

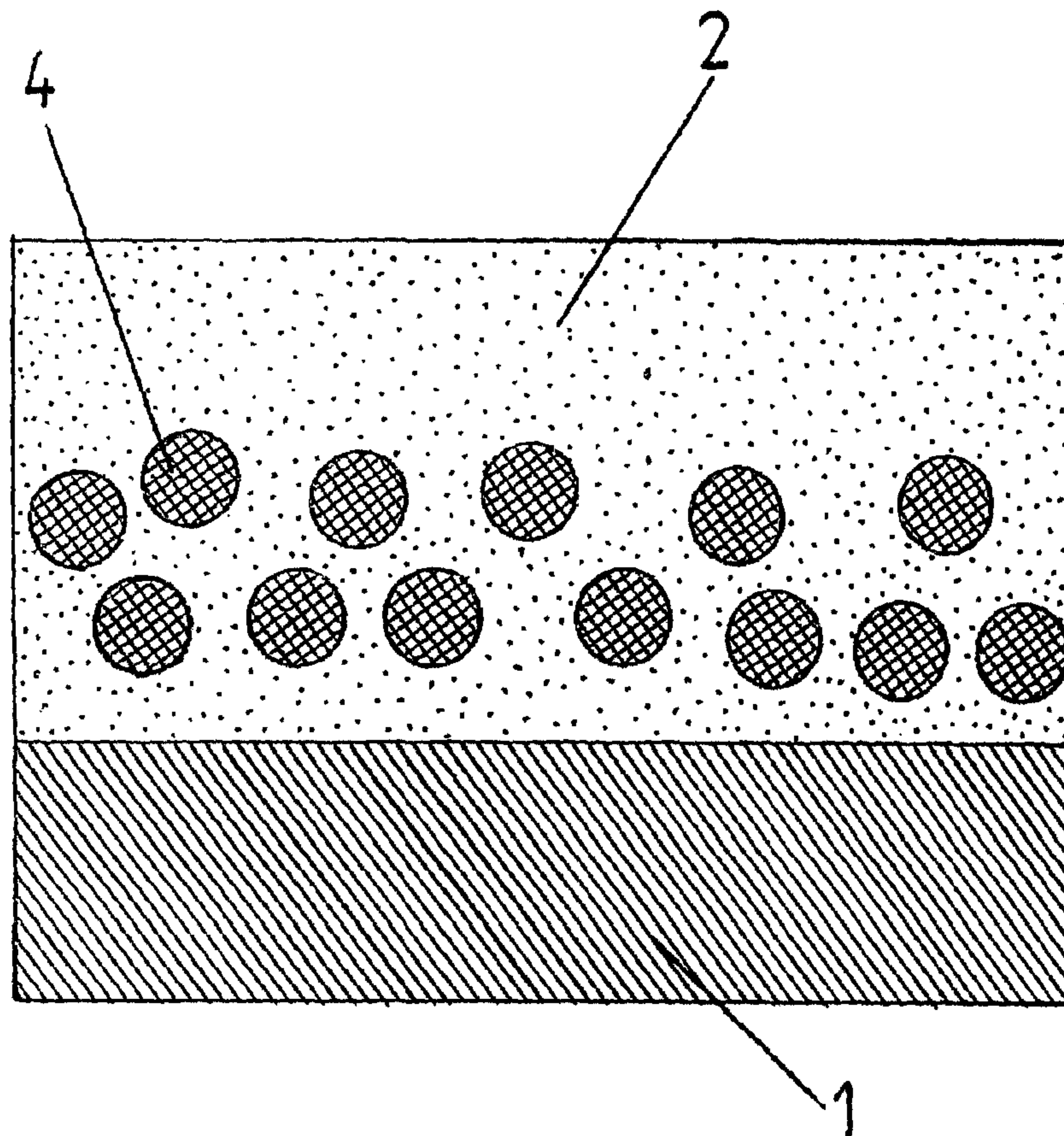


(86) Date de dépôt PCT/PCT Filing Date: 2003/02/19
(87) Date publication PCT/PCT Publication Date: 2003/09/12
(45) Date de délivrance/Issue Date: 2010/09/21
(85) Entrée phase nationale/National Entry: 2005/09/06
(86) N° demande PCT/PCT Application No.: DE 2003/000500
(87) N° publication PCT/PCT Publication No.: 2003/074278
(30) Priorité/Priority: 2002/03/07 (DE102 10 146.9)

(51) Cl.Int./Int.Cl. *B41J 2/44* (2006.01),
B41M 5/24 (2006.01), *B41M 5/40* (2006.01),
C09D 5/00 (2006.01)
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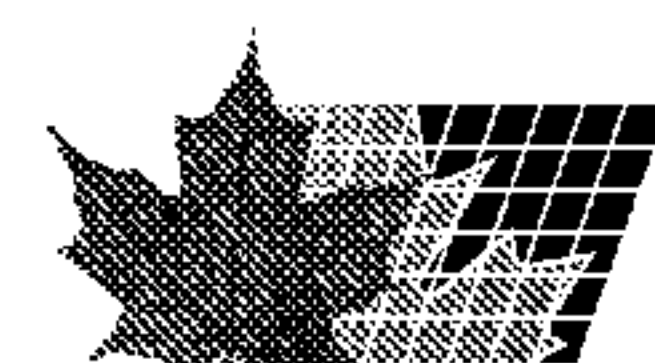
(54) Titre : PROCÉDE D'IMPRESSION DE QUALITE ET MACHINE D'IMPRESSION ET SUBSTANCE D'IMPRESSION A
CET EFFET

(54) Title: QUALITY PRINTING METHOD, PRINTING MACHINE, AND CORRESPONDING PRINTING SUBSTANCE



(57) Abrégé/Abstract:

The invention relates to a printing method for transferring a printing substance (2) from a color carrier (1) onto a material (6) that is to be imprinted, according to which the printing substance (2) undergoes a change in volume and/or position by means of an



(57) **Abrégé(suite)/Abstract(continued):**

energy-dispensing device which conveys heat in the form of electromagnetic waves (3) during a process time. In order to create a printing method which provides an improved printing quality and requires substantially less energy for printing a printing dot while being able to print at a high speed and at a high resolution, and which creates a corresponding printing machine and a corresponding printing substance with which the inventive printing method can be carried out, energy is transferred from the electromagnetic wave (3) into the printing substance (2) by means of absorption bodies (4).

Shapiro Cohen No. 0419P53CA01

Abstract

The invention relates to a printing method for transferring a printing substance (2) from a color carrier (1) onto a material (6) that is to be imprinted, according to which the printing substance (2) undergoes a change in volume and/or position by means of an energy-dispensing device which conveys heat in the form of electromagnetic waves (3) during a process time. In order to create a printing method which provides an improved printing quality and requires substantially less energy for printing a printing dot while being able to print at a high speed and at a high resolution, and which creates a corresponding printing machine and a corresponding printing substance with which the inventive printing method can be carried out, energy is transferred from the electromagnetic wave (3) into the printing substance (2) by means of absorption bodies (4).

QUALITY PRINTING METHOD, PRINTING MACHINE, AND
CORRESPONDING PRINTING SUBSTANCE

5 FIELD OF THE INVENTION

The present invention relates to the field of printing and in particular, to a quality printing method, printing machine, and corresponding printing substance.

BACKGROUND OF THE INVENTION

10 The present invention relates to a printing process for the transfer of printing substance from an ink carrier onto an imprinting material, in which, with the help of an energy-emitting apparatus which emits energy during a process period in the form of electromagnetic waves, the printing substance undergoes a change in volume and/or position, and for example as a result a transfer of a printing point onto the imprinting
15 material takes place, as well as a printing machine and a printing substance for this.

By a printing process is meant primarily a process for the reproduction as often as required of text and/or image patterns by means of a printing plate which is re-inked after each impression. In general, a distinction is made here between four basically
20 different printing processes. Thus firstly the relief printing process is known, in which the printing elements of the printing plate are raised, while the non-printing parts are recessed. This includes for example letterpress printing and so-called flexographic or aniline printing. Furthermore, flatbed-printing processes are known in which the printing elements and the non-printing parts of the printing plate essentially lie in one level. These
25 include offset printing in which strictly speaking the inked drawing on the printing plate is not printed directly onto the imprinting material, but is first transferred onto a rubber cylinder or a rubber blanket and only then is the imprinting material printed from this. Where in the following reference is made to imprinting material, however, this is to be understood as both the actual imprinting material, i.e. the material to be
30 printed on, and any chosen transfer means, such as e.g. a rubber cylinder. A third

process is the so-called gravure printing process in which the printing elements of the printing plate are recessed. A gravure printing process used industrially is so-called
5 rotogravure printing. Finally, a porous printing process is also known in which at the printing positions the ink is transferred onto the imprinting material through screen-like openings of the printing plate.

These printing processes are all characterized by the fact that they require a printing
10 plate which was more or less costly to produce, with the result that these printing processes operate profitably only with very long print runs, usually well over 1000 units.

For the printing of short print runs, printers are already used which are often connected to
15 an electronic data processing system. These use generally digitally triggerable printing systems which are in a position to print individual printing points as required. Such printing systems use various processes with different printing substances on different imprinting materials. Some examples of digitally triggerable printing systems are: laser printers, thermal printers and ink jet printers. Digital printing processes are characterized
20 by the fact that they do not require printing plates.

Thus for example an electro-thermal ink jet printing process is known for example from GB 2 007 162, in which the water-based ink is briefly heated in a suitable ink jet by electrical pulses until it boils, with the result that a gas bubble suddenly forms and an ink
25 drop is ejected from the jet. This process is generally known by the term "bubble-jet". However, these thermal ink printing processes have in turn the disadvantage that on the one hand they consume a great deal of energy for the printing of an individual printing point and on the other hand they are suitable only for printing processes which are water-based. Furthermore, every single printing point must be triggered separately by the
30 jet. On the other hand, piezoelectric ink printing processes suffer from the disadvantage that the required jets are easily blocked, with the result that only special and expensive inks can be used for this.

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20 based. Furthermore, every single printing point must be triggered separately by the jet. On the other hand, piezoelectric ink printing processes suffer from the disadvantage that the required jets are easily blocked, with the result that only special and expensive inks can be used for this.

- 25 It is known from DE 197 46 174 that a laser beam, through very short pulses in a printing substance which is located in cells of a printing roller, induces a procedure with the result that the printing substance undergoes a change in volume and/or position. As a result, the printing substance spreads over the surface of the printing plate and it is possible to transfer a printing point onto an imprinting material moved up against same. However, in
30 this process it is disadvantageous that the filling of the cells is very difficult due to the small diameter of the cells. Therefore it is proposed in DE 100 51 850 to apply the

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30

If on the other hand the printing substance is heated indirectly by introducing the energy firstly into an absorption layer, the required energy is generally even higher as, in addition to the printing substance, the absorption layer must also now be

heated. In addition, the heat conduction in the absorption layer must not be ignored, with the result that a larger area of the absorption layer is necessarily heated, which
5 likewise increases the required energy. Moreover, with the known processes, even a detachment of the absorption layer often occurs.

SUMMARY OF THE INVENTION

The object of the present invention is therefore to provide a printing process which
10 has an improved printing quality and which requires much less energy for printing a printing point, but which at the same time allows a high printing speed with high resolution capacity. The object of the present invention is also to provide a corresponding printing machine and a corresponding printing substance with which the printing process according to the invention can be realized.

15

As regards the process, the object is achieved in that the energy is transferred from the electromagnetic radiation into the printing substance with the help of absorption bodies.

In accordance with one aspect of the invention, there is provided a printing process for
20 the transfer of liquid printing substance from an ink carrier to an imprinting material, in which, with the help of an energy-emitting apparatus, which, during a process period, emits energy in the form of electromagnetic waves, the printing substance undergoes a change in volume and/or position, wherein, with the help of absorption bodies, energy is transferred from the electromagnetic waves into the printing substance, wherein through the change in volume
25 and/or position the printing substance is first transferred to a print transfer medium and then from the print transfer medium onto the imprinting material.

In accordance with another aspect of the invention, there is provided a printing machine for printing on an imprinting material with an ink carrier and an energy-emitting apparatus, which is arranged such that energy can be transferred in a targeted manner onto certain areas of the
30 ink carrier, wherein absorption bodies are provided for absorbing the energy, wherein the printing machine is arranged such that liquid printing substance can be transferred from the ink carrier to a print transfer medium and from the print transfer medium onto the imprinting

4a

material.

Without absorption bodies, the electromagnetic wave penetrates far into the printing
5 substance and is absorbed along a relatively large area. To now achieve the necessary
change in volume and/or position of the printing substance, a relatively large area of
the printing substance must be heated until a gas bubble forms. The effect of using
absorption bodies is that the electromagnetic wave is absorbed essentially at the
surface of the absorption body, i.e. over a much smaller area. As a result, even with a
10 very much smaller energy contribution, a heating occurs at certain points with the
result that the desired change in volume and/or position of the printing substance
already takes place earlier. Moreover, a delay in boiling can be effectively prevented
through the presence alone of the boundary surfaces between printing substance and
absorption bodies which act as a type of crystal nucleus.

15

Through the use of absorption bodies, the required energy can thus be drastically
reduced. There is also a controlled change in position and/or volume of the printing
substance, which moreover scarcely still depends on the printing substance used.

20 Another preferred version of the process according to the invention provides that through
the induced change in position, some of the printing substance is detached from the ink
carrier and the ink carrier then comes directly into contact with the imprinting material
with the result that, at those points at which a change in position has been induced, no
transfer of printing substance onto the imprinting material takes place. In other words,
25 with this version, the electromagnetic wave is directed to those areas which are not to
transfer printing substance.

In a particularly preferred version of the present invention, absorption bodies are used which are smaller than the wavelength of the electromagnetic waves, preferably smaller than a tenth, particularly preferably smaller than a fiftieth of the wavelength of the electromagnetic waves.

5

Through the use of such small absorption bodies, the absorption effect is further increased as the waves are no longer scattered at such smaller bodies, but exclusively absorbed.

10 Advantageously, the energy-emitting apparatus emits energy in the form of laser light. With the help of highly coherent monochromatic laser light, a relatively high amount of energy can be emitted onto a very small area with very short light pulses. As a result, the quality of the print format and in particular the resolution is increased. A short light pulse need not necessarily come from a pulsed laser. It is, rather, actually advantageous if a
15 laser is used in CW operation instead. The pulse duration or better the exposure time does not then depend on the length of the laser pulse but on the scanning speed of the focus. Moreover, the data to be transferred need no longer be synchronized to the fixed pulse frequency.

20 In a further particularly preferred version it is provided that a printing substance is used which contains the absorption bodies. As a result, the area in which the electromagnetic waves are absorbed can be reduced still further, which leads to a further reduction of the required energy supply.

25 A further particularly preferred version provides that the absorption bodies absorb essentially all the light wavelengths. This ensures that the absorption is as complete as possible.

