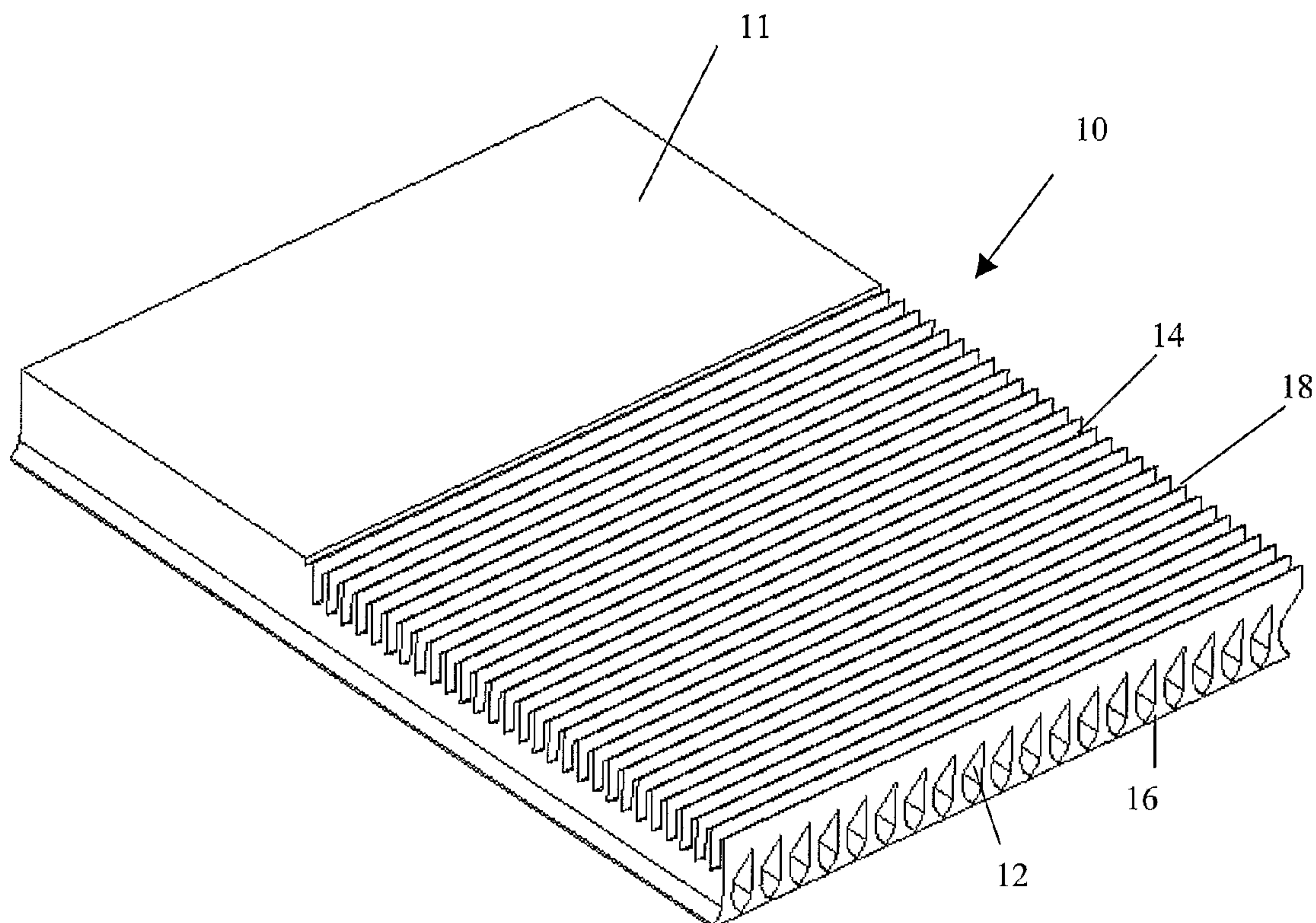




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(54) Titre : SURFACE DE TRANSFERT THERMIQUE POUR REFROIDISSEMENT ELECTRONIQUE
(54) Title: HEAT TRANSFER SURFACE FOR ELECTRONIC COOLING



(57) **Abrégé/Abstract:**

A cooling surface for cooling an electronic component, the surface having two sets of fins, each set of fins defining a set of channels, and a number of passageways connecting the sets of channels. The cooling surface can be attached to an electronic component, such as a chip, and refrigerant supplied to at least one of the sets of channels. When the temperature of the electronic component rises, the heat is transferred to the refrigerant in the cooling surface, at least some of which vaporizes to carry heat away from, and facilitate cooling of, the component.



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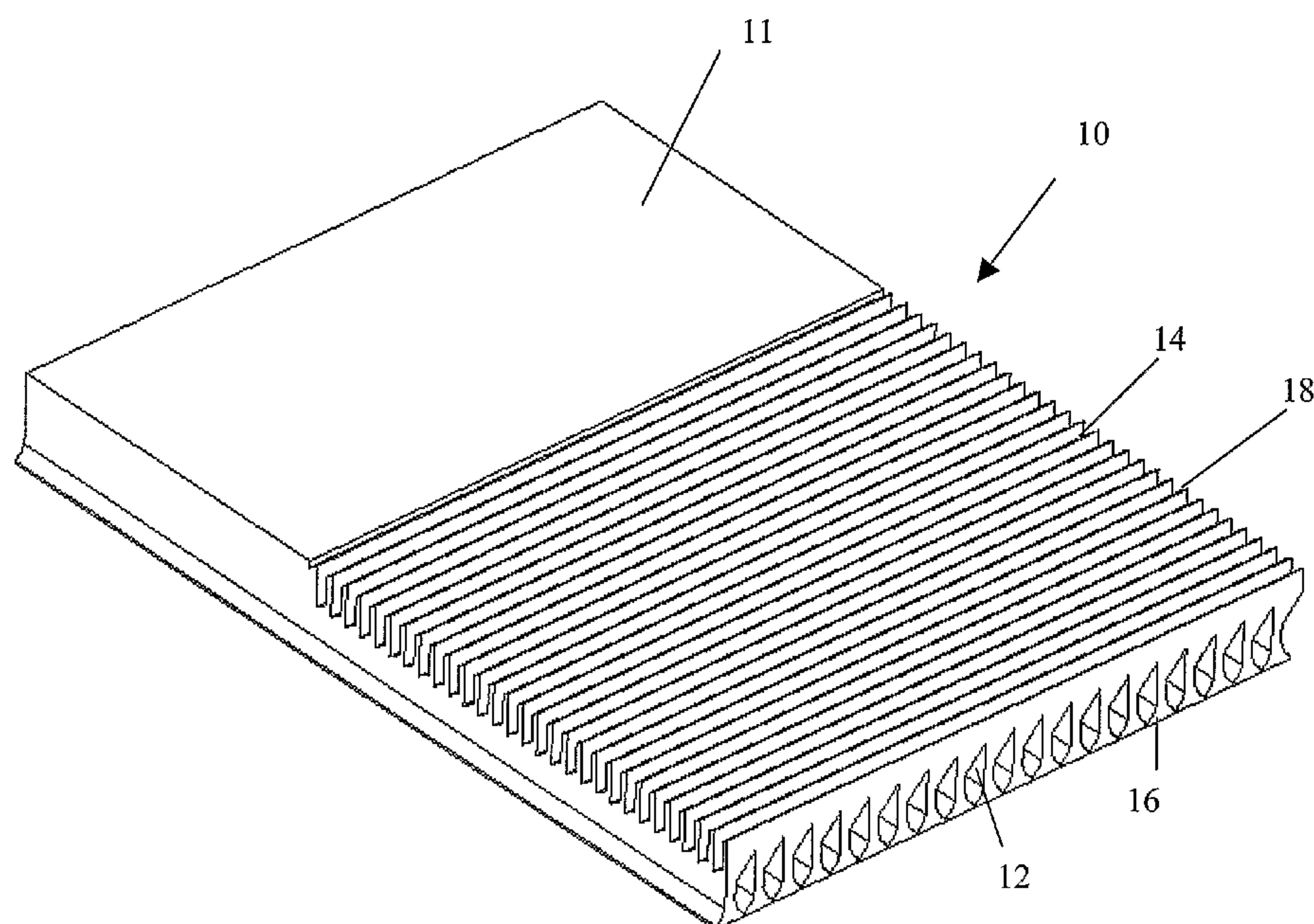
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(54) Title: HEAT TRANSFER SURFACE FOR ELECTRONIC COOLING



(57) **Abstract:** A cooling surface for cooling an electronic component, the surface having two sets of fins, each set of fins defining a set of channels, and a number of passageways connecting the sets of channels. The cooling surface can be attached to an electronic component, such as a chip, and refrigerant supplied to at least one of the sets of channels. When the temperature of the electronic component rises, the heat is transferred to the refrigerant in the cooling surface, at least some of which vaporizes to carry heat away from, and facilitate cooling of, the component.

