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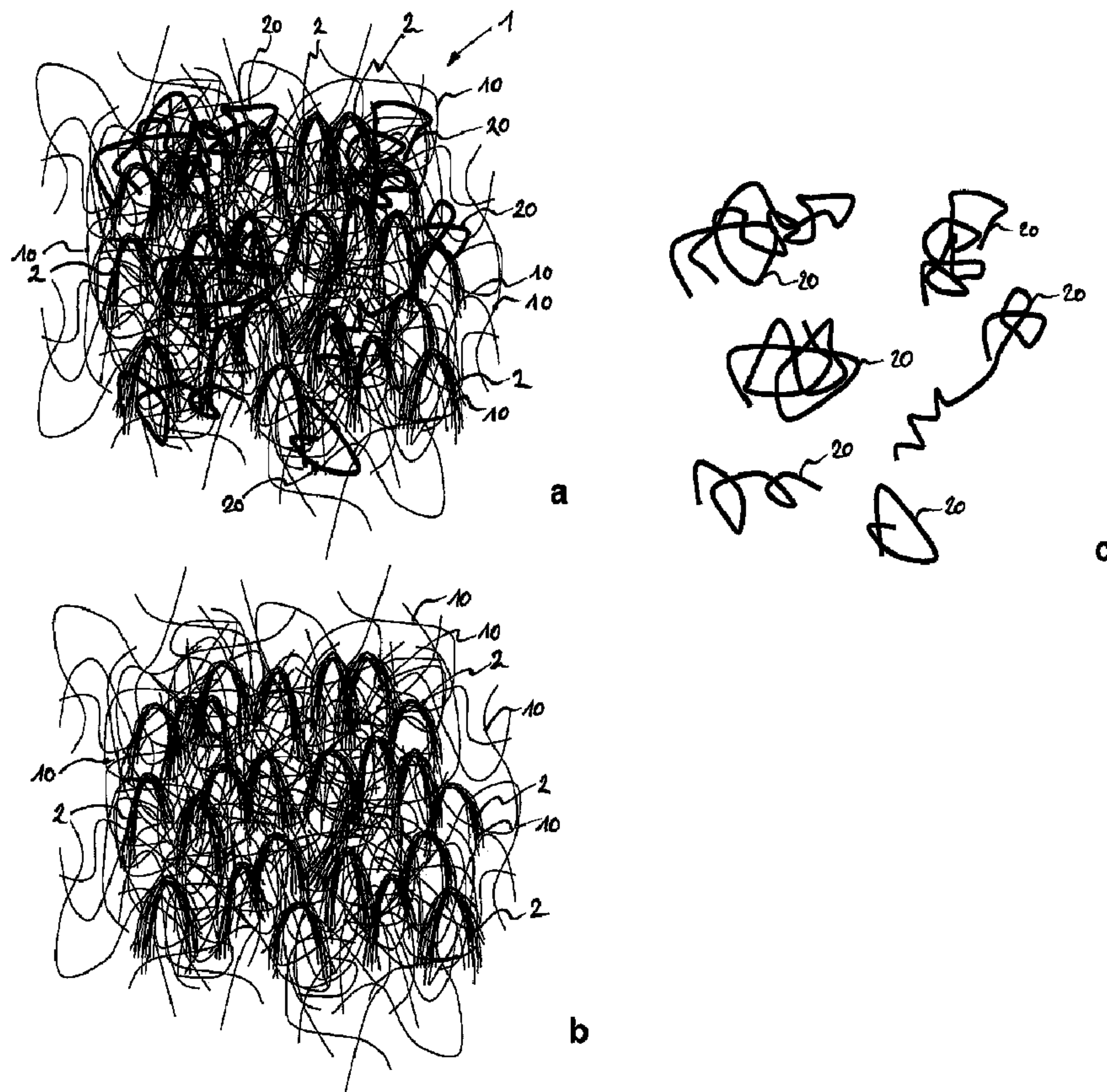
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(54) Title: PILE LAYER WITH CARBON-FIBER ENCOMPASSING BUNDLES



(57) Abrégé/Abstract:

The invention relates to a pile layer, comprising a plurality of bundles, which are partially opened up into individual fibers and which comprise carbon fibers, and comprising foreign substances, and wherein the carbon fibers have at least a mass fraction of 70% of

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the total mass of the pile layer, and the foreign substances no more than 30%, but not less than 2%, wherein the foreign substances are obtained from a recycling process.

Abstract

The invention relates to a pile layer, comprising a plurality of bundles, which are partially opened up into individual fibers and which comprise carbon fibers, and comprising foreign substances, and wherein the carbon fibers have at least a mass fraction of 70% of the total mass of the pile layer, and the foreign substances no more than 30%, but not less than 2%, wherein the foreign substances are obtained from a recycling process.

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Pile Layer with Carbon-Fiber Encompassing Bundles

The present invention relates to a pile layer, which exhibits a plurality of bundles partially broken up into single fibers and encompassing carbon fibers, as well as foreign materials, as

well as to a method for manufacturing such a pile layer.

The invention

further relates to a nonwoven or nonwoven material, which encompass such pile layers.

Pile layers encompassing carbon fibers are especially well suited as an initial structure for manufacturing nonwovens or nonwoven materials, which are used in numerous applications in the automobile industry. They are used above all for manufacturing automobile components. In particular after suitably impregnated with a resin, for example in an RTM procedure, the nonwovens and nonwoven materials in question are advantageously processed into light, yet mechanically very resilient fiber composite structures, which are increasingly being viewed as a preferred and pioneering material.