30 However, the consequence of this, in particular when the absorption bodies are contained in the printing substance, can be that not all colours, in particular no bright colours, can

be used as the colour of the printing substance is changed by the addition of the absorption bodies which absorb essentially all the light wavelengths.

Therefore it is provided in another particularly preferred version that the absorption
5 bodies essentially absorb only radiation with a wavelength or in a wavelength range
which corresponds to the wavelength or the wavelength range of the electromagnetic
waves emitted by the energy-emitting apparatus. The absorption bodies thus merely filter
the light of the energy-emitting apparatus out of the incident light, while all the other
light wavelengths can pass unhindered, with the result that the influence of the absorption
10 bodies on the colour of the printing substance is negligible. Through this measure, the
variety of the printing substances to be used can be clearly increased, as the absorption
bodies need merely be added to the printing substances.

Naturally it is also possible, through a suitable choice of the wavelength range in which
15 incident light is absorbed, to also use the absorption bodies as a dye or pigment.

In a particularly preferred version of the present invention, the energy-emitting apparatus
or the beam path of the electromagnetic waves are arranged such that the absorption
bodies are accelerated through the electromagnetic waves of the energy-emitting
20 apparatus in the direction of the imprinting material. As a result the change in volume
and/or position of the printing substance is supported in advantageous manner. The
acceleration of the absorption bodies alone results in a type of shock wave in the printing
substance with the result that, in combination with the forming gas bubble, a defined drop
detachment is favoured. This can be realized for example in that the ink carrier is
25 designed transparent and the light beam from the side of the ink carrier facing away from
the printing substance is focussed through the former into the printing substance. On the
side of the absorption body facing the ink carrier, a gas bubble then forms explosively
which ensures the acceleration of the absorption body in the direction of the imprinting
material.

Naturally it is not absolutely necessary for the absorption bodies to be arranged in the printing substance. In particular when using transparent printing substances an ink carrier is used according to the invention on the surface of which, provided to receive the printing substance absorption bodies are present which preferably form a solid layer.

5

The only essential is that the printing substance comes into contact with the absorption body as directly as possible. However the printing substance need not surround the absorption bodies completely. Because the energy is now no longer absorbed in an absorption layer, but on an absorption body, the surrounding area is heated only very slightly. It is thus possible through the process according to the invention to heat the – preferably very small – absorption body in a targeted manner without losses occurring due to heat conduction.

Because a targeted and reproducible change in position and/or volume of the printing substance can be induced with the help of the absorption bodies, the printing-point size can now advantageously be controlled through the amount of energy emitted by the energy-emitting apparatus. This control can be effected for example by varying the process period or the pulse duration. Although such a control has already been proposed in principle in DE 100 51 850, it was not practicable without the use of absorption bodies as the uncontrolled scatter of the printing-point size overlays the control of the printing-point size via the pulse duration.

When using laser light in another particularly preferred version the printing-point size can also be controlled by the profile of the laser light. By profile of the laser light is meant various transverse electromagnetic modes TEM.

Differences in brightness of the image to be printed can advantageously be achieved by variation of the printing-point size.

30 Surprisingly, tests have shown that the best printing results are achieved

When the process period or the pulse duration is shorter than 1 μ s, preferably shorter than 250 nanoseconds, particularly preferably shorter than 100 nanoseconds and best of all shorter than 50 nanoseconds.

- 5 Moreover it is particularly preferred if during the process period or during the pulse duration an energy density higher than 500 kW/cm², preferably higher than 2 MW/cm² and particularly preferably higher than 10 MW/cm² is achieved at the surface of the irradiated absorption body.
- 10 Furthermore, tests have shown that the best printing quality can be achieved when the radiation-exposed surface of the absorption body is heated during the process period or pulse duration at an average heating rate greater than 10⁹ K/s, preferably greater than 10¹⁰ K/s, particularly preferably greater than 10¹¹ K/s.
- 15 Through the last-named measures a very rapid, point-precise heating of the absorption body results, with the result that – in contrast to the processes of the state of the art – a shock wave and not a sound wave is produced, which leads to a clear improvement of the printing quality.
- 20 The above measures for improving the printing quality are also based, among other things, on a novel raster method, which is preferably used in the present invention, but which in principle can also be used independently of the other features of the present invention. This consists of a line spacing in which printing occurs line-by-line and the individual lines have a very tight distance between each other and even touch in an ideal
- 25 case, with the result that in vertical direction the resolution is set by the distance between lines or the line width. However no fixed point raster is provided in horizontal direction. Instead the “pixels” consist in horizontal direction of line segments of the respective raster lines of varying length with any chosen starting and end point. The scanning of the individual lines preferably takes place with a continuous wave laser which according to
- 30 requirements is simply masked or switched off or its energy is reduced, so as to not print individual sections of the raster lines, while those line segments where the laser is not

masked or turned off are printed. However, the laser itself continues to operate in continuous wave mode in principle. The length of a printed line segment depends simply on the length of the switching-on or revealing time of the laser on the respective line. A printed line thus consists of a sequence of line segments which in general are of different
5 length, their length being determined simply by the switching-on time of the laser, the individual line segments having a line width which essentially remains constant, which ideally corresponds exactly to the distance between adjacent scanning lines or can even be slightly larger (or smaller).

10 However these lines have at their ends small "run-outs" or "roundings", which correspond to the rise time or fall time of the laser during switching on or off or during masking or revealing. Only if the switch-on period or the exposure period for a specific line segment becomes shorter than the rise time and/or fall time at the ends of the respective line segments is the width of the printed line also reduced with the
15 correspondingly reduced length of the printed "line", with the result that when switch-on time is extremely short only points are printed and when switch-on times vary on in the range of the rise and fall times, points of different sizes or different diameters below the line width can be printed. In principle any chosen and very fine shades of grey can be produced in this way.

20

The position of the individual line segments, i.e. in particular their start and end, is not specified by any one grid, but can be varied as desired. In this respect the corresponding printing process is strictly speaking screened only in vertical direction, i.e. perpendicular to the pattern of the individual printed lines, while a "continuous" printing takes place
25 within the lines, i.e. in principle a continuous line is printed which can however be interrupted at any chosen points and for any lengths, with the result that the printed line sections are corresponding line segments of constant width and any choosable length. Only when the length of these line segments is comparable with their width or even shorter is the width of these lines also reduced, with the result that the corresponding line
30 segments are then shortened to individual points, which can also be reduced even further

in their diameter measured in width direction of the lines by further reducing the switch-on time of the laser.

The laser used is preferably a phase-coupled or a CW laser with an average output of more than 10 watts and a beam parameter $M^2 < 1.5$. The “switching-on” and “switching-off” of the laser expediently takes place via a pulse-width modulator in combination with a suitable laser switch (e.g. AOM, EOM). However, in the preferred variant of the invention the laser beam is not fully “turned off” but is only reduced in its energy or energy density to below a threshold limit beneath which there is no detachment of dye drops from the ink carrier. For example there is a reduction in the laser output to 15 % of the value used for a full printing point. This simplifies the control and monitoring of the laser energy when printing, in particular an improved and more effective use of the laser switches or modulators is thereby made possible. In the case where an AOM “switch” is used the laser can thus be used at order 0, while conventional applications of AOM switches have to use the 1st diffraction order. Advantageously the laser has a wavelength between 0.5 μm and 3 μm .

In addition the selected thickness of the printing substance on the ink carrier should be less than 50 μm , preferably less than 30 μm , particularly preferably less than 20 μm . The thickness of the printing substance layer should not fall below 5 μm , however. The optimal range is between 10 and 15 μm .

Advantageously the printing substance is selected such that the viscosity lies between 0.05 and 0.5 Pas.

25

The energy required can be even further reduced if absorption bodies and printing substance are selected such that the absorption bodies are wetted as well as possible by the printing substance. It is thereby ensured that the energy applied to the absorption body is dissipated in the printing substance as directly as possible.

30

As regards the printing machine, the object mentioned at the start is achieved by means of a printing machine for printing on an imprinting material which has an ink carrier and an energy-emitting apparatus which is arranged such that the energy can be transferred in a targeted manner to certain areas of the ink carrier, absorption bodies being provided for
5 absorbing the energy. The energy-emitting apparatus is preferably a laser.

Preferably the absorption bodies have a size smaller than 1 μm , preferably smaller than 200 nanometers and particularly preferably a size between 10 and 50 nanometers. With such small absorption bodies it is ensured that almost no light scattering occurs. The
10 absorption bodies preferably consist of carbon black particles.

The absorption bodies are preferably arranged in an absorption layer applied to the ink carrier.

15 In a particularly preferred version the proportion of absorption bodies in the absorption layer is more than 40 wt.-%, preferably more than 70 wt.-% and particularly preferably more than 90 wt.-%.

In another particularly preferred version the absorption layer consists of pressed
20 absorption bodies.

The absorption bodies can also be embedded in an organic or inorganic polymer matrix, such as e.g. polysilicates but also epoxy resin. It is also possible to embed the absorption bodies in an elastomer matrix, for example rubber. It is thereby ensured that the
25 absorption bodies are arranged largely separated from one another.

An expedient version provides that the ink carrier consists of a transparent polymer strip (polyester), because there is then a good wettability for printing substances based on an alcoholic, aqueous or aromatic solvent.

As regards the printing substance, the object mentioned at the start is achieved by a printing substance which contains absorption bodies.

These absorption bodies advantageously are of a size smaller than 1 μm , preferably
5 smaller than 200 nm and particularly preferably between 10 and 50 nm.

In particularly preferred versions of the printing substance the printing substance consists of binder, dye or pigment, solvent, additives and the absorption bodies.

10 In another particularly preferred version the absorption body forms the dye, i.e. the absorption body has a natural frequency band in the visible region, with the result that selectively determined frequency areas are absorbed.

A further advantageous version provides that the printing substance has a blowing agent.
15 A blowing agent is an agent which boils at a relatively low temperature, so that gas bubbles already form at a low temperature. A further reduction of the energy to be supplied can thereby be achieved. Printing substances which boil at a temperature $\leq 100^\circ\text{C}$ are particularly suitable. Advantageously the blowing agent is used as solvent at the same time. Alcohols, esters, ketones and water among others may be used as blowing
20 agent. In the case of solvent-free inks, e.g. offset inks or UV inks, blowing agents are expediently added.

Expediently more than 10 wt.-%, preferably more than 12 wt.-% and particularly preferably more than 15 wt.-% blowing agent is added. The blowing agent content should
25 be less than 30 wt.-% overall, however.

According to the invention the described printing substance is used in the described printing process according to the invention and/or in the described printing machine according to the invention.

In the preferred version of the invention the printing machine contains a printing carrier which has a surface structure consisting of recesses and elevations, which is designed such that it acts at least partly focussing on a shock wave produced on or immediately above the surface of the ink carrier. These microstructures, e.g. recesses or elevations, are

5 firstly to be smaller than a typical laser beam diameter which is used to produce the shock wave by local heating of the printing substance and they should above all be arranged periodically in at least one dimension, with the period also having a shorter repetition interval than corresponds to the typical diameter of the laser beam. It is also sufficient if there is also microstructurization in essentially only one direction, i.e. if the

10 microstructures consist of e.g. grooves or ribs, which typically run perpendicular to the scanning direction of the laser beam. Preferably the recesses or elevations have a diameter or distance of the order of magnitude of 30 μ and smaller, preferably smaller than 15 μ . The focussing effect is achieved for the pressure waves in a similar way as for the electromagnetic, in particular optical waves. Specifically, therefore, slightly concave

15 shapes, e.g. grooves with an elliptical or concave, optionally also circular cross-section, are provided, where the focussing direction should run as perpendicular as possible to the enveloping surface of the ink carrier, in order that the dye drops ejected essentially perpendicular to the enveloping surface of the ink carrier by a correspondingly directed shock wave have as short a path as possible to the imprinting material and thus have as

20 small as possible a divergence.

The exact design of the recesses depends among other things on the irradiation direction of the laser beam and on whether the laser beam is directed onto an absorption layer or whether absorption bodies are contained in the printing ink itself.

25

It is to be borne in mind, as already mentioned, that in contrast to the state of the art, which partly also already shows surface structures, the surface structures according to the invention have considerably smaller characteristic dimensions, with the result that a specific printing point thus generally comprises several adjacent structural elements.

30

The focussing effect of specific structures can also theoretically be determined according to the rules of optics or optical reflection and/or refraction. The result of a laser beam striking in the area of corresponding structural elements is a very sudden local heating and/or evaporation of the blowing agent, with the result that an explosive pressure wave develops at the site of the heating. This pressure wave is either produced at the base of the ink carrier itself or is reflected there, with the result that on this basis the preferable alignment and focussing of the pressure wave in a preset surface structure can already be easily estimated. Although smaller scatter proportions can never be completely avoided, these are generally not important, especially when, because of the low energy of this scatter proportion, this energy is not sufficient to detach small ink drops or if the surface tension of the ink drop is sufficient to essentially hold the latter together and to detach it only in the main direction of the shock wave.

15

The microstructurization and the restriction of the microstructures to characteristic dimensions, which are even smaller than the diameter of the laser beam scanned away via the ink carrier are thus also important because, in contrast to the state of the art, the afterflow of ink into the microstructures is to be as unrestricted and rapid as possible. Because of the small size of the microstructures the ink layer is also always thicker than the depth of the microstructures, with the result that for these reasons alone the individual recesses cohere over the ink layer.

20

It is understood that elevations attached in a targeted manner periodically and on a small scale can also be designed such that they have a corresponding focussing effect.

25

Other advantages, features and possible applications of the present invention will become apparent from the following description of preferred versions and from the associated figures.

30

BRIEF DESCRIPTION OF THE FIGURES

Figures 1A through 1C show schematic representations of the operating principle of
5 a first version of the process,

Figures 2A and 2B show a schematic representation of the operation of a process of
the state of the art,

10 Figures 3A and 3B show a schematic representation of an advantageous effect of the
first version of the printing process according to the invention,

Figures 4A through 4C show a schematic illustration of a second version of the
process according to the invention,

15

Figures 5A and 5B show a schematic representation of the influence of the correct
energy parameters,

Figures 6A and 6B show a schematic representation of the influencing of the
20 printing-point size,

Figure 7 shows a schematic representation of the influence of the microstructure on
the printing point,

25 Figure 8 shows a schematic representation of the influence of light-focussing
elements,

Figures 9A and 9B show exemplary arrangements of the light-focusing elements,

30 Figure 10 shows another version in a "negative" arrangement, and

Figure 11 shows another version with an additional, interposed ink carrier.

15a

DETAILED DESCRIPTION OF THE INVENTION

Figure 1a shows diagrammatically the situation in the case of a printing process of the state of the art. A laser beam 3 is focussed into the printing substance 2 through the ink carrier 1. The laser beam thus passes through the ink carrier into the printing substance and is absorbed over a large area. The result is that the energy requirement for printing a point is very high, which slows down the printing process and thus reduces the printing speed.