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HEAT TRANSFER SURFACE FOR ELECTRONIC COOLING**RELATED APPLICATIONS**

[0001] This application claims priority to U.S. Provisional Application Serial No. 60/688,254, filed June 7, 2005 and entitled "Heat Transfer Surface For Electronic Cooling," the entirety of which is hereby incorporated by reference.

FIELD OF THE INVENTION

[0002] The invention generally relates to a cooling surface that can be conductively attached to and cool electronic components.

BACKGROUND OF THE INVENTION

[0003] Electronic devices, such as computers, process information on computer chips and these chips generate heat during use. The faster or longer the chips process information the hotter they become. If the chips become too hot they will burn up or otherwise malfunction. Thus, structures are provided in electronics to cool the chips during processing. For example, computers have fans that activate if the computer detects that the chips are getting too hot. Moreover, computers will also slow processing if it detects the chips are getting too hot. These conventional cooling methods are often ineffective because they do not cool the electronic components sufficiently to prevent damage to the components.

[0004] In other conventional cooling devices and methods, conductive structures are attached adjacent to the chip to conduct heat away from the chip to those structures. Such structures can take a variety of forms. For example, copper blocks have been attached to chips so that the heat conducts from the chip to its attached block. Fins have been provided on a single surface of such blocks to enhance heat transfer. Oftentimes these structures cannot cool the chips sufficiently, however, so ultimately the chips burn up or otherwise malfunction.

SUMMARY OF THE INVENTION

[0005] This invention provides a cooling surface for electronic components, such as electronic chips, that better facilitates electronic cooling. While for ease of discussion the cooling surface is described for use with an electronic chip, applicants in no way intend that the surface be used only with electronic chips. Rather, one of skill in the art will recognize that the surface may be used with any electronic component for which facilitation of cooling is desirable. A first set of fins that define a first set of channels is provided on one side of the surface. The first set of fins and channels are oriented on the surface at a first orientation. A second set of fins that define a second set of channels is provided on the side of the surface opposite the first set of fins and channels. The second set of fins and channels are oriented on the surface at a second orientation, preferably at an angle relative to the first orientation. Passageways connecting the first and second set of channels extend through the surface.

[0006] The cooling surface is attached to an electronic chip. The tips of the first set of fins can be flattened to facilitate attachment of the cooling surface (via the first fins) to the electronic chip. Liquid refrigerant is supplied to at least one of the sets of channels, preferably the first set of channels proximate to the electronic chip. As liquid is supplied to the cooling surface, the first set of channels fills with liquid refrigerant. The liquid refrigerant flows through the passageways and into the second set of channels. In so doing, the liquid refrigerant coats the walls of the sets of fins.

[0007] As the electronic chip rises in temperature, the cooling surface conducts heat away from the chip. The heat is then transferred to the refrigerant that is coated on the fins of the cooling surface. At least some of the refrigerant vaporizes, and the resulting vapors escape through the passageways in the surface and away from the chip.

[0008] There is provided an electronics cooling surface, a method of forming an electronics cooling surface, and an electronics cooling system.

[0009] The invention is pointed out with particularity in the appended claims. To gain an improved understanding of the advantages and features of the current invention, reference may be made to the following drawings and descriptive matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 is a perspective view of a cooling surface according to one embodiment of the invention.

[0011] FIG. 2 is a partial end view of the cooling surface of FIG. 1 illustrating the lower fins.

[0012] FIG. 3 is a photomicrograph of a cross-sectional view of the lower fins of a cooling surface according to an embodiment of the invention.

[0013] FIG. 4 is a photomicrograph of a cross-sectional view of the upper fins of a cooling surface according to an embodiment of the invention.

[0014] FIG. 5 is a photomicrograph of a cross-sectional view of the upper fins of a cooling surface according to another embodiment of the invention.

[0015] FIG. 6 is a photomicrograph of a cross-sectional view of the lower fins of a cooling surface according to another embodiment of the invention.

[0016] FIG. 7 is a photomicrograph of a top plan view of a cooling surface according to still another embodiment of the invention.

[0017] FIG. 8 is a photomicrograph of a bottom plan view of a cooling surface according to still another embodiment of the invention.

[0018] FIG. 9 is a photomicrograph of a top plan view of an electronics cooling surface in accordance with an embodiment of the invention.

[0019] FIG. 10 is a photomicrograph of a top plan view of an electronics cooling surface in accordance with an embodiment of the invention, shown after stretching.

DETAILED DESCRIPTION OF EMBODIMENTS

[0020] Figure 1 illustrates one embodiment of a partially-formed surface 10 of this invention. The surface 10 includes two sets of channels 12, 14 formed by two sets of fins 16, 18, respectfully. The surface 10 is preferably, but does not have to be, attached to a microchip (not shown) so that the lower set of channels 12 is positioned adjacent to the chip and runs in a first direction and the upper set of channels 14 is positioned above the lower set of channels 12 and runs in a second direction that is at an angle to the first direction. The sets of channels 12, 14 are preferably interconnected to one another by a plurality of passageways 20 (see Figure 9).

[0021] The surface 10 is preferably formed from a blank of conductive material, such as metal (including copper, titanium, aluminum, gold, stainless steel, etc.) and more preferably copper. The surface 10 can be formed of any highly-conductive material, however, such as a carbide with a high carbon content. Carbon itself could be used to form the surface 10.

[0022] Figure 1 illustrates a partially-formed surface 10 formed from a blank 11. In a finished surface 10, fins 16, 18 are preferably, but do not have to be, formed over the entirety of the blank 11. To form the surface 10, a lower set of upstanding fins 16 is formed on one side of the blank 11, thereby creating the lower set of channels 12 between the adjacent fins 16. An upper set of upstanding fins 18 is then formed on the opposite side of the blank 11, thereby creating the upper set of channels 14 between the adjacent fins 18. The sets of fins 16, 18 may be formed by many methods known in the art, but preferably are formed by cutting the sets of fins 16, 18 and subsequently lifting the sets of fins 16, 18 to a desirable angle. More specifically, the sets of fins 16, 18 are formed by cutting layers in the surface of the blank 11 and lifting the cut layers to a desirable angle to form upstanding sets of fins 16, 18. This cutting and lifting method and a tool for performing this method are disclosed in co-pending applications US 2004-0069467 and US 2005-0145377, the entirety of which are hereby incorporated by reference. While the sets of fins 16, 18 may be formed on a flat blank, in a preferable method, the uncut

Blank is wrapped around a rotatable drum so that the surface of the blank is curved in a semi-circle. In this configuration, the blank emulates a tube surface and conventional tube surface enhancement techniques may be used on each side of the blank to form fins 16, 18. It makes no difference which set of fins 16, 18 (and thus which set of channels 12, 14) are formed in the blank first.

