34 is not new.

5.1 D2 discloses (figure 2 and paragraphs 33 and 35) a membrane for a pellicle for EUV lithography, the membrane comprising a grating (the passages refer to a "pitch" which is characteristic of a grating) comprising a plurality of holes (the holes correspond to the depressions of the pressed part 212 in figure 2).

5.2 Similarly, the mesh of D3 comprises an array of holes (paragraph 73 and SP1 in figure 2C for example).

6 Dependent claims 2-7, 25-27 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty and/or inventive step:

6.1 Claims 2, 3: In view of D1 and of the effect of improving heat radiation, it is considered that reaching the pore density of claims 2 and 3 is a natural option. In D2, diameters and spacing of the nanotubes are given that correspond to such pore densities.

6.2 Claim 4: See the stack in D1. D2 discloses a nanotube substrate carrying the metal layer.

6.3 Claim 5: D1 discloses a polycrystalline Si (paragraph 37) substrate with a metal reinforcing layer (paragraph 35).

6.4 Claims 6, 7: D1 discloses a thickness up to 10nm (paragraph 35).

6.5 Claims 25-27: In D1, when the third layer (reinforcing layer) is a metal, the first material (core layer) is the substrate, and the pores can be formed before or after deposition of the third metal (paragraph 39).

7 **Positive opinion:** The combination of the features of dependent claims 8-19, 28-33, 35-40 is neither known from, nor rendered obvious by, the available prior art. The reasons are as follows:

7.1 D1 is regarded as being the prior art closest to the subject-matter of claim 8. The use of a semimetallic layer with a thickness of at least 10nm is an alternative to the metal coating.

This alternative is considered inventive because no semimetallic coating was found in the prior art at hand.

7.1.1 Dependent claims 9-19 incorporate the features of claim 8 and are therefore also novel and inventive.

7.1.2 Independent claims 22 and 23 are also considered novel and inventive insofar as they incorporate the features of novel and inventive dependent claims.

7.2 Claims 28-33 are novel over D1 because this document only discloses an etching step for forming the pores. These claims provide alternative processing methods to obtain the porosity. The subject-matter of these claims is considered inventive because no indication is found that would lead the skilled person to their combination of features.

D2 and D3 are not relevant for these claims because they do not involve forming pores into a substrate with an appropriate density, which is a feature of present claim 24, on which claims 28-33 depend.

D4 discloses (see the passages indicated in the search report) the use of template for forming pores. However, as D1 achieves a roughness of less than 10nm and D4 only mentions holes of less than one micron, which is considered too vague and remote from the target of D1, the skilled person would not consider implementing the teachings of D4 in the process of D1.

D5 (see the passages in the search report) discloses alternative processes to obtain textures with sizes compatible with the claimed pore density, but does not use the right processes and, in the case of the formation of the pellicle (second embodiment in D5), uses materials that are not compatible (polymers) with the materials of D1.

7.3 Claim 35 is novel over D1 because this document does not disclose a regular arrangement of pores that could be called a grating having a pitch of less than 200 nm. D2 discloses a lower limit of 200 nm for the pitch, D3 does not disclose a pitch at all. D2 and D3 are therefore also not prejudicial to the novelty of claim 35.

Claim 35 is considered inventive because the skilled person would not be led to decrease the pitch for the membranes of D2 and D3: Using a smaller pitch solves the problem of improving thermal radiative emission. In both documents, a nanostructure is already present (the membranes are made of nano-fibers), which nullifies the effects of a diminution of the pitch of the holes. Increasing the complexity of the process would therefore have no positive effect. Claim 35 is therefore considered inventive.

7.3.1 Claims 36-40 are dependent on claim 35 and are therefore also considered novel and inventive.

<u>Re Item VII</u>

Certain defects in the international application

1 The features of the claims are not provided with reference signs placed in parentheses.

2 The relevant background art disclosed in D1-D4 is not mentioned in the description, nor are these documents identified therein.

<u>Re Item VIII</u>

Certain observations on the international application

1 Claims 5 and 6 relate to a metallic layer. As claim 1 only relates to a membrane contains a metallic **<u>or</u>** a semimetallic layer, claims 8-10 cannot be dependent on claims 5 and 6. The dependency relations therefore render said claims 8-10 unclear.

2 Claim 14 limits the choice of metals the periods 4 and 5, but claim 15, which is also declared dependent on claim 14, relates to elements of other periods (Ta or Pt for example). The dependency relations therefore render claims 14 and 15 unclear.