10 Figure 1b shows diagrammatically a first version of the printing process according to the invention. Here, absorption bodies 4 are introduced into the printing substance 2. Here, the laser beam 3 now ensures that the surface of the absorption body 4 heats up strongly, with the result that the energy introduced by the laser beam 3 essentially leads to a punctiform heating of the absorption body 4. Absorption body 4 and printing
15 substance 2 are advantageously selected such that the printing substance 2 wets the absorption bodies

4 very satisfactorily, with the result that the absorption bodies 4 and the printing substance 2 produce a homogeneous suspension. Through the essentially punctiform heating of the absorption bodies 4, an essentially punctiform heating of the printing substance 2 is achieved at the point at which the printing substance 2 wets the absorption body 4. In the version shown in Figure 1, the absorption bodies have an average size of approximately 1 μm .

Figure 1c shows essentially the same situation as Figure 1b, except that here the absorption bodies are very much smaller, namely very much smaller than laser light wavelength. Through the very much smaller absorption bodies 4, the absorption effect is further enhanced as, when the light beam 3 strikes an absorption body 4, only light absorption is still brought to bear, but not light scatter.

The satisfactory wetting of the absorption bodies 4 by the printing substance can be achieved for example in that both absorption bodies 4 and also the printing substance 2 are designed polar, e.g. an alcohol can be used as solvent. Because of the electrostatic attraction, this automatically leads to satisfactory wetting. On the other hand, if the printing substance is designed less polar, if for example benzene or toluene is used as solvent, then the absorption bodies should also be as non-polar as possible, in order to guarantee satisfactory wetting.

In particular in the case of dark printing substances 2 the absorption body 4 can be developed such that it absorbs light with essentially all the light wavelengths. The result is the most complete possible absorption of the emitted laser light by the absorption bodies. However it is also possible to develop the absorption body 4 such that it absorbs only light of the corresponding laser wavelength. As an alternative to this, the absorption bodies 4 can also absorb light of whole wavelength ranges, with the result that the absorption bodies 4 are used simultaneously as dye or pigment.

A further advantage which is achieved by the use of the absorption bodies 4, is illustrated with reference to Figures 2a and 2b in comparison with Figures 3a and 3b. Figures 2a and

2b once again show diagrammatically a printing process known from the state of the art. In Figure 2a, it can be seen that the printing substance 2 is applied to the ink carrier 1. If, as shown in Figure 2b, a laser beam is focussed into the printing substance through the ink carrier 1, vapour bubbles 8 form in the printing substance 2. As no absorption bodies
5 4 are present, the energy of the laser beam 3 is absorbed over a large area, with the result that the energy requirement is very high. The forming vapour bubbles 8 in addition emit a printing pulse essentially in all directions, which can lead to uncontrolled disturbances in the movement of the printing substance 2, with the result that in general no defined drop can become detached, but the printing substance is sprayed in uncontrolled manner.

10

If therefore, as shown in Figure 3a, there are absorption bodies 4 in the printing substance 2, less thermal energy is required for the ejection of a drop from the printing substance 2. This is because, firstly, the thermal energy is essentially absorbed on the surface of the absorption bodies 4, i.e. within a very small volume and, secondly, the surfaces of the
15 absorption bodies 4 form a kind of "crystal nucleus", which ensures controlled formation of gas bubbles. As shown in Figure 3b, during irradiation of the absorption bodies 4 by a laser beam 3 on the side of the absorption bodies 4 which the laser beam 3 strikes, a defined bubble formation occurs, which in turn accelerates the absorption body essentially in one direction, namely in the direction of the irradiated laser beam. Through
20 this movement of the absorption bodies 4 the defined change in volume and/or position of the printing substance 2 is further supported, with the result that a defined drop detachment is favoured. The printing process as a whole is clearly shortened and can be carried out with much less energy.

25 Figures 4a to 4c show a second version of the process according to the invention. Figure 4a once again shows diagrammatically a printing process from the state of the art. Here a laser beam 3 is passed through the printing substance 2 onto an absorption layer 4, which is applied to an ink carrier (not shown). The absorption layer 4 is clearly heated by the laser beam 3. However this does not take place just in punctiform manner, as the heat can
30 spread relatively rapidly in the absorption layer.

According to the invention it is therefore proposed that, as shown in Figures 4b and 4c, the absorption layer 4 contains absorption bodies 8. Here, too, the effect of the absorption bodies 8 is that the heat is essentially focussed in a limited manner on a local area, with the result that in a very short time the detachment of a drop from the printing substance 2
5 can be achieved with relatively little energy, as symbolized by the inkjet 5.

With this version also, it is advantageous to ensure that the absorption bodies provided on or in the absorption layer 9 are satisfactorily wetted by the printing substance 2. Here, also, the absorption bodies 4 are chosen to be as small as possible, i.e. so far as possible
10 very much smaller than $1\text{ }\mu\text{m}$ in diameter, and can for example consist of carbon black particles.

In order to achieve as good as possible and largely punctiform absorption, the proportion of absorption bodies 4 in the absorption layer 9 is as high as possible. The absorption
15 layer 9 advantageously even consists completely of pressed absorption bodies. It is also possible to embed the absorption bodies in an organic or inorganic polymer matrix or in an elastomer matrix, such as e.g. rubber.

Because the laser light is directly absorbed by the absorption body, and only a very small
20 quantity of heat is transferred to adjacent absorption bodies or the absorption layer, in general energy of less than $5\text{ }\mu\text{J}$ is already sufficient for a printing point with a diameter of $> 200\text{ }\mu\text{m}$. For a printing point with a diameter $< 40\text{ }\mu\text{m}$, $1\text{ }\mu\text{J}$ of energy is even sufficient. In comparison with this, an electro-thermal heating element, such as is used for
25 example in the bubble-jet process mentioned at the start, requires between 20 and $30\text{ }\mu\text{J}$ of energy for a printing point with a diameter of approximately $100\text{ }\mu\text{m}$. The energy consumption in the case of direct laser absorption, i.e. the energy required per printing point in the case of a printing process without absorption bodies, is in general even higher.

30 The printing substance 2 can either be present in cells or in other regular structures, such as are known for example from DE 197 46 174, mentioned at the start, or else be

designed as a homogeneous colour film. The advantage of the continuous homogeneous colour film is that the laser beam does not have to be directed into preset structures, such as occurs for example through the cells, but can be directed independently to any desired position, with the result that the printing process operates independently of resolution.

5 However, when cells or the like are not used, the printing substance is no longer guided, with the result that the printing points lose some sharpness. In order to still be able to detach defined drops from an essentially smooth coloured surface by direct laser firing, according to the invention, besides the use of absorption bodies, which as described make possible the defined detachment of a printing point with low energy, further conditions

10 are also observed. Thus the ink viscosity, the ink-layer thickness, the laser exposure time, the laser energy and the laser energy density in the focus as well as the correct blowing agent ratio have to be set in the printing substance. If the exposure time can be kept very short, i.e. very much less than $1\ \mu\text{s}$, and the process energy in the laser focus lies clearly above the threshold value (very much greater than $500\ \text{kW}/\text{cm}^2$) at a laser wavelength of

15 approximately $1\ \mu\text{m}$, the ejection of a drop occurs due to the very high rate of heating up in such a short time that a shock wave spreads perpendicular to the surface in the direction of the imprinting material and the adjacent printing substance is a kind of guide because of its mass moment of inertia.

20 This has been once again illustrated in Figures 5a and 5b. Figure 5a shows the situation in which the preset printing parameters are observed. The laser beam 3 is focussed into the printing substance 2, with the result that a drop 5 detaches from the printing substance 2 and generates a defined sharp printing point 7 on the imprinting material 6. In contrast to this, Figure 5b shows the situation in which the preset parameters are not observed. As

25 the energy used here is clearly higher and the whole area surrounding the focus is also heated up, the result here is an uncontrolled ejection of a drop 5, with the result that a much larger printing point 7 forms on the imprinting material 6.

Figures 6a and 6b show how, according to the invention, the printing-point size can be

30 changed by variation of individual printing parameters. Tests have shown that the size of the printing point and the colour density of the printing point increase with increasing

exposure time, i.e. with the pulse duration of the laser. The size of the printing point can thus be varied in almost infinitely small steps. Differences in brightness in the image to be printed can therefore be represented by printing points of different size. Overall it is possible, through the printing process according to the invention, to clearly improve the print format. The resolution can be increased almost at will, as the printing process is not connected with any kind of preset raster.

Figure 7 shows a further preferred version of the invention. It is clear that the ink carrier 1 has a surface with recesses and/or elevations. The recesses are here applied in the form of grooves 10. The recesses and/or elevations 10 preferably have a diameter of less than 25 μm . The respective depth and height of the recesses and/or elevations is also preferably less than 25 μm . The structure is thus extremely fine. The printing substance forms a continuous surface on the structure of the ink carrier, as also shown in Figure 6. The laser beam 3 passes from behind through the transparent ink carrier 1. The microstructure applied to the ink carrier 1, which can also have the form of cells and/or grooves, ensures that the shock wave conveyed through the absorption bodies runs as far as possible perpendicular to the surface of the ink carrier 1. Surprisingly in several tests it was established that, by suitable "roughening" of the surface of the ink carrier, the quality of the generated printing point 7 on the imprinting material 6 can be considerably enhanced.

At the same time almost any desired fine resolution can be achieved. This is an essential feature distinguishing this version from those printing processes in the state of the art which use cells on the ink carrier. The known cells are distinctly larger, with the result that the printing substance is situated exclusively in the cells (any supernatant printing substance is scraped off). In contrast to this the microstructure here is chosen so that the printing substance forms a continuous layer beyond the structure. The structure is thus completely covered by the printing substance.

The microstructure is irregularly structured in a particularly preferred version, i.e. the individual recesses and/or elevations vary in their extent and depth. A variation of

approximately 10 - 50% of the dimension of the recess and/or elevation is advantageously chosen. The elevations and/or recesses are expediently formed such that the shock wave produced upon striking of the electromagnetic wave is advantageously shaped, with the result that the cleanest possible printing point forms.

5

Figure 8 shows a further version of the present invention. Here light-focussing elements 11 are applied to the ink carrier 1. These light-focussing elements form a microlens system which ensures that the incident focussed light beam is once again split into several small focal spots, so-called "hot spots". The result of this is that the energy density is further increased at certain points, with the result that the energy to be introduced overall can be still further reduced. The individual light-focussing elements 11 are smaller than the focus of the laser, i.e. smaller than 30 μm , preferably smaller than 15 μm , and particularly preferably smaller than 10 μm . The light-focussing elements can, in the arrangement shown in Figure 7 with a transparent ink carrier 1, in principle be arranged both on the side of the ink carrier 1 facing away from the printing substance 2, and also on the side of the ink carrier 1 wetted with printing substance 2. Of course the light-focussing elements can also be integrated into the ink carrier 1.

Figures 9a and 9b show versions with different arrangements of the light-focussing elements 11.

Finally, Figure 10 shows a "negative" arrangement of the printing process according to the invention. The laser beam 3, which is focussed on the ink carrier 1, can be seen. The cylindrical ink carrier 1 is in contact on one side with a dipping roller 14 which in turn dips into a bath with printing substance 2. Upon rotation of the dipping roller and the ink carrier 1 it is ensured that the surface of the ink carrier 1 is covered with printing substance 2.

At certain points individual areas of the printing-substance layer are removed from the ink carrier by means of the laser beam 3. As the ink carrier 1 additionally comes into contact with the imprinting material running over a printing roller 13, that part of the

printing substance which has not been removed by the laser is transferred onto the imprinting material 6. Unlike the process described at the start, here the laser is focussed on the areas which are not to contribute to the transfer of the printing substance.

- 5 It is understood that the additional features of the versions described can also be advantageously realized in other printing processes or in other printing machines.

Finally, Figure 11 shows a further version of the present invention in which, between an inking roller with an absorption layer, onto which the laser is directed, and the printing
10 material guided over a supporting roller, or the web to be imprinted, a continuous blanket guided over several rollers is provided as print transfer medium. This can in particular be a rubber blanket, rubber blankets having the favourable property that they can be guided over particularly narrow radii of curvature.

- 15 The supporting or carrying roller for the rubber blanket, arranged opposite the inking roller, can then have a relatively small diameter, such that it is possible to allow the laser to strike the absorption layer of the inking roller at a relatively steep angle and yet in very close proximity to the rubber blanket, with the result that the drops of ink thereby detached have only a very short distance to travel before they reach the rubber blanket.
- 20 The rubber blanket is then guided over a printing roller, which lies opposite a supporting roller for the printing web, with the result that the ink can be transferred from the rubber blanket onto the printing web.

- Any ink residues still adhering to the rubber blanket after the printing procedure are then
25 removed by a cleaning roller.

CLAIMS

1. A printing process for the transfer of liquid printing substance from an ink carrier to an imprinting material, in which, with the help of an energy-emitting apparatus, which, during a process period, emits energy in the form of electromagnetic waves, the printing
5 substance undergoes a change in volume and/or position, wherein, with the help of absorption bodies, energy is transferred from the electromagnetic waves into the printing substance, wherein through the change in volume and/or position the printing substance is first transferred to a print transfer medium and then from the print transfer medium onto the imprinting material.
- 10 2. The printing process according to claim 1, wherein the print transfer medium is an endless cloth.
3. The printing process according to claim 2, wherein the print transfer medium is a rubber cloth.
4. The printing process according to any one of claims 1 to 3, wherein absorption
15 bodies are used which are smaller than the wavelength of the electromagnetic waves.
5. The printing process according to claim 4, wherein absorption bodies are used which are smaller than 1/10 of the wavelength of the electromagnetic waves.
6. The printing process according to claim 5, wherein absorption bodies are used which are smaller than 1/50 of the wavelength of the electromagnetic waves.
- 20 7. The printing process according to any one of claims 1 to 6, wherein the apparatus emits energy in the form of laser light.
8. The printing process according to claim 7, wherein the printing-point size is controlled by the profile of the laser light.
9. The printing process according to any one of claims 1 to 8, wherein a printing sub-
25 stance is used which contains absorption bodies.

10. The printing process according to any one of claims 1 to 9, wherein the absorption bodies absorb essentially all the light wavelengths.
11. The printing process according to any one of claims 1 to 9, wherein the absorption bodies absorb essentially only the radiation with a wavelength or in a wavelength range
5 which corresponds to the wavelength or wavelength range of the electromagnetic waves emitted by the energy-emitting apparatus.
12. The printing process according to claim 11, wherein the absorption bodies are also used as dye.
13. The printing process according to claim 11 or 12, wherein the absorption bodies are
10 accelerated in the direction of the imprinting material by the electromagnetic waves of the energy-emitting apparatus.
14. The printing process according to any one of claims 1 to 10, wherein an ink carrier is used, on whose surface provided to receive the printing substance absorption bodies are present which preferably form a solid layer.
- 15 15. The printing process according to any one of claims 1 to 14, wherein the printing-point size is controlled by the quantity of energy released by the energy-emitting apparatus.
16. The printing process according to claim 15, wherein the quantity of energy released by the energy-emitting apparatus is controlled by the process period.
17. The printing process according to any one of claims 1 to 16, wherein differences in
20 brightness of the image to be printed are achieved by variation of the printing-point size.
18. The printing process according to any one of claims 1 to 17, wherein the process period is shorter than 1 μ s.
19. The printing process according to claim 18, wherein the process period is shorter than 250 ns.