[0023] It is preferable, but not necessary, that channels 12, 14 formed by fins 16, 18 extend slightly beyond the centerline of the thickness of the blank 11. In this way, passageways 20 (see Figure 9) are formed at the intersection of and extend between the upper and lower set of channels 12, 14. The portion of channel 12 that extends beyond the centerline of the blank intersects with the corresponding portion of channel 14 that extends beyond the centerline. This intersection forms a passageway 20 between the two channels 12, 14. Figures 9 and 10 illustrate the passageways 20. While it is preferable that the channels of both sets of channels 12, 14 extend beyond the centerline of the blank thickness, the channels of only one set of channels 12, 14 may so extend to form the passageways 20.

[0024] While the sets of fins 16, 18 (and thus the resulting sets of channels 12, 14) of Figure 1 are shown oriented perpendicular to each other, the sets of fins 16, 18 may be formed at any angle relative to each other. Furthermore, the fins *within* the upper and/or lower sets of fins 16, 18 (and thus the channels *within* the upper and/or low sets of channels 12, 14) need not be parallel to each other.

[0025] Any number of fins 16, 18 (and thus any number of channels 12, 14) may be formed on the cooling surface 10. "Fin pitch" as used herein is defined as the width of a single channel plus the thickness of one of the fins defining the channel. The fin pitch of the upper and lower sets of fins 16, 18 is preferably, but does not have to be, between 20-1200 fins per inch. The fin pitch may vary between the lower and upper sets of fins 16, 18 so that the lower set of fins 16 has a different fin pitch than the upper set of fins 18. Also, the fin pitch can vary within each set

of fins 16, 18, so that for example a portion of the upper set of fins 18 has a different fin pitch than another portion of the upper set of fins 18.

[0026] Moreover, the height of the fins 16, 18 (and thus the depth of the upper and lower channels 12, 14) may also vary between the sets of fins 16, 18 so that the lower set of fins 16 has a different fin height than the upper set of fins 18. Similarly, the fin height can vary within each set of fins 16, 18, so that for example a portion of the upper set of fins 18 has a different fin height than another portion of the upper set of fins 18.

[0027] The optimal geometries of the sets of fins 16, 18 and the sets of channels 12, 14 will depend on a number of factors, including the type of refrigerant used and the amount of heat needed to be conducted away from the surface 10. It is preferable, but not necessary, that the aspect ratio A for each set of fins 16, 18 (defined as the fin height divided by the channel width) be in the range between $0.1 < A < 400$ and more preferably between $0.1 < A < 40$.

[0028] Figure 3 is a cross-sectional view showing the lower set of channels 12 of surface 10 formed by fins 16 having a fin pitch of 100 fins/inch and a fin height of .023 inches. Figure 4 is a cross-sectional view showing the upper set of channels 14 of surface 10 formed by fins 18 having a fin pitch of 200 fins/inch and a fin height of approximately .0205 inches. Figure 5 is a cross-sectional view showing the upper set of channels 14 of surface 10 formed by fins 18 having a fin pitch of 200 fins/inch and a fin height of approximately .0175 inches. Figure 6 is a cross-sectional view showing the lower set of channels 12 of surface 10 formed by fins 16 having a fin pitch of 200 fins/inch and a fin height of approximately .021 inches. Figure 7 is a plan view of the upper set of fins 18 forming channels 14.

[0029] In use, surface 10 is preferably attached to a chip so that the lower set of channels 12 is proximal the chip. The surface 10 can be attached to the chip in any number of ways, including by soldering or using an adhesive or paste. It is preferable that the adhesive or paste used be conductive to further facilitate cooling of the chips.

[0030] To facilitate attachment and retention of the surface 10 on and to a chip, it is preferable, but not necessary, that the tips of the lower set of fins 16 be flattened, as shown in Figures 2, 3, and 6. Such flattening creates additional surface area for attachment to the chip. Moreover, the additional surface area provided by flattened tips of the lower set of fins 16 assists in the conduction of heat. Figure 8 is a plan view of the lower set of fins 16 forming channels 12. The fins of the lower set of fins 16 have been flattened.

[0031] The tips of the set of fins 16 may be flattened using conventional flattening techniques or those described in US 2005-0145377, incorporated herein by reference. In addition to flattening, the tips of the set of fins 16 may also be bent over to form a relatively flat surface or cut so as to have thickened tips and thus create more surface area at the tips for attachment. Methods and tools for bending and thickening fin tips, as well as angling adjacent fin tips relative to each other (which is also contemplated by this invention), are also described in US 2005-0145377. It is within the scope of the present invention to flatten or otherwise enhance the tips of the upper set of fins 18 in addition to or instead of flattening the tips of the lower set of fins 16.

[0032] During chip use, a liquid refrigerant is supplied to at least one of the sets of channels 12, 14. It is preferred that refrigerant is supplied at least to the lower set of channels 12. Any number of refrigerants can be used, including but not limited to water or HFE-7100, which is manufactured by 3M. Alternatively, manufacturers such as DuPont or Allied Signal manufacture refrigerants known as 134A or 123 that are also appropriate for use in the current invention. The refrigerant runs through the lower set of channels 12 to coat the surface of the lower set of fins 16. As the lower set of channels 12 becomes filled with the refrigerant, the refrigerant is discharged through the passageways 20, and into the upper set of channels 14 to coat at least some of the surface of the upper set of fins 18. In another embodiment, refrigerant

may be supplied directly to the upper set of channels 14 instead of or in addition to supplying refrigerant to the lower set of channels 12.

[0033] The heat generated by the chip is transferred to the conductive surface 10. By virtue of this heat transfer, the temperature of the liquid refrigerant in channels 12, 14 elevates, converting at least some of the liquid refrigerant to vapor. At least some of the vapor produced in the lower set of channels 12 is discharged through passageways 20 and into the upper set of channels 14, thereby carrying heat away from the chip. Moreover, as the refrigerant that is not vaporized flows through and exits the sets of channels 12, 14, heat generated by the chip is carried away in that refrigerant. In this way, heat generated by the chip is carried away by the refrigerant, either in liquid or vapor form.

[0034] A pump (not shown) can be used to pump the liquid refrigerant into one or both of the channels 12, 14 and thereby prevent all of the refrigerant from vaporizing. Rather, while some of the refrigerant will turn to vapor during the heat transfer process, the pump replenishes the refrigerant to the cooling surface 10 so that a combination of liquid refrigerant and vapor is present in the sets of channels 12, 14. The pump can continuously supply refrigerant to the sets of channels 12, 14. Alternatively, a controller for the pump may be used to monitor the temperature of the chip and activate the pump only when the temperature increases to a predetermined amount.

[0035] Supplying refrigerant to the sets of channels 12, 14 (either continuously or with a sensor) ensures that the sets of fins 16, 18 remain coated with refrigerant. It is desirable that only a thin film of the refrigerant coat the sets of fins 16, 18. The heat transfer coefficient is a measure of how effectively heat is transferred away from the chip – a higher heat transfer coefficient ensures that heat is more effectively transferred away. A thin film of refrigerant is preferred because the heat transfer coefficient is inversely proportional to the thickness of the refrigerant layer on the sets of fins 16, 18. Accordingly, a thin film of refrigerant ensures a high

"heat transfer coefficient," thereby improving the ability of the cooling surface 10 to transfer heat away from the chip.

[0036] Provision of two sets of channels 12, 14 formed by two sets of fins 16, 18 in cooling surface 10 is particularly beneficial in this application. By forming two sets of fins 16, 18, the fin height of the surface 10 and consequently the surface area available for contact with the refrigerant is essentially doubled, as compared to a cooling surface that has only a single set of channels and fins. The increased surface area allows more heat to be conducted into the refrigerant and away from the chip.

[0037] Figures 1 and 9 illustrate surfaces 10 where the upper set of fins 18 and channels 14 are formed at substantially 90° relative to the lower set of fins 16 and channels 12. As explained above, however, the upper and lower sets of fins and channels need not be oriented 90° relative to each other. Rather, the upper and lower sets of fins and channels may be formed at acute angles relative to each other, as shown in Figure 10.

[0038] In one embodiment of the current invention, the cooling surface 10 can be stretched after the cooling surface 10 is formed. Stretching is particularly suitable with surfaces 10 having set of fins 16, 18 and channels 12, 14 oriented at acute angles relative to each other. Stretching leads to manufacturing conveniences. As opposed to manufacturing a variety of cooling surfaces 10 each with characteristics (fin height, pitch, etc.) intended for a specific application, a single cooling surface 10 may be manufactured and then stretched to tailor the surface to a particular application. For example, stretching the cooling surface 10 can increase the fin pitch or alter the aspect ratio. Moreover, as explained above, all of the fins in a set of fins 16, 18 need not have the same fin pitch or fin count and indeed it may be desirable that they do not. Stretching the cooling surface 10 allows selective variation of the fin characteristics within a set of fins 16, 18 to better tailor the cooling surface 10 to a particular application and thus enhance the effectiveness of the cooling surface 10. Figure 10 illustrates a partially-stretched cooling surface

10. The portion of the surface 10 in the lower left hand corner of Figure 10 has been stretched to a lesser degree than the remaining portions of the surface 10.

[0039] The foregoing is provided for the purpose of illustrating, explaining and describing embodiments of the present invention. Further modifications and adaptations to these embodiments will be apparent to those skilled in the art and may be made without departing from the spirit of the invention or the scope of the claims.

CLAIMS

1. A cooling surface for transferring heat from an electronic component comprising:
 - a. a first set of fins defining a first set of channels on a first side of the surface;
 - b. a second set of fins defining a second set of channels on a second side of the surface opposite the first side; and
 - c. a plurality of passageways extending through the surface and connecting the first and second sets of channels.
2. The cooling surface of claim 1, wherein the surface comprises metal.
3. The cooling surface of claim 1, wherein the surface comprises copper.
4. The cooling surface of claim 1, wherein the surface comprises a thickness and at least some of the channels of the first or second set of channels extend more than halfway through the surface thickness.
5. The cooling surface of claim 1, wherein the first set of fins is oriented at an angle relative to the second set of fins.
6. The cooling surface of claim 1, wherein each of the first and second sets of fins comprises a fin pitch and wherein the fin pitch of the first set of fins differs from the fin pitch of the second set of fins.
7. The cooling surface of claim 6, wherein the fin pitch of at least one of the first and second sets of fins is between and including 20-1200 fins per inch.

8. The cooling surface of claim 1, wherein each of the first and second sets of fins comprises a fin height and wherein the fin height of the first set of fins differs from the fin height of the second set of fins.

9. The cooling surface of claim 1, wherein the aspect ratio of at least one of the first and second sets of fins is approximately between 0.1 and 40.

10. The cooling surface of claim 1, wherein the fins of the first set of fins and the second set of fins comprise tips and wherein at least some of the tips of the first set of fins or the second set of fins are flattened.

11. A method of forming a cooling surface for transferring heat from an electronic component comprising:

- a. providing a blank;
- b. forming a first set of fins defining a first set of channels on a first side of the blank;
- c. forming a second set of fins at an angle to the first set of fins and on a second side of the blank opposite the first side, the second set of fins defining a second set of channels; and
- d. creating a plurality of passageways extending through the blank and connecting the first and second sets of channels.

12. The method of claim 11, wherein the blank comprises a thickness and at least some of the channels of the first or second set of channels extend more than halfway through the blank thickness to create the plurality of passageways.

13. The method of claim 11, wherein forming the first and second sets of fins comprises cutting layers into the blank and lifting the layers to form the fins.

14. The method of claim 11, wherein the fins of the first set of fins and the second set of fins comprise tips and wherein the method further comprises flattening the tips of at least some of the fins of either the first or second set of fins.

15. The method of claim 11, further comprising stretching the blank after at least some of the fins are formed.

16. An electronic cooling system comprising the cooling surface of claim 1 attached to an electronic component.

17. The electronic cooling system of claim 16, wherein the electronic component is an electronic chip.

18. The electronic cooling system of claim 16, wherein at least some of the fins of the first set of fins comprise flattened tips positioned more proximal the electronic component than the second set of fins.

19. The electronic cooling system of claim 16, wherein the cooling surface is soldered or adhered to the electronic component.

20. The electronic cooling system of claim 16, wherein refrigerant is supplied into at least one of the first and second sets of channels.

21. A cooling surface for transferring heat from an electronic component comprising:
- a. a first set of fins defining a first set of channels on a first side of the surface;
 - b. a second set of fins defining a second set of channels on a second side of the surface opposite the first side, wherein the second set of fins is oriented at an angle relative to the first set of fins; and
 - c. a plurality of passageways extending through the surface and connecting the first and second sets of channels,
- wherein the surface comprises metal and has a thickness and wherein at least some of the channels of the first or second set of channels extend more than halfway through the surface thickness.

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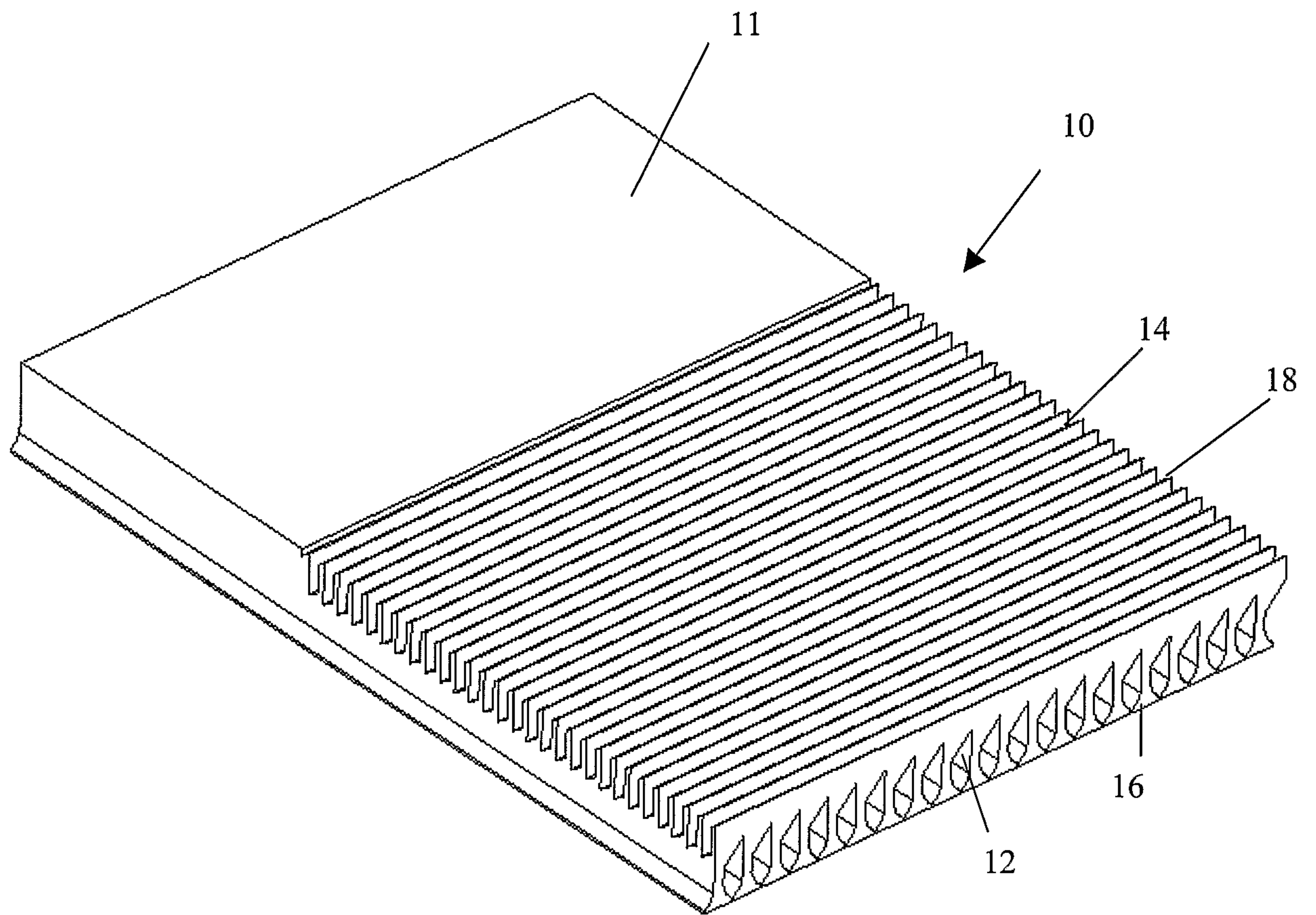