20. The printing process according to claim 19, wherein the process period is shorter than 100 ns.
21. The printing process according to claim 20, wherein the process period is shorter than 50 ns.
- 5 22. The printing process according to any one of claims 1 to 21, wherein during the process period an energy density higher than 500 kW/cm^2 is generated at the absorption body.
23. The printing process according to claim 22, wherein during the process period an energy density higher than 2 MW/cm^2 is generated at the absorption body.
- 10 24. The printing process according to claim 23, wherein during the process period an energy density higher than 10 MW/cm^2 is generated at the absorption body.
25. The printing process according to any one of claims 1 to 24, wherein the absorption bodies are heated during the process period with an average heating rate greater than 10^9 K/s .
- 15 26. The printing process according to claim 25, wherein the absorption bodies are heated during the process period with an average heating rate greater than 10^{10} K/s .
27. The printing process according to claim 26, wherein the absorption bodies are heated during the process period with an average heating rate greater than 10^{11} K/s .
28. The printing process according to any one of claims 1 to 27, wherein the chosen
20 thickness of the printing substance on the ink carrier is less than $50 \text{ }\mu\text{m}$.
29. The printing process according to claim 28, wherein the chosen thickness of the printing substance on the ink carrier is less than $30 \text{ }\mu\text{m}$.
30. The printing process according to claim 29, wherein the chosen thickness of the printing substance on the ink carrier is less than $20 \text{ }\mu\text{m}$.

31. The printing process according to any one of claims 1 to 30, wherein the printing substance is selected so that the viscosity lies between 0.05 and 0.5 Pas.
32. The printing process according to any one of claims 1 to 31, in which absorption bodies and printing substance are selected so that the absorption bodies are wetted as well
5 as possible by the printing substance.
33. The printing process according to any one of claims 1 to 32, wherein, for the production of a printing point with a diameter greater than 100 μm , an energy of not more than 10 μJ is transferred.
34. The printing process according to claim 33, wherein, for the production of a
10 printing point with a diameter greater than 100 μm , an energy of not more than 5 μJ is transferred.
35. The printing process according to any one of claims 1 to 34, wherein printing is line-by-line, areas to be printed within a line being formed by line segments of any choosable length and any choosable position.
- 15 36. The printing process according to claim 35, wherein the line-by-line printing takes place with a continuous wave laser, which travels line-by-line down the lines of print following a preset raster and which can be switched on and off or revealed or masked as desired along a line.
- 20 37. A printing machine for printing on an imprinting material with an ink carrier and an energy-emitting apparatus, which is arranged such that energy can be transferred in a targeted manner onto certain areas of the ink carrier, wherein absorption bodies are provided for absorbing the energy, wherein the printing machine is arranged such that liquid printing substance can be transferred from the ink carrier to a print transfer medium and from the print transfer medium onto the imprinting material.
- 25 38. The printing machine according to claim 37, wherein the energy-emitting apparatus is a laser.

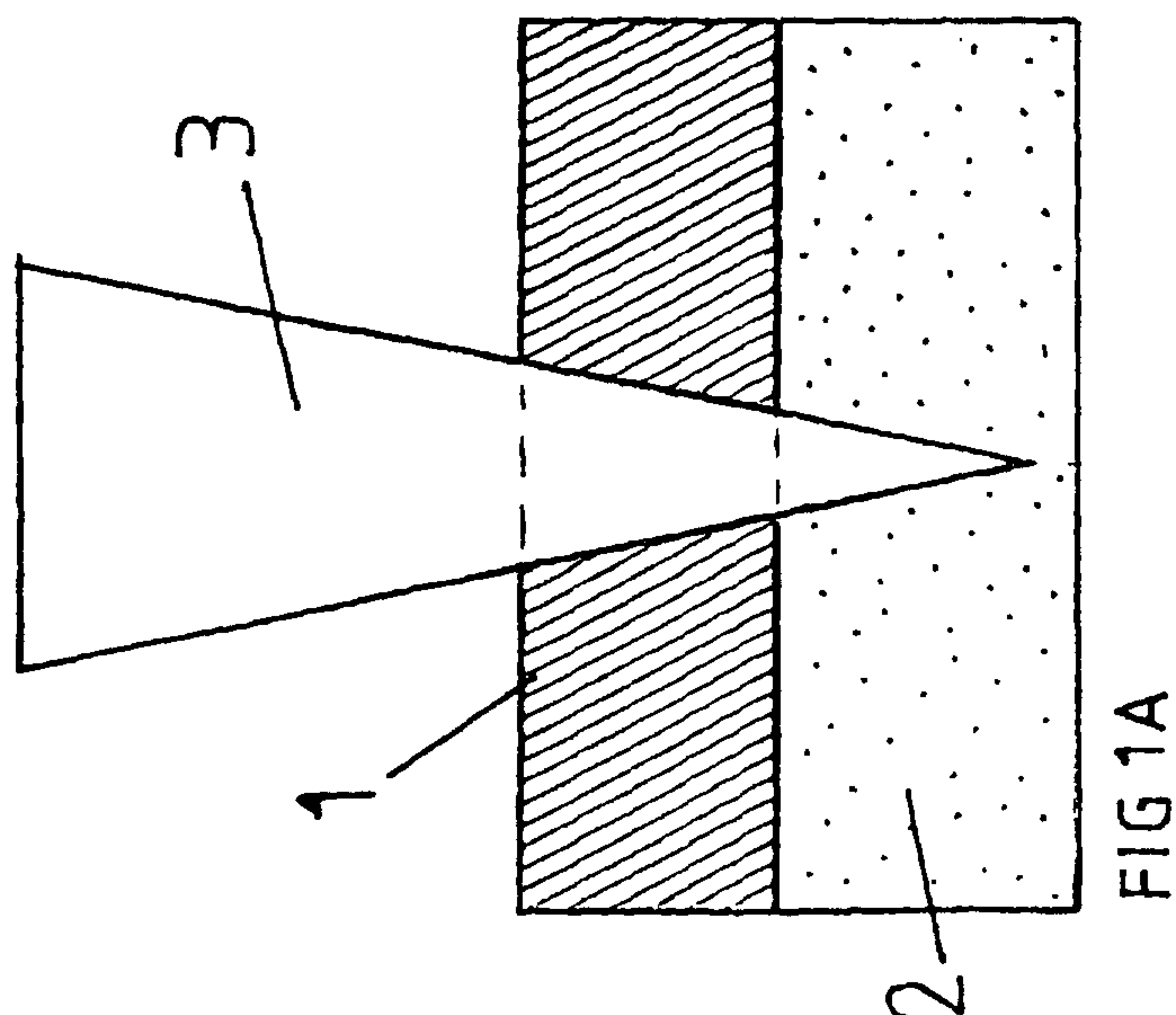
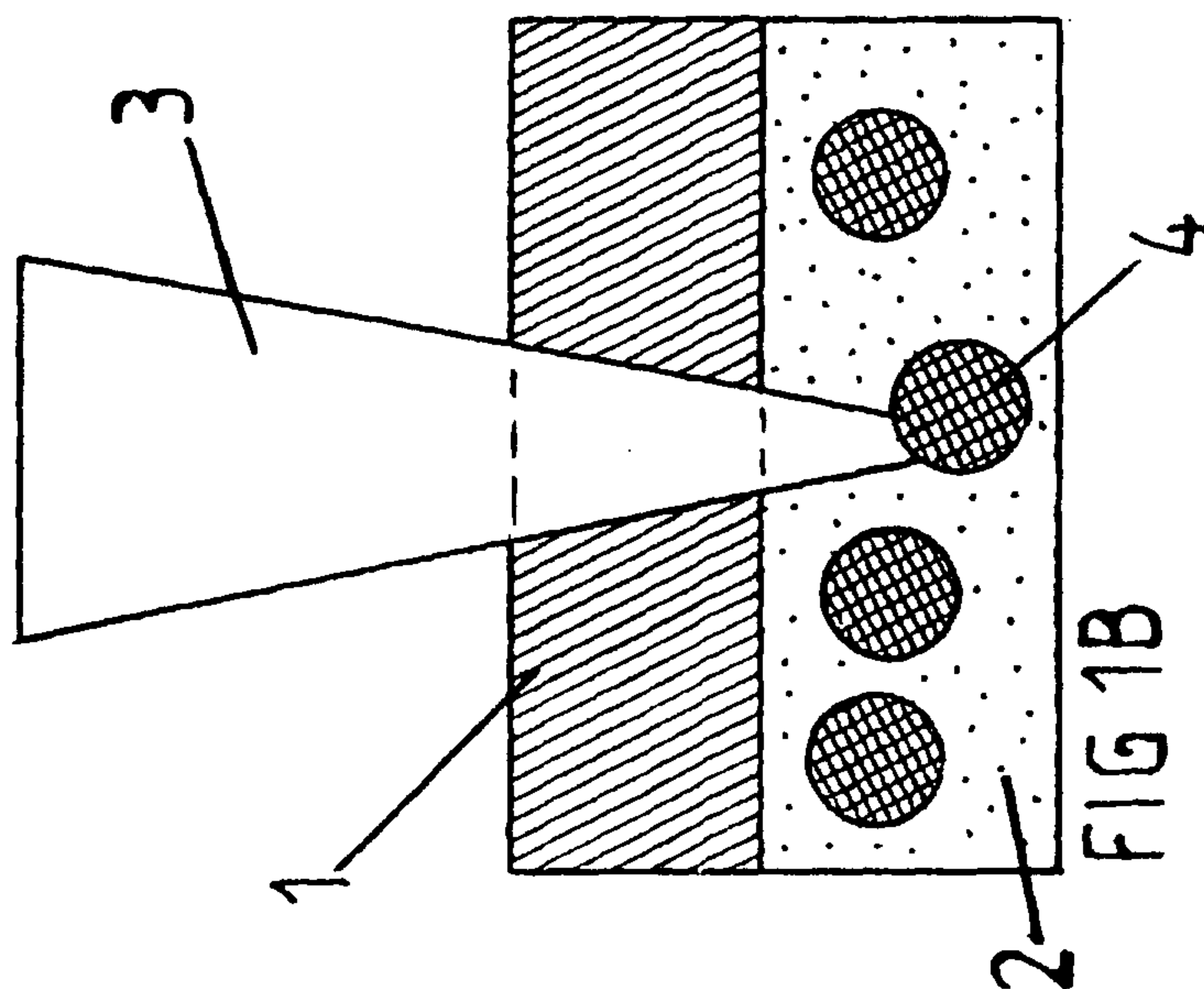
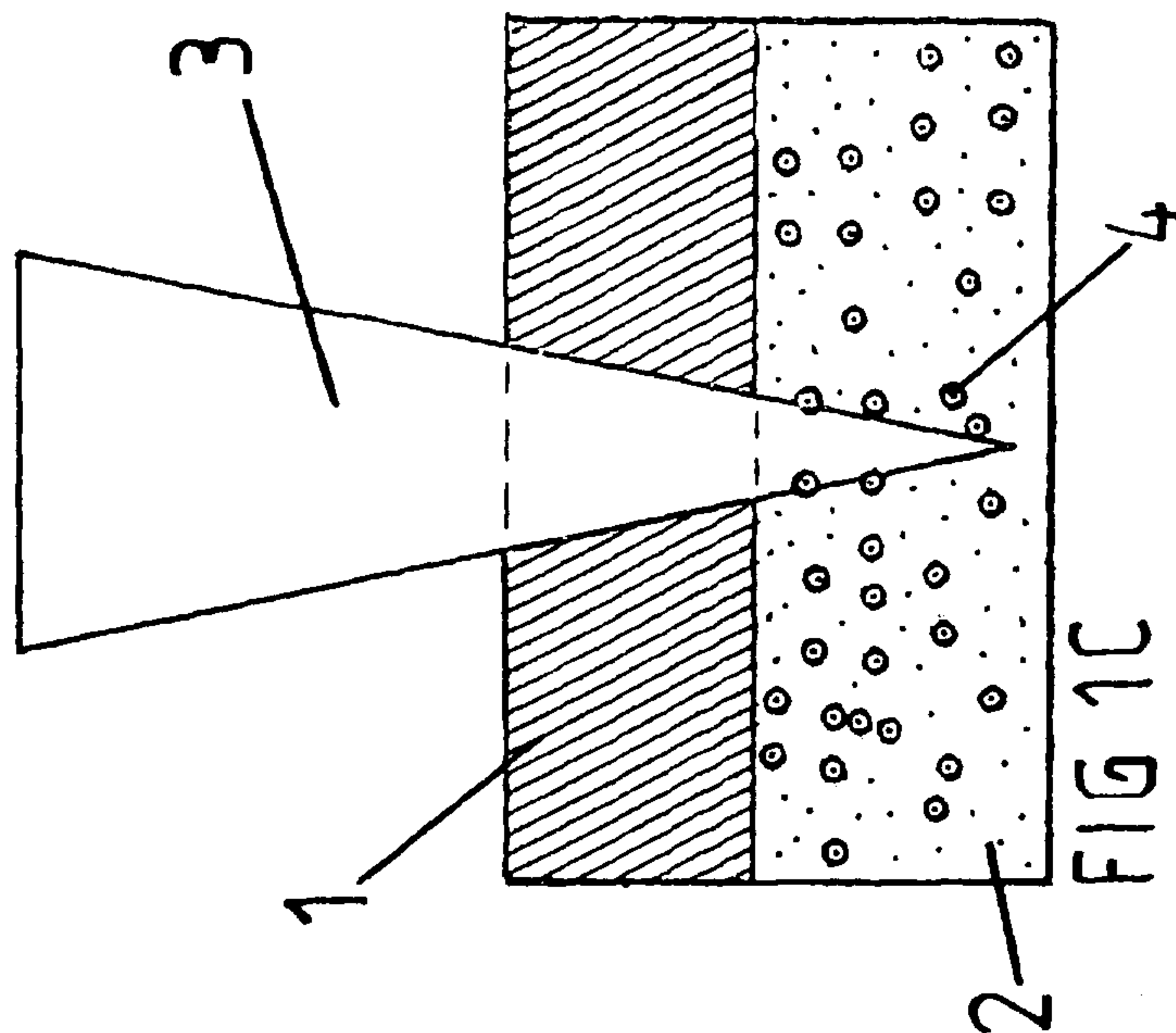
39. The printing machine according to claim 37 or 38, wherein the absorption bodies are of a size which is smaller than 1 μm .
40. The printing machine according to claim 39, wherein the absorption bodies are of a size which is smaller than 200 nm.
- 5 41. The printing machine according to claim 40, wherein the absorption bodies are of a size between 10 and 50 nm.
42. The printing machine according to any one of claims 39 to 41, wherein the absorption bodies consist of carbon black particles and/or titanium nitride.
43. The printing machine according to any one of claims 37 to 41, wherein the
10 absorption bodies are arranged in an absorption layer arranged on the ink carrier.
44. The printing machine according to claim 43, wherein the ink carrier is cylindrical and the absorption layer is fixed on the ink carrier.
45. The printing machine according to claim 43, wherein the absorption layer is arranged on the ink carrier in the form of a flexible strip.
- 15 46. The printing machine according to any one of claims 43 to 45, wherein the proportion of the absorption bodies in the absorption layer is greater than 40 wt.-%.
47. The printing machine according to claim 46, wherein the proportion of the absorption bodies in the absorption layer is greater than 70 wt.-%.
48. The printing machine according to claim 47, wherein the proportion of the
20 absorption bodies in the absorption layer is greater than 90 wt.-%.
49. The printing machine according to any one of claims 43 to 48, wherein the absorption layer consists of pressed absorption bodies.
50. The printing machine according to any one of claims 43 to 49, wherein the absorption bodies are embedded in an organic or inorganic polymer matrix.