FIGURE 1

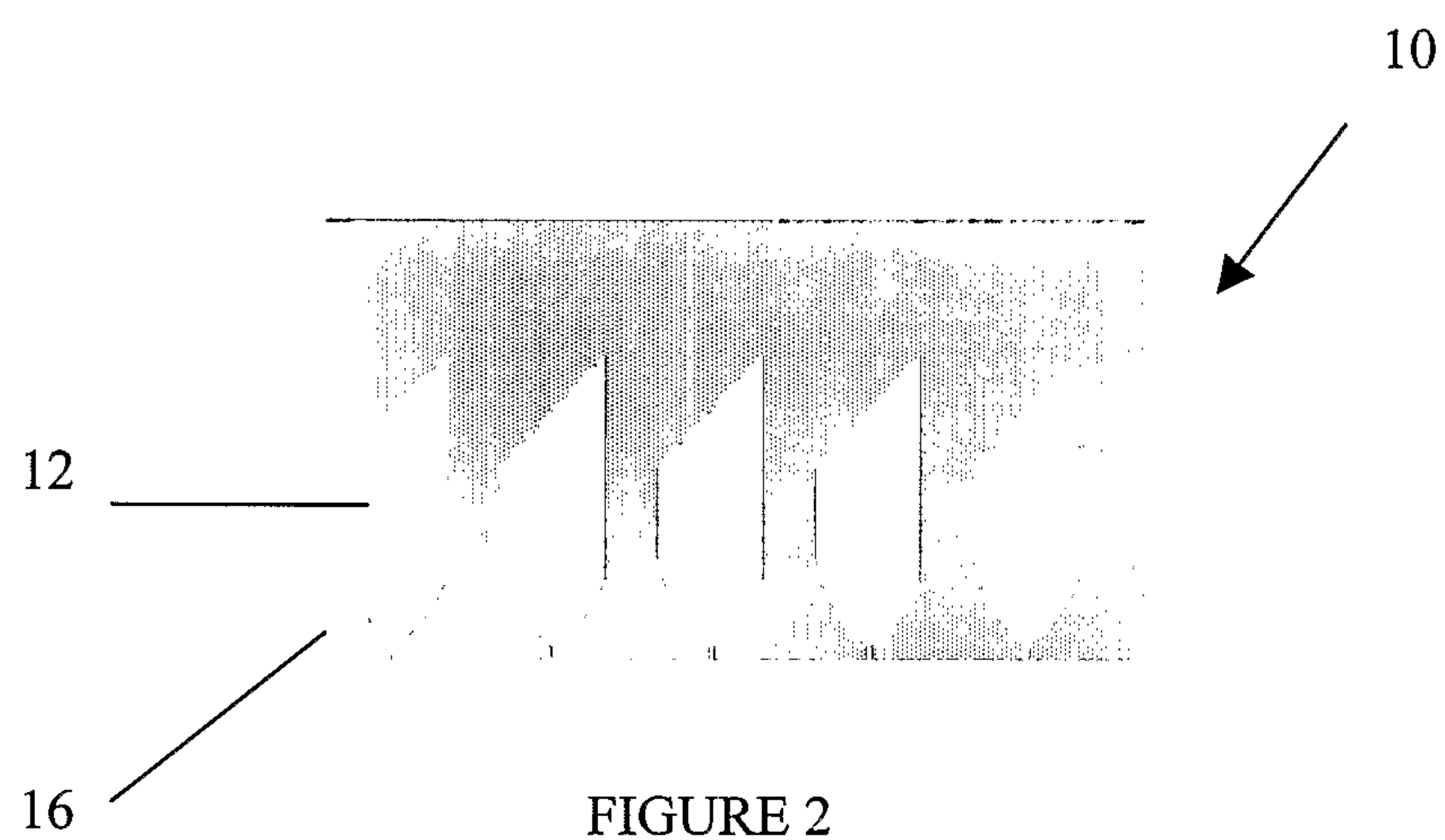


FIGURE 2

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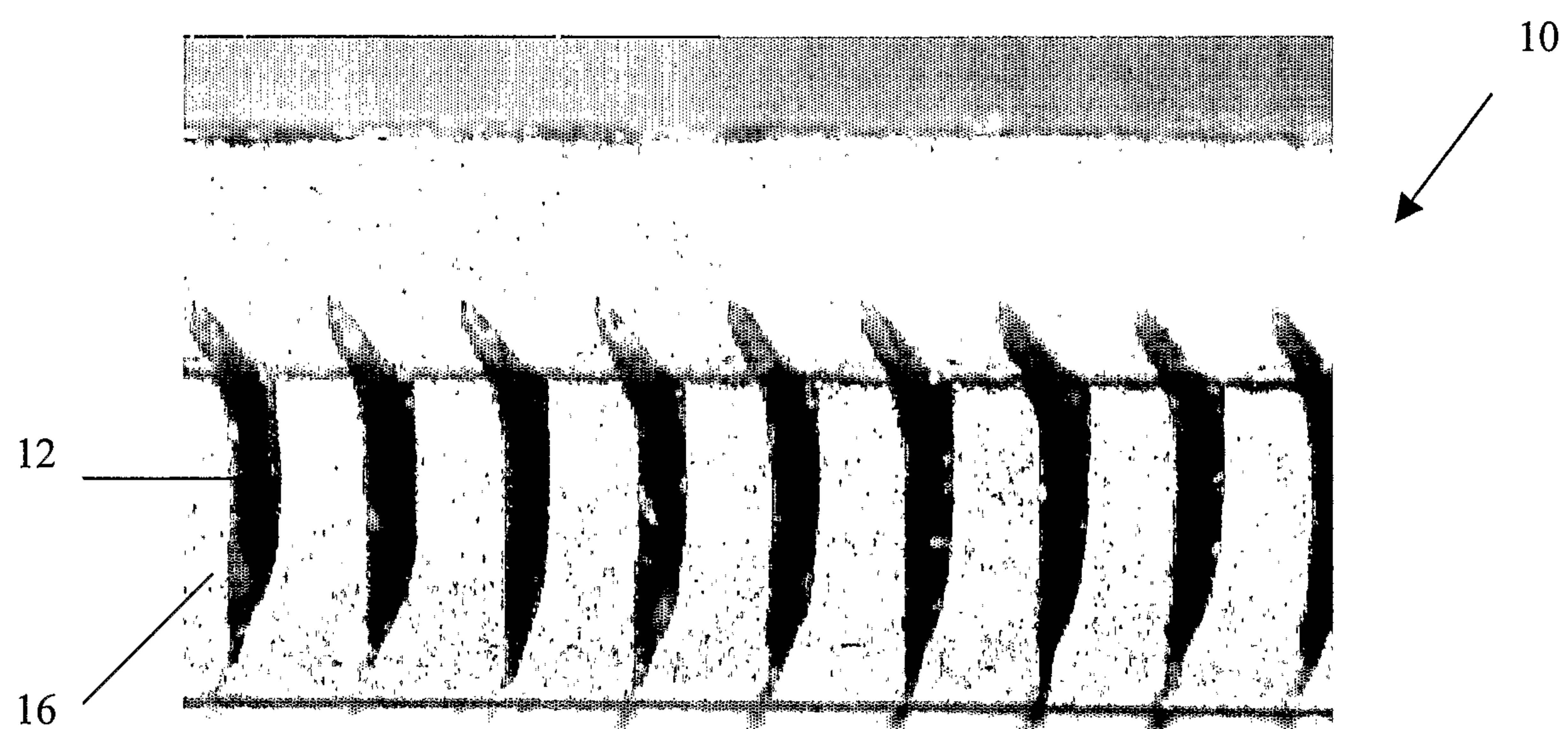


FIGURE 3

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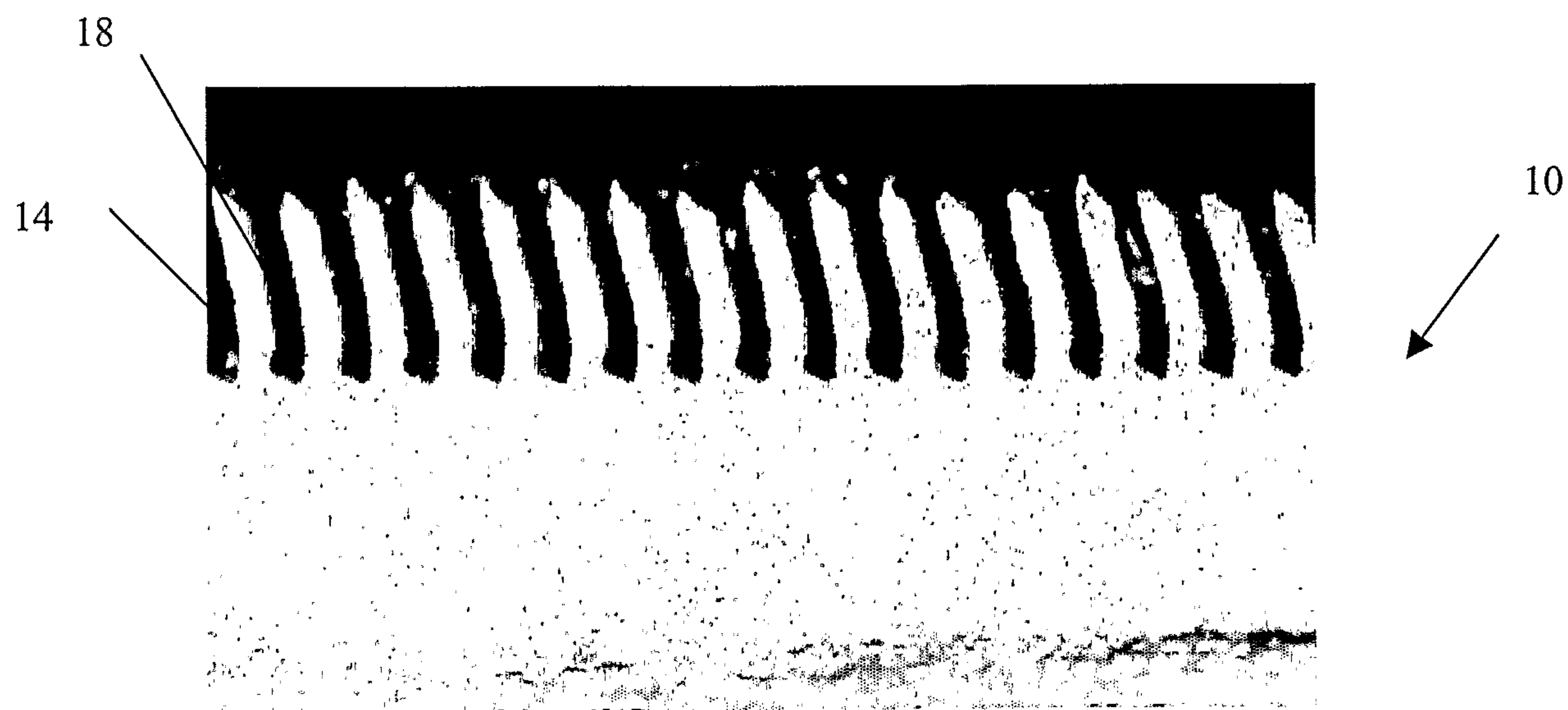