51. The printing machine according to any one of claims 43 to 50, wherein the absorption bodies are embedded in an elastomer matrix.
52. The printing machine according to claim 51, wherein the absorption bodies are embedded in rubber.
- 5 53. The printing machine according to any one of claims 37 to 52, wherein the ink carrier has a surface structure which consists of recesses and/or elevations.
54. The printing machine according to claim 53, wherein the recesses and/or elevations have a diameter smaller than 30 μm .
55. The printing machine according to claim 54, wherein the recesses and/or elevations
10 have a diameter smaller than 15 μm .
56. The printing machine according to any one of claims 53 to 55, wherein the recesses and/or elevations have a diameter greater than 2 μm .
57. The printing machine according to any one of claims 53 to 56, wherein the recesses and/or elevations have different diameters.
- 15 58. The printing machine according to any one of claims 53 to 57, wherein the recesses and/or elevations are groove-shaped.
59. The printing machine according to any one of claims 53 to 58, wherein the recesses and/or elevations are arranged on an absorption layer which contains the absorption bodies.
60. The printing machine according to any one of claims 37 to 59, wherein light-
20 focussing elements are applied to the ink carrier.
61. The printing machine according to claim 60, wherein the light-focussing elements have a diameter smaller than 30 μm .
62. The printing machine according to claim 61, wherein the light-focusing elements have a diameter smaller than 10 μm .

63. The printing machine according to any one of claims 60 to 62, wherein the ink carrier is transparent and the light-focussing elements are integrated into the ink carrier.

64. The printing machine according to any one of claims 60 to 63, wherein the light focussing elements are formed by a flexible polymer film.

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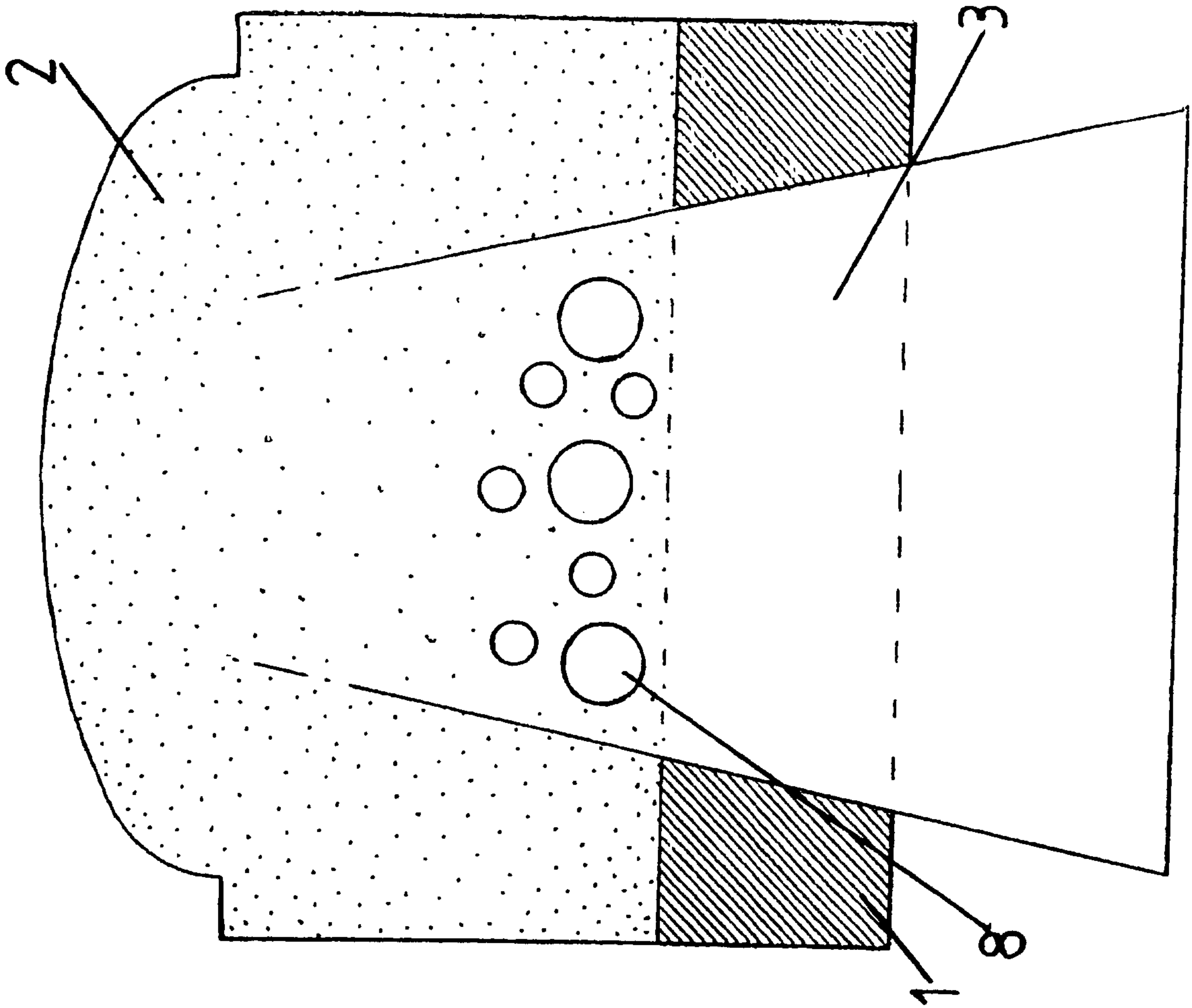