FIGURE 4

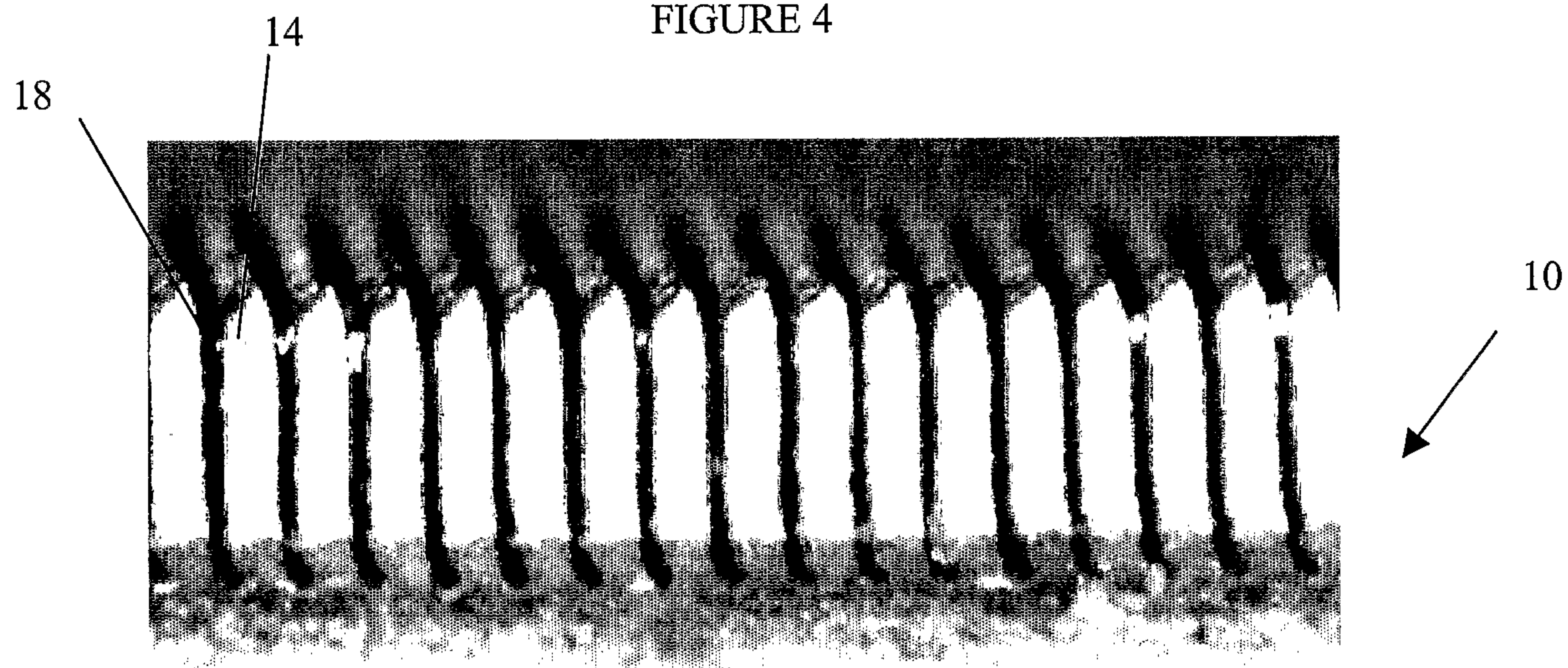


FIGURE 5

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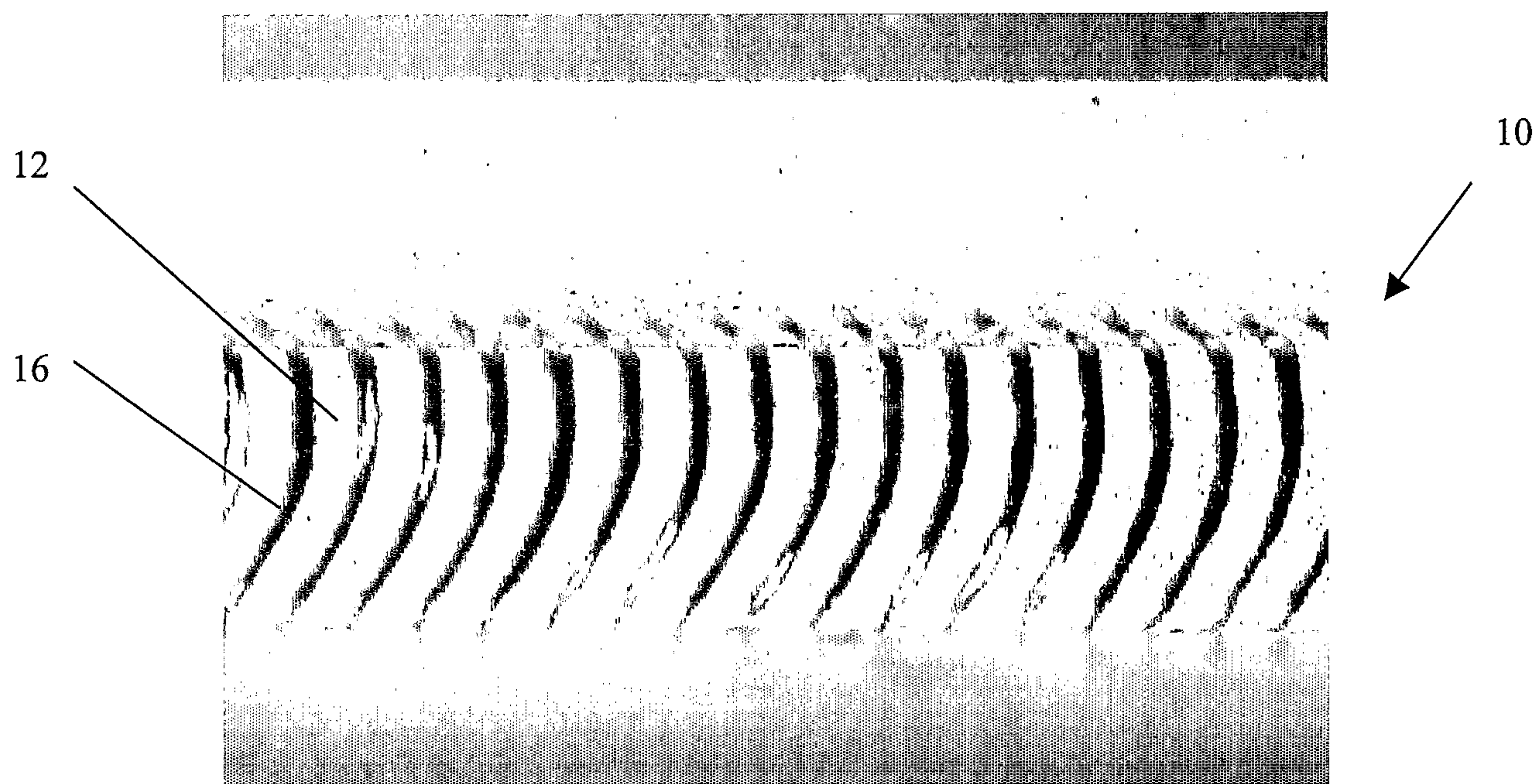


FIGURE 6

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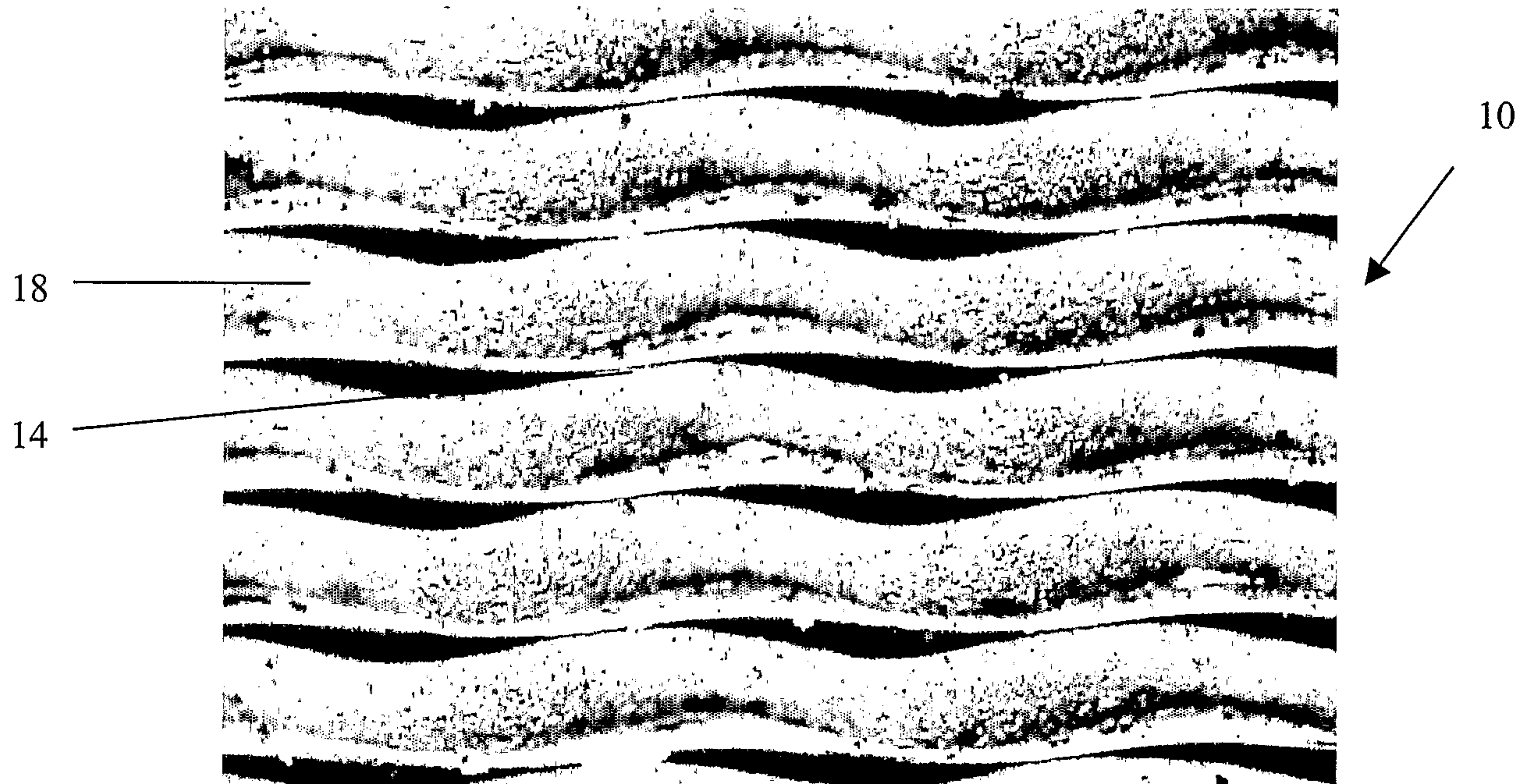


FIGURE 7



FIGURE 8

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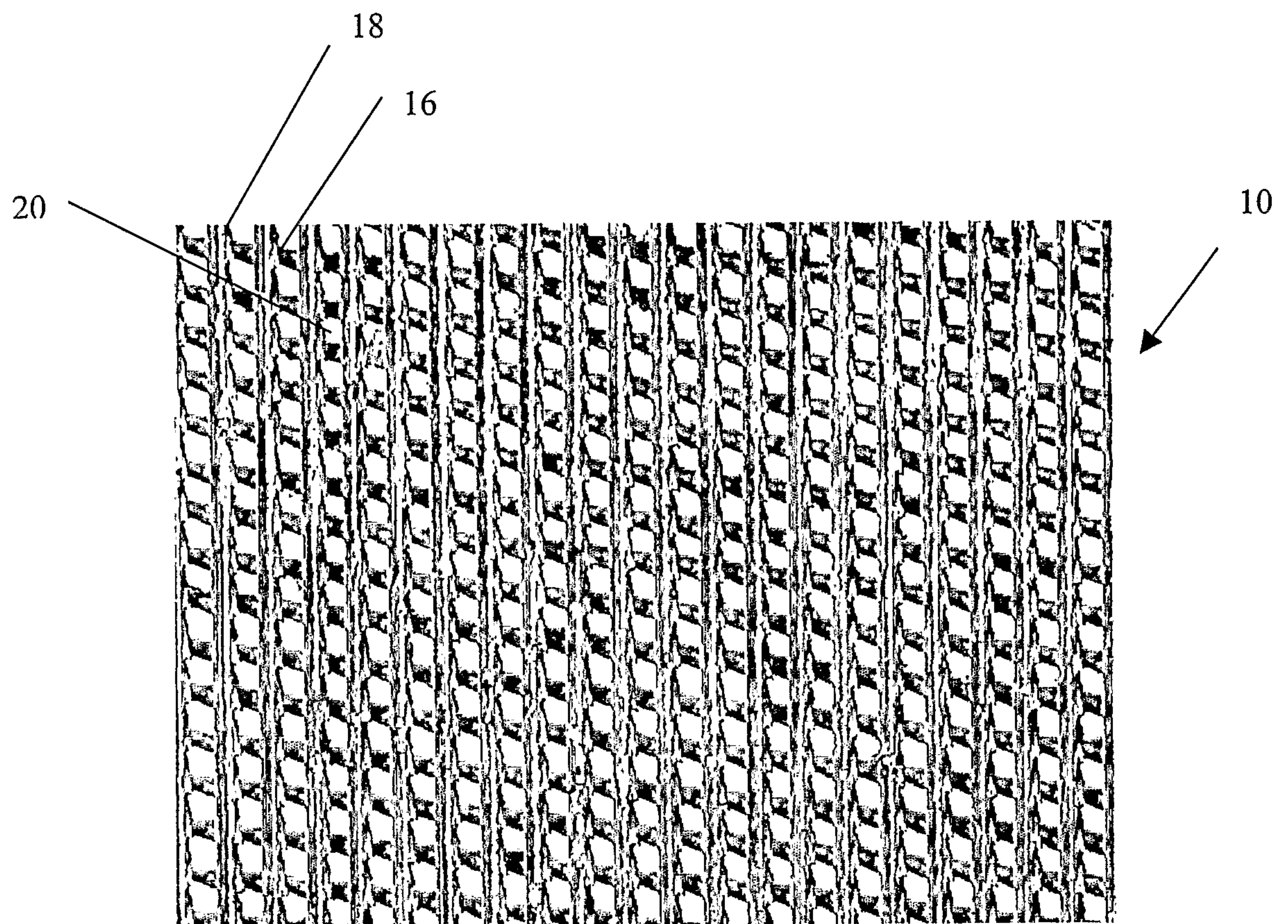


FIGURE 9

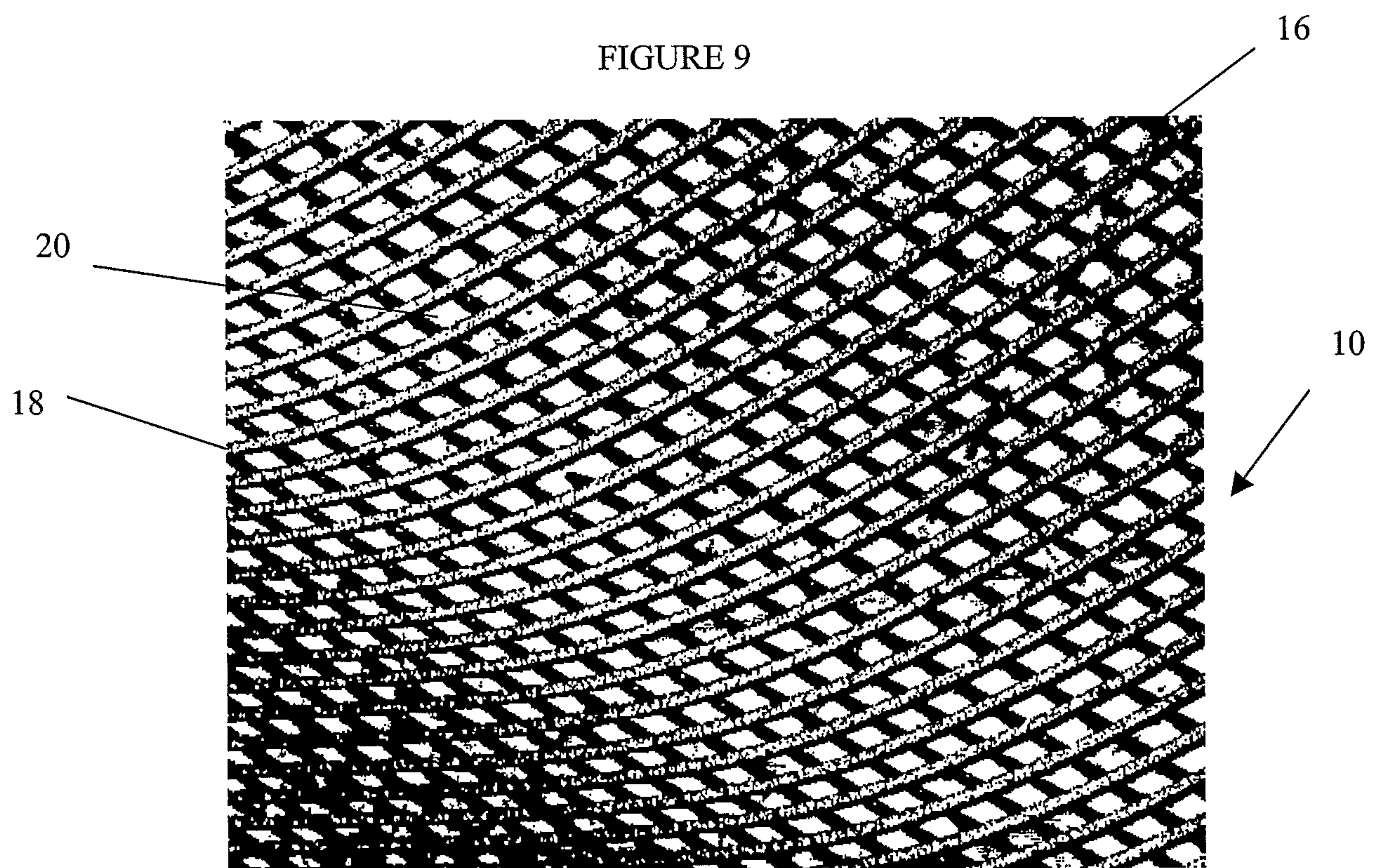


FIGURE 10