FIG 2B

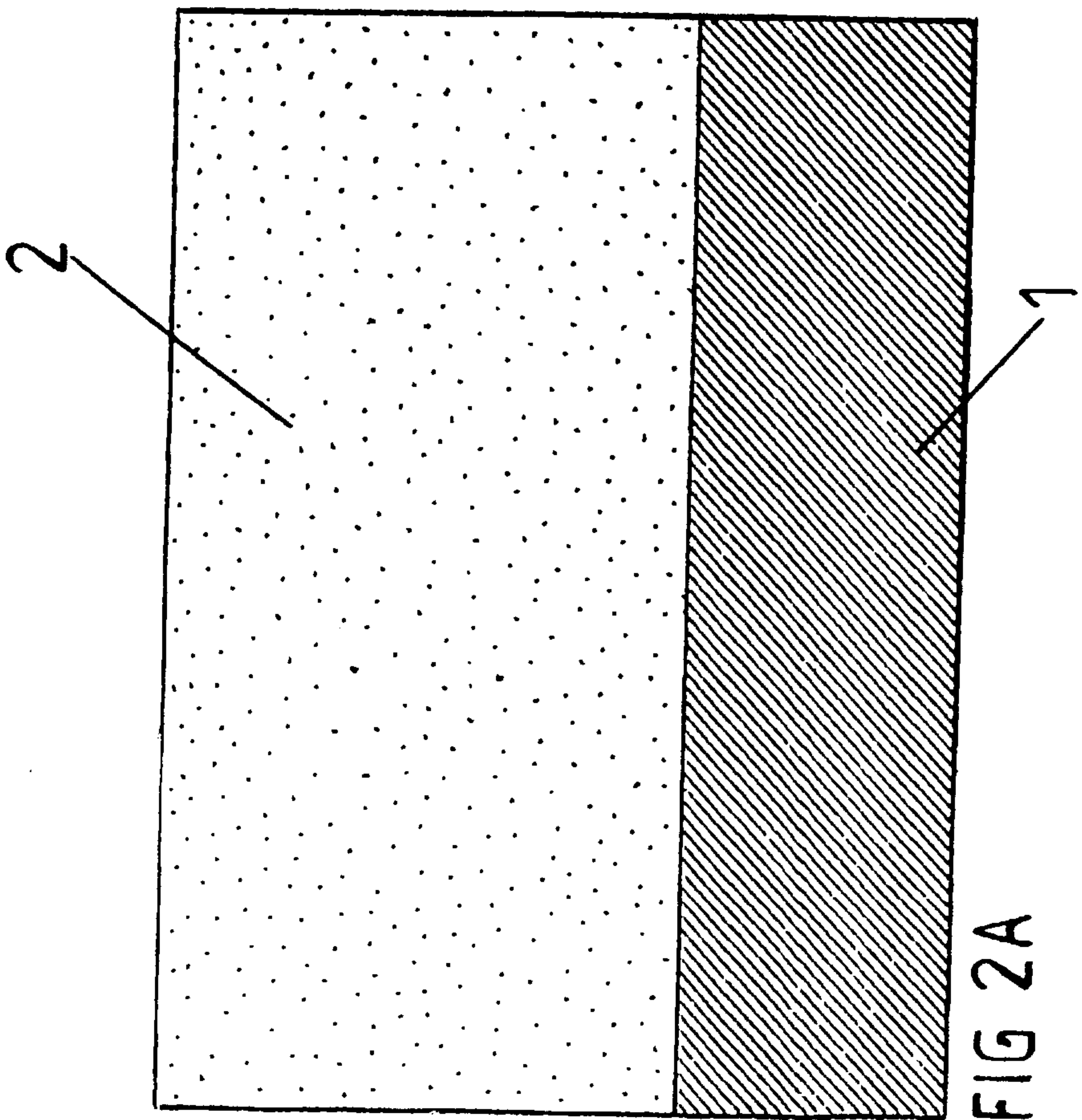


FIG 2A

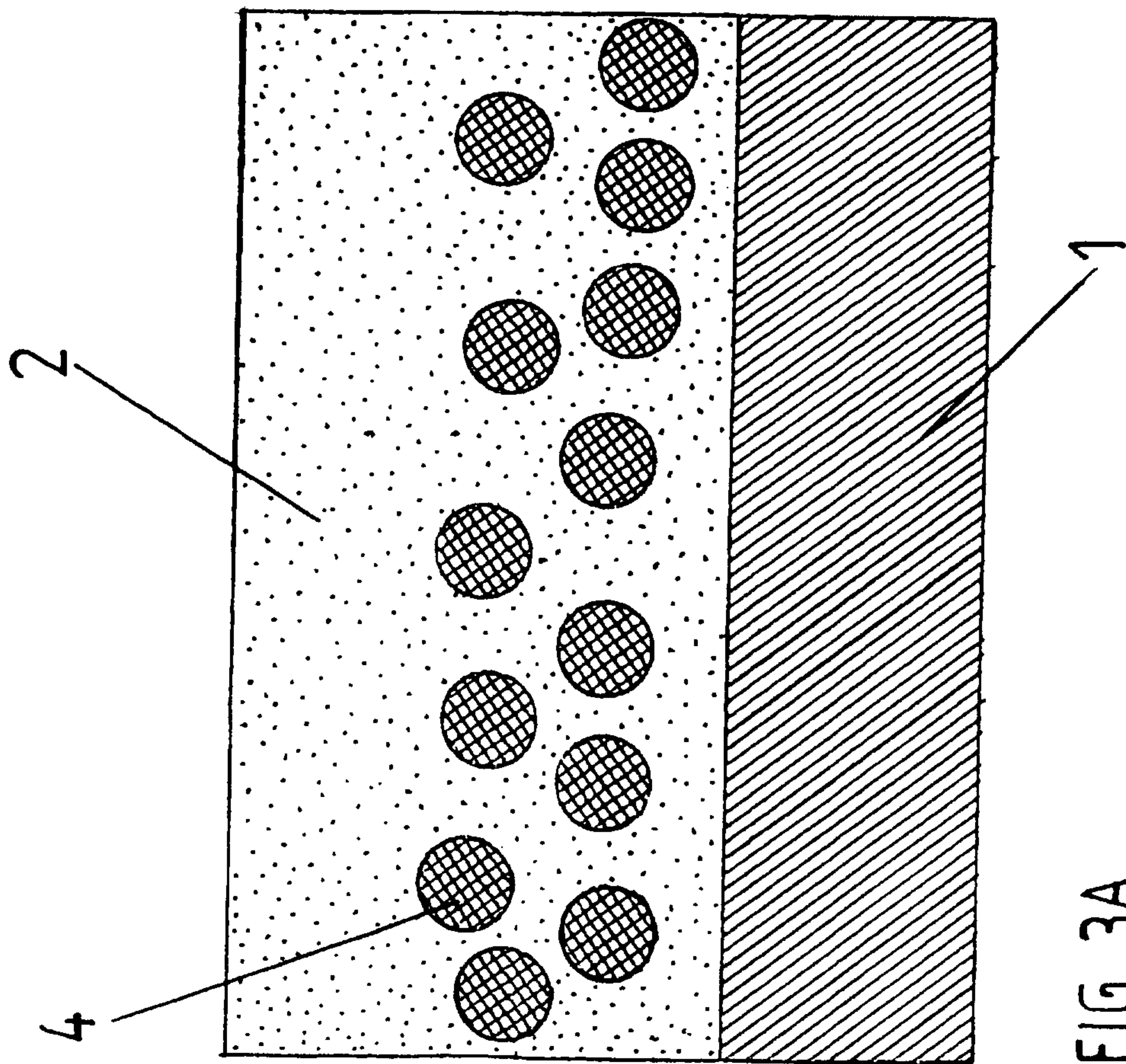


FIG 3A

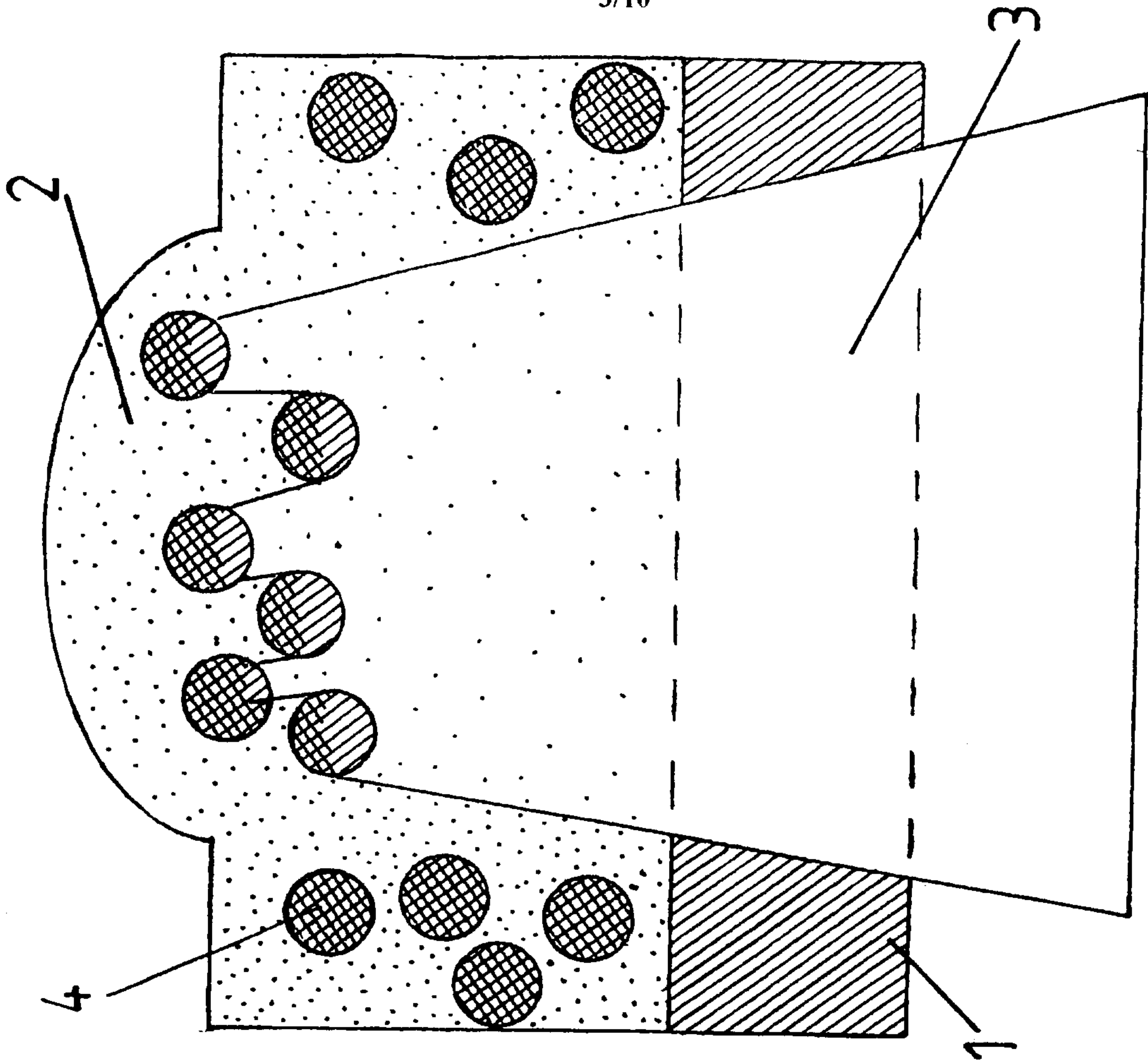
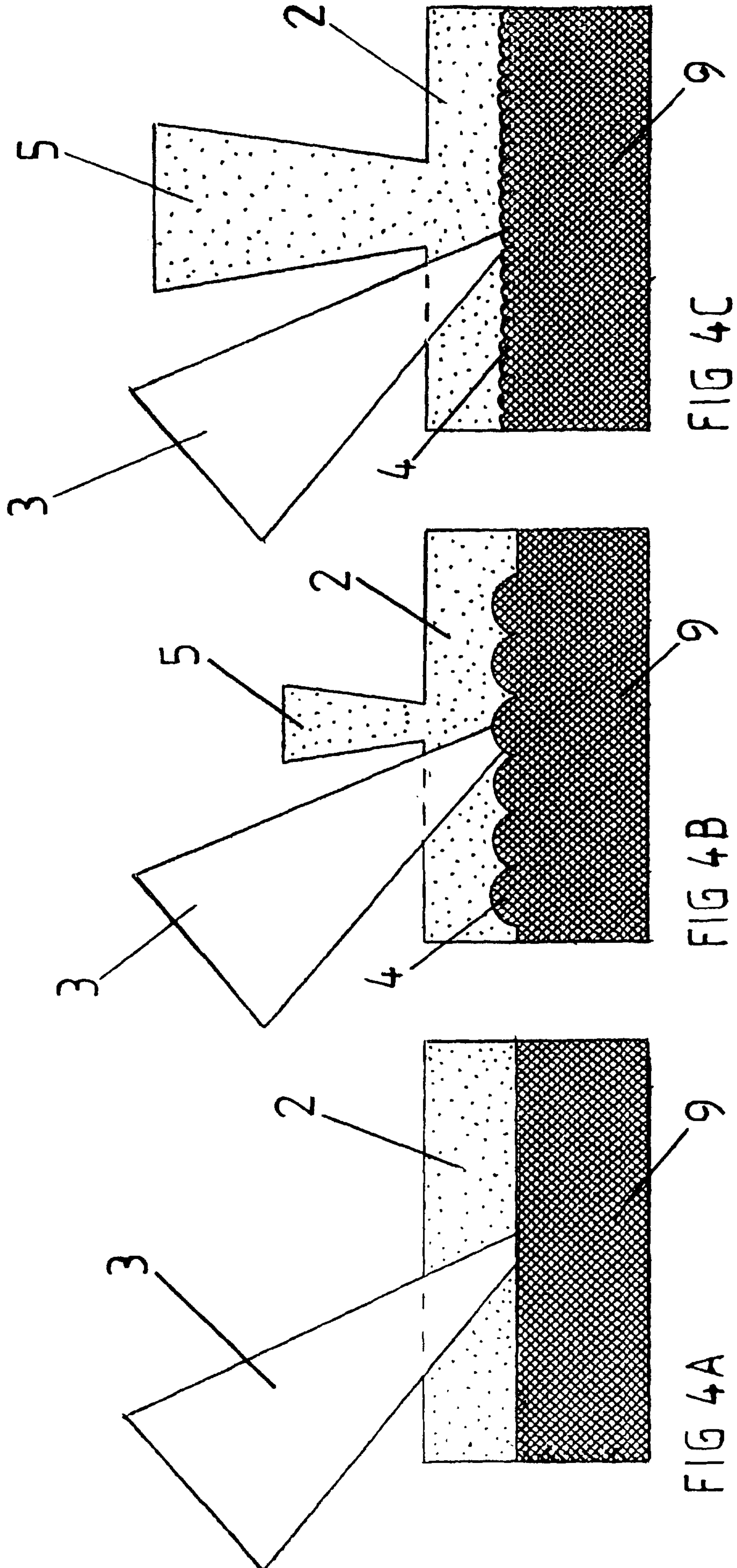


FIG 3B

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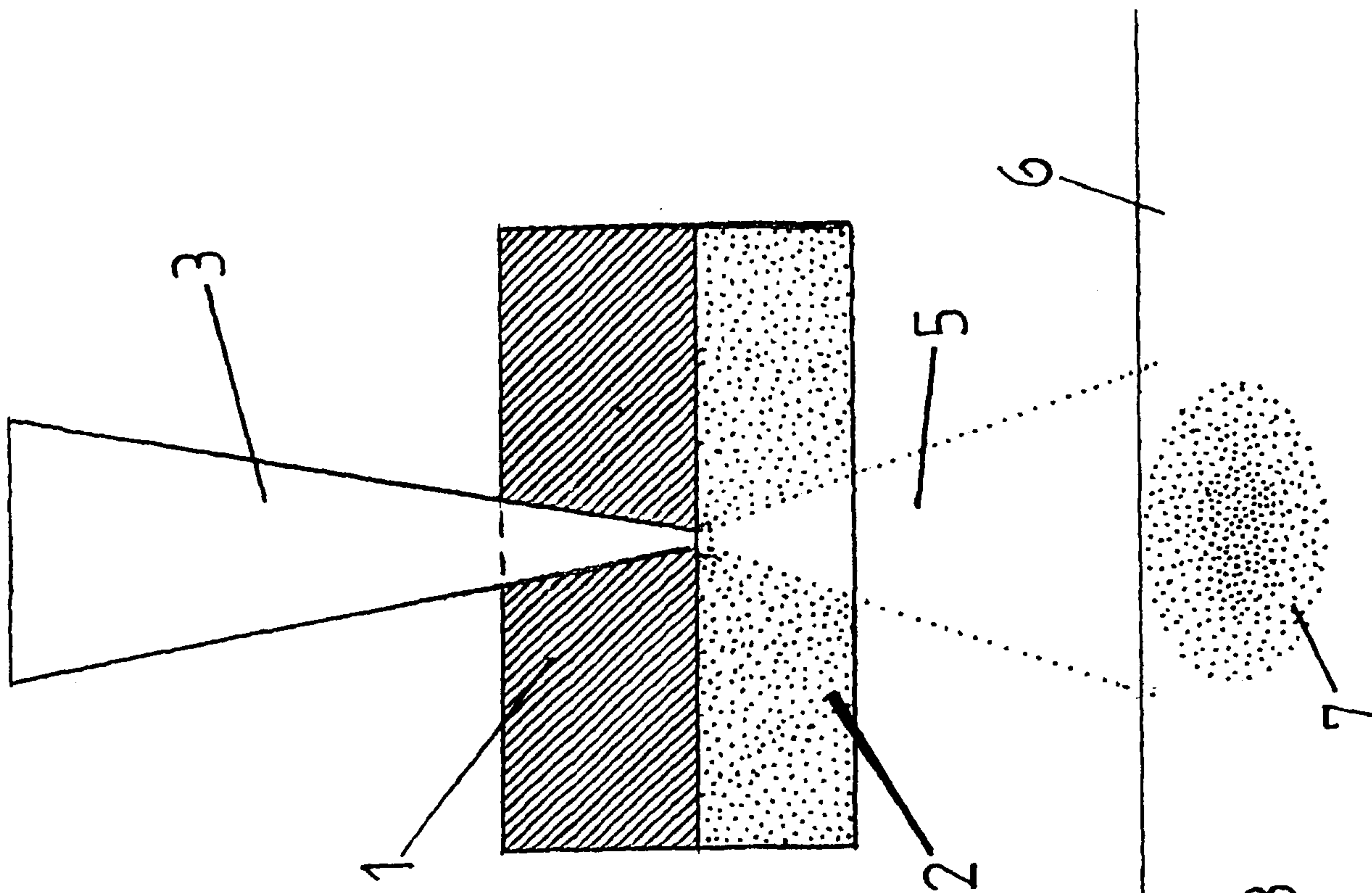


FIG 5B

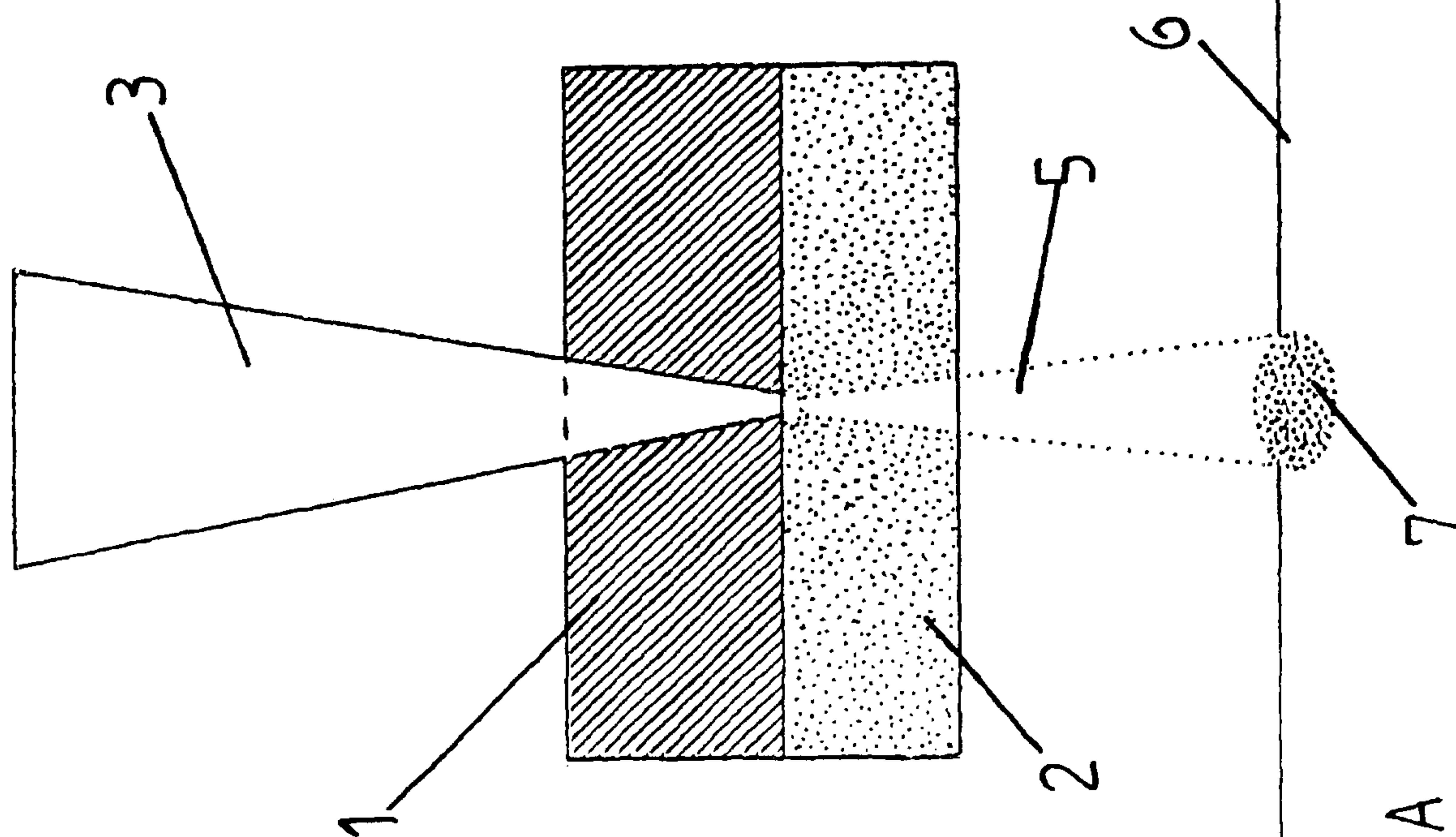
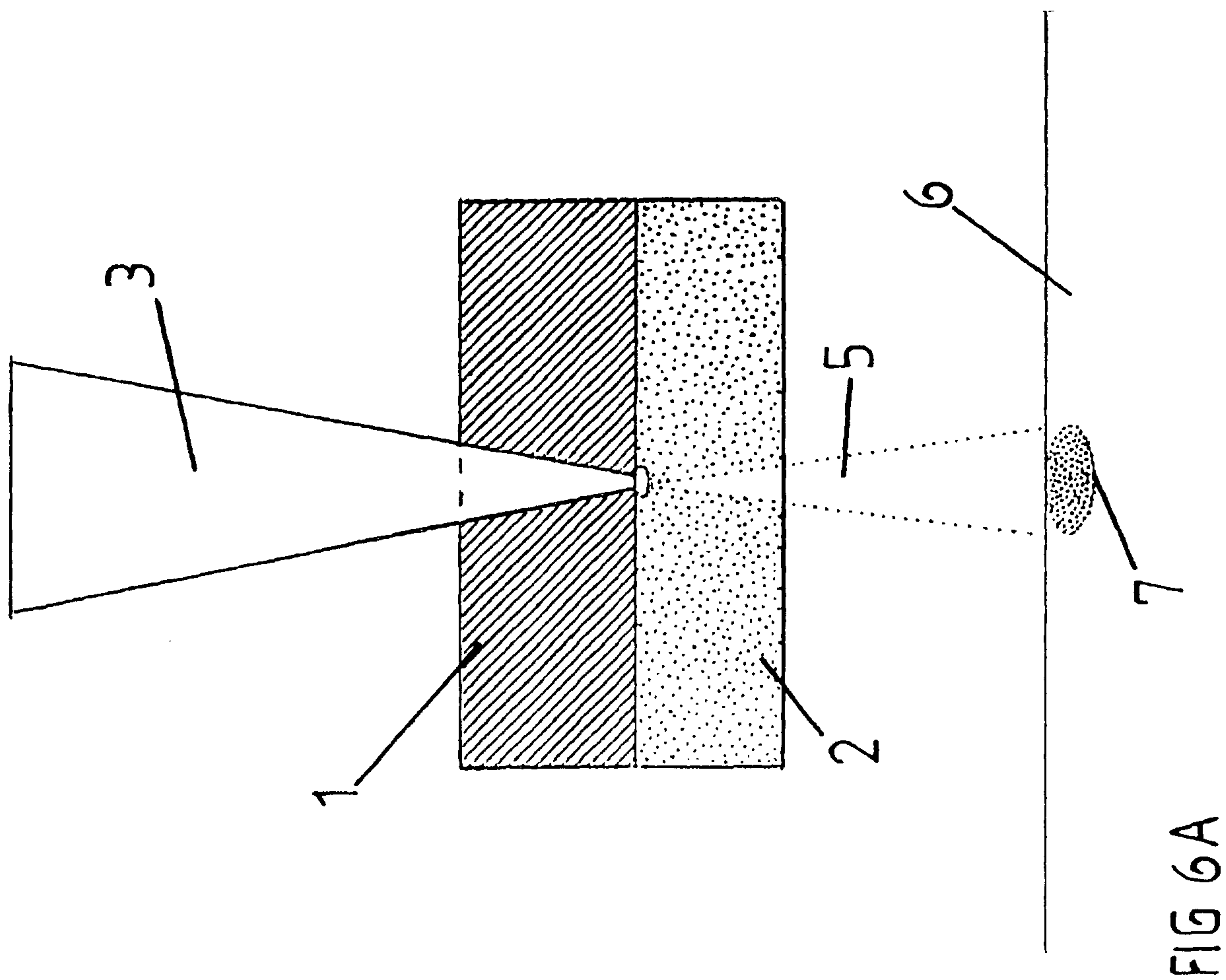
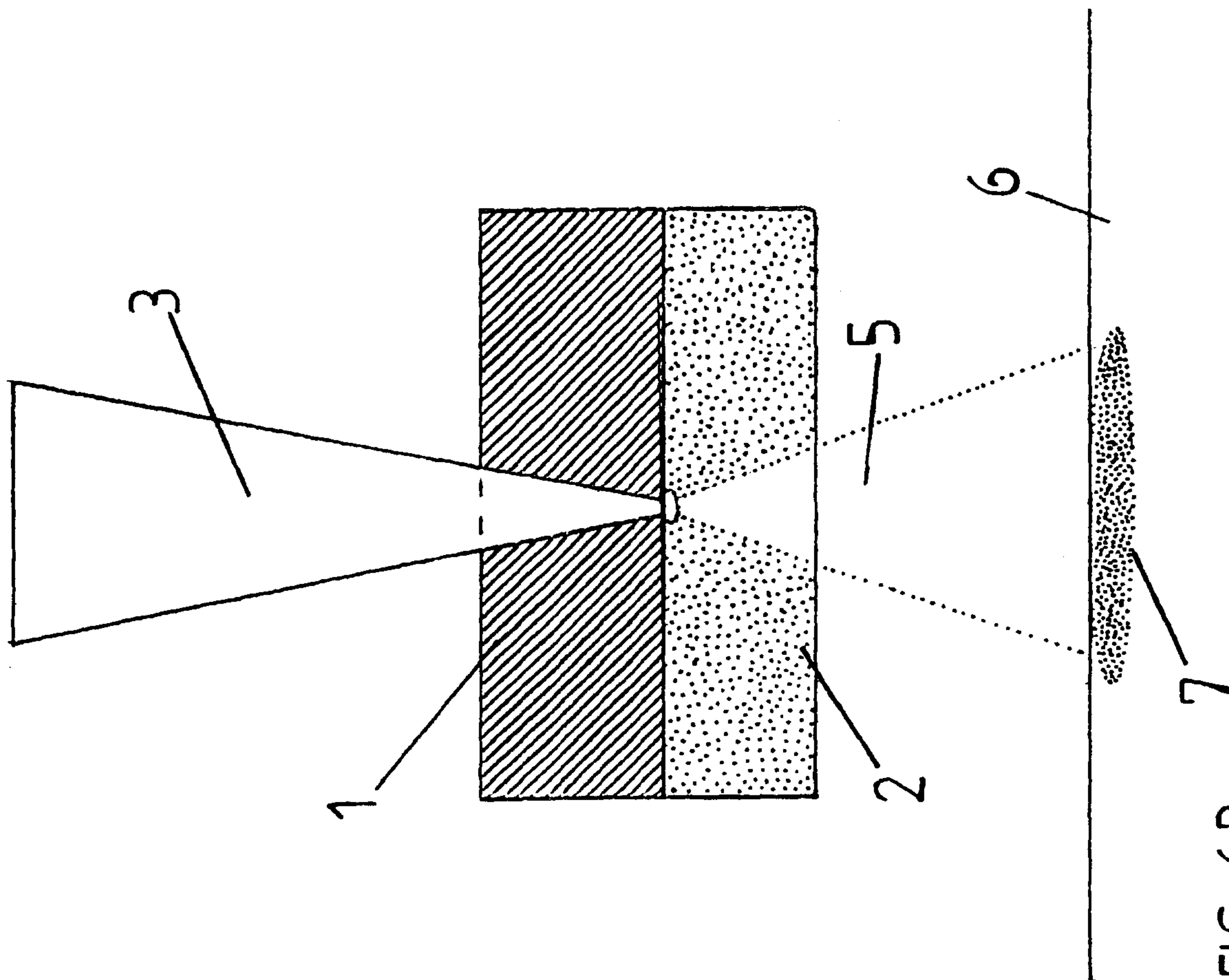


FIG 5A



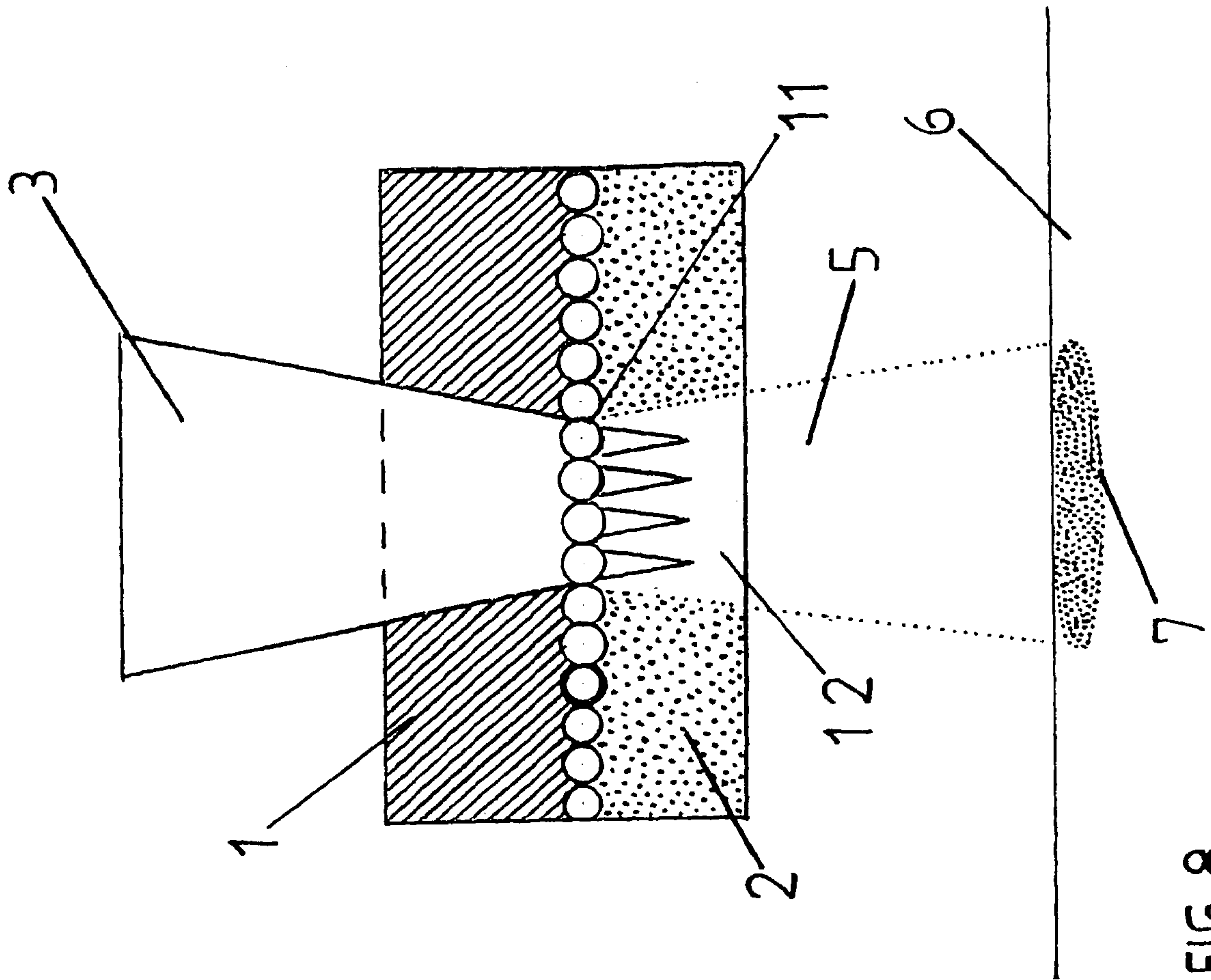


FIG 8

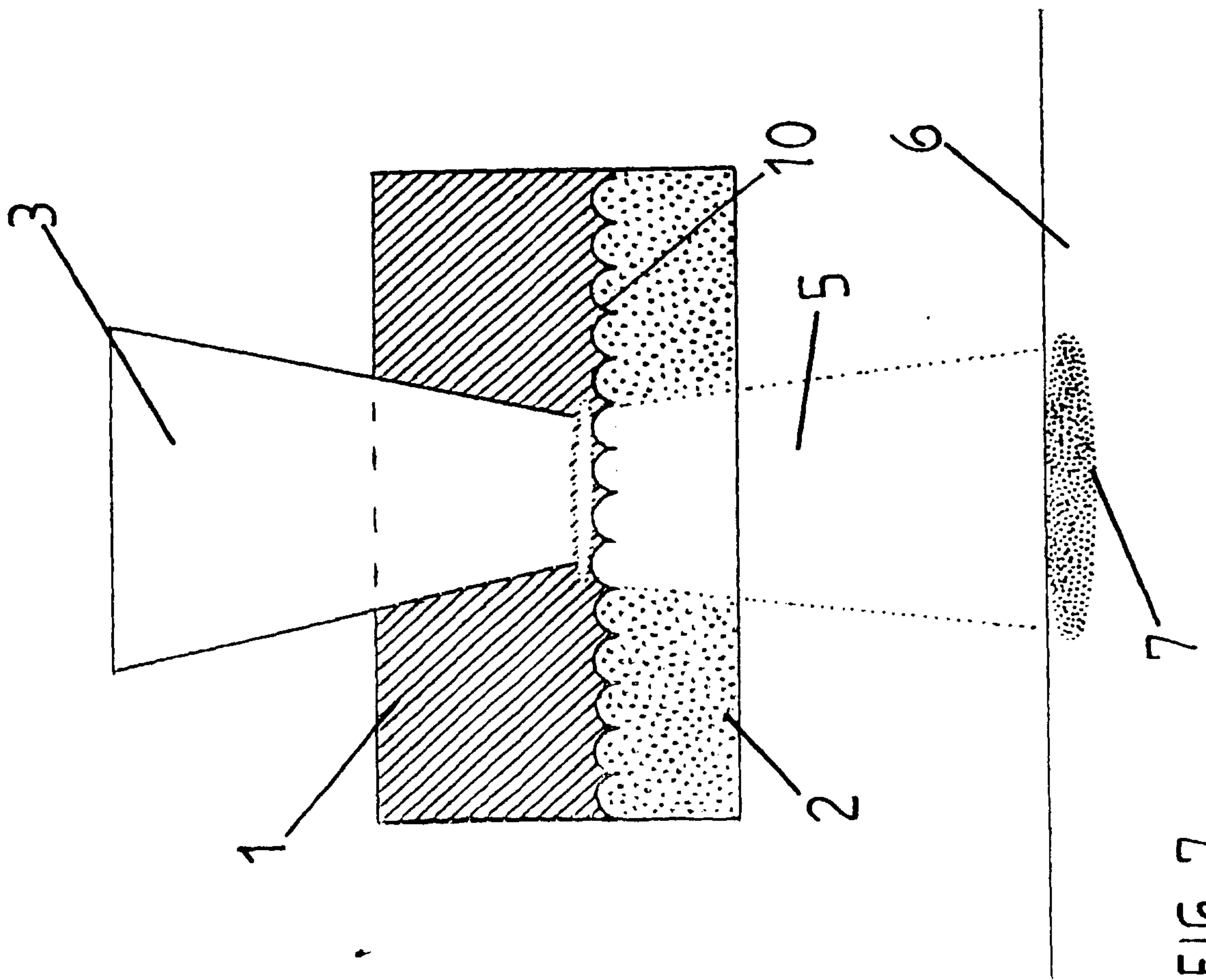
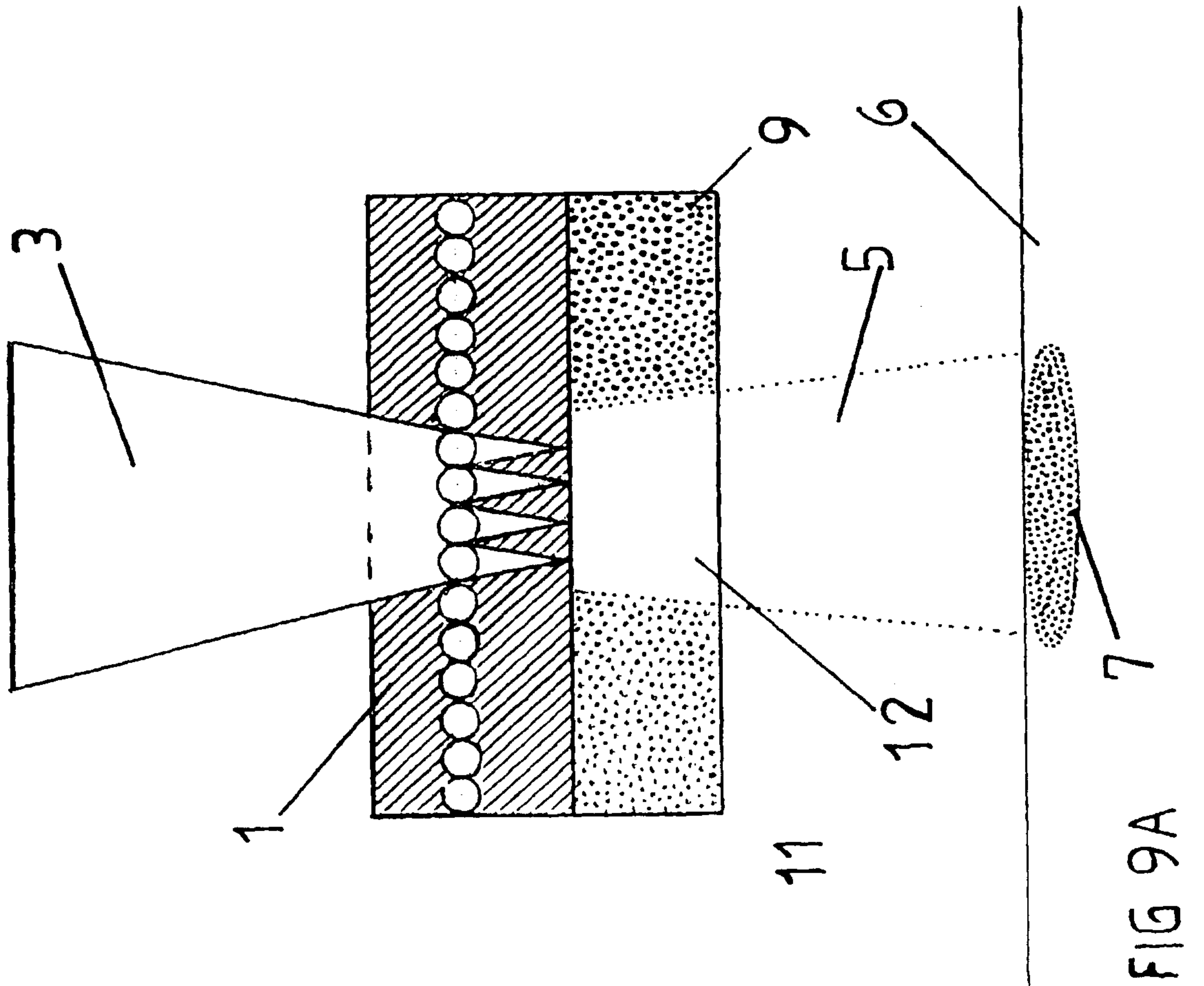
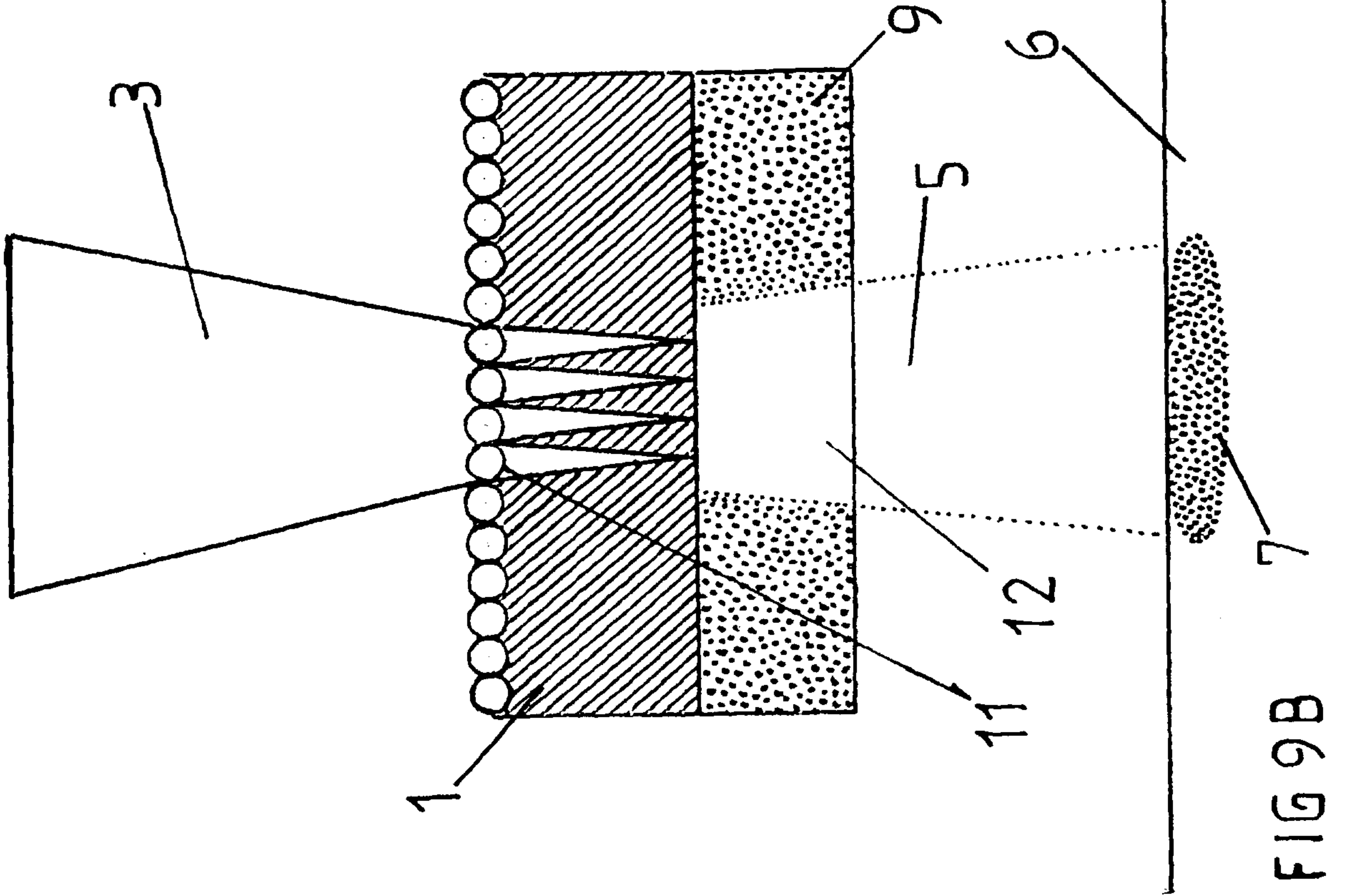


FIG 7



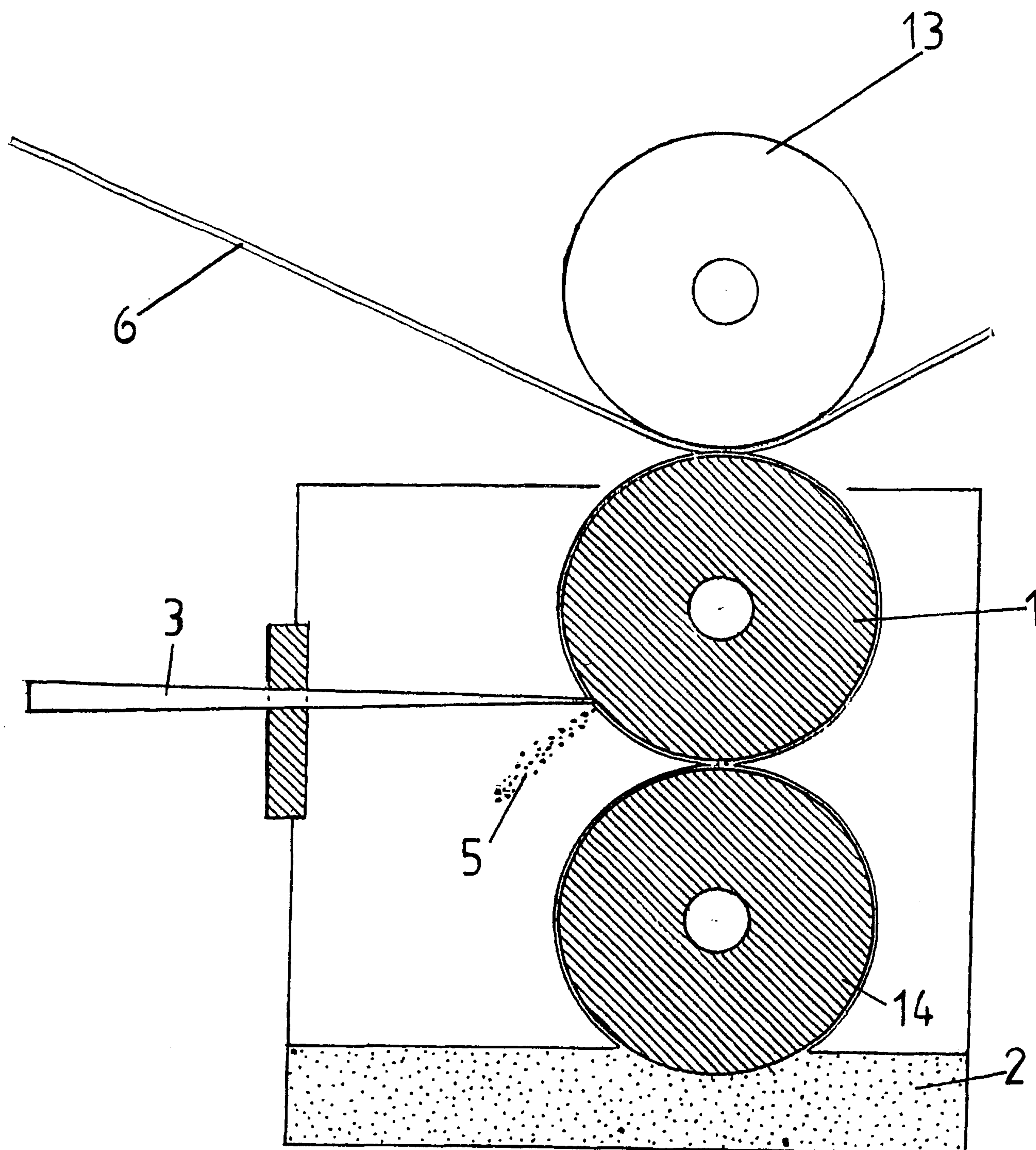


FIG 10

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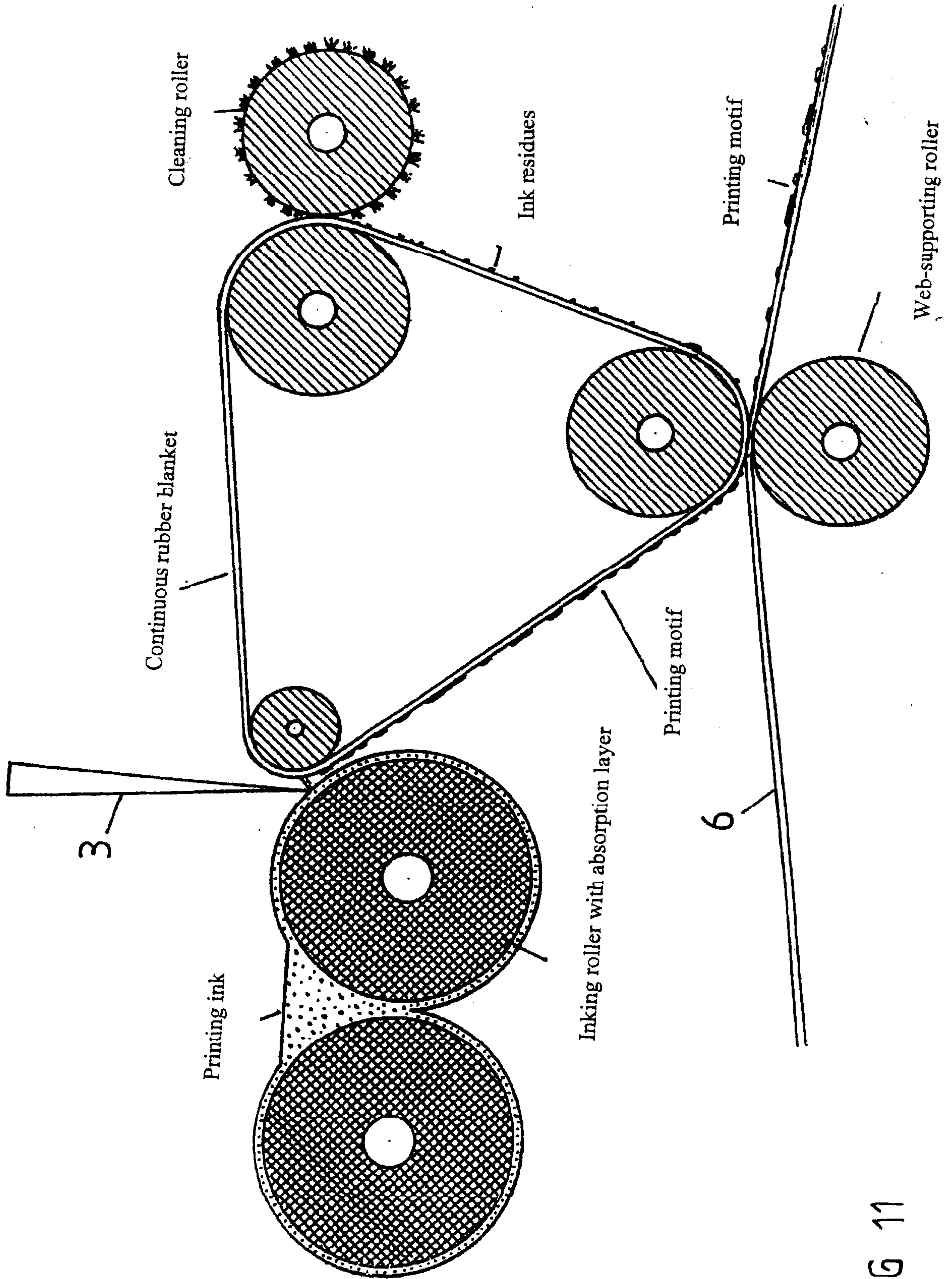


FIG 11