Pile formation typically involves supplying single fibers having a predetermined length distribution to a pile forming machine via suitable feeding devices. For example, such a pile forming machine can be designed as a carding machine. However, air-operated, pneumatic or eluent-assisted pile forming machines are known alternatives. Suitable functional components in the respective pile forming machines intertwine the single fibers, so that a flat structure is formed, to which the intertwined fibers impart enough intrinsic stability to withstand the outer mechanical stresses that arise during continued processing.

The pile layers removed from pile forming machines can be processed into nonwoven materials in additional steps. For

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example, the pile layers can be doubled, i.e., the pile layers can be laid one on top of the other, so as to create a nonwoven with a desired thickness and suitable overall fiber content, which even once solidified, e.g., via needling, can be relayed to another processing step as a nonwoven material. Nonwoven materials generally differ from conventional nonwovens in that they have undergone a chemical, mechanical or thermal solidification.

Within the framework of the present invention, no distinction is made between a pile layer and a nonwoven. All of these structures are obtained in a process aimed at intertwining the fibers into a mechanically relatively stable flat structure. On the other hand, the nonwoven material is distinguished from the nonwoven or pile layer by the subsequent additional step of solidification, as described further above.

However, the problem with respect to the described procedures is that the single fibers fed to the pile forming machines must typically be subjected to complex mechanical preparation. Used for this purpose are opening and/or mixing units, which break up and prepare the fibers, for example at classic spinning mills. Especially the manufacture of pile layers using carbon fibers also requires a complicated preparation of carbon fibers. For example, the carbon fibers can be removed from carbon fiber strands. To this end, the latter must first be removed from a spool and fed to a cutting device. After cut o a suitable length, the bundles of carbon fibers must be broken up by separating the carbon fibers in the bundle sections. Before fed into the pile forming machine, the fibers must also be suitably accumulated and metered into the pile forming process. Only thereafter are the isolated, i.e., completely broken up fibers, fed to the pile forming machine, in which the fibers can be processed into a pile.

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However, not only are all of these processing steps relatively cost-intensive, they are also associated with a higher maintenance outlay for the devices in the entire procedural sequence.

These preparation costs are elevated even further when the objective is to manufacture fiber-reinforced composite materials based on fiber scraps and/or recycled carbon fibers. Numerous fabrication processes in the carbon fiber-processing industry yield numerous cut scraps, which should go toward another use to economize on costs. Obtained aside from such cut scraps are rejects produced in the textile manufacturing process, which can provide equally valuable carbon fibers intended for use in further applications so as to save on costs and raw materials. In addition, it can also be anticipated that even larger amounts of carbon fiber scraps will in the future come about during the pyrolytic recovery of carbon fibers from carbon fiber-reinforced plastics, which will then also be recirculated as recycled materials, so as to permit a closed chain of recycled materials.

But it is preparation that becomes especially complicated precisely when processing fiber scraps or recycled fibers, since several additional processing steps also become necessary for breaking up, opening and sometimes even cleaning the fibers, so as to obtain isolated fibers. Only after a number of preparatory steps does it become possible to obtain fibers that can be relayed to processes typically carried out with original, i.e., as yet unused, carbon fibers.

Also required for purposes of reuse is that carbon fiber scraps be cleaned to remove foreign materials, in order to obtain a raw material exhibiting sufficiently pure carbon fiber content. Such a cleaning process is again very cost intensive on the one hand, and is at present also only

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sufficiently managed or controllably applied in conjunction with specific parent substances on the other. However, good material characteristics are necessary for being able to produce properties of the material to be fabricated with a high enough grade and constant level of quality.

According to an aspect of the present invention, there is provided a pile layer, which exhibits a plurality of bundles partially broken up into single fibers and encompassing carbon fibers, as well as foreign materials, wherein the carbon fibers comprise at least 70% by weight of the overall weight of the pile layer, and the foreign materials comprise no more than 30%, but not less than 2%, wherein the foreign materials are derived from a recycling process.

According to another aspect of the present invention, there is provided a nonwoven or nonwoven material that exhibits at least two pile layers as described above.

According to another aspect of the present invention, there is provided a nonwoven material that exhibits a pile layer as described above, which is needed for solidification purposes.

According to another aspect of the present invention, there is provided a method for manufacturing a pile layer, encompassing the following steps: cutting a flat structure that exhibits bundles encompassing carbon fibers, and is at least partially fixed by means of foreign materials; processing the cut flat structure to partially break open the bundle into single fibers in an opening unit; introducing the batch partially broken up as the result of being processed in this way into a pile forming machine; operating the pile forming machine in such a

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way as not to completely isolate the bundles into single fibers, but rather to intertwine carbon fibers in the bundles with additional fibers; and removing the pile layer from the pile forming machine.

5 Some embodiments of the present disclosure propose a pile layer along with a method for manufacturing such a pile layer that enables the simple return of materials obtained from recycling processes, in particular of carbon fibers, to textile structures suitable for technical applications. In particular,
10 some embodiments of the present disclosure propose a pile layer that also permits the use of recycled carbon fibers, while not diminishing the suitability of the pile layer for technical application. In particular, in some embodiments, it must be possible to sufficiently ensure the quality of the product for
15 the desired application. In like manner, some embodiments of the present disclosure suggest a nonwoven or nonwoven material that encompasses these types of pile layers. In some embodiments of the present disclosure, the manufacturing process may provide a less cost-intensive method for
20 fabricating a pile layer by comparison with the method known from prior art.

In particular, some embodiments provide a pile layer comprising a plurality of bundles that are partially broken up into single fibers and encompass carbon fibers, as well as foreign
25 materials, wherein the carbon fibers comprise at least 70% by weight of the overall weight of the pile layer, and the foreign materials comprise no more than 30%, but not less than 2%,

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and wherein the foreign materials are derived from a recycling process.

Some embodiments of the present disclosure provide a method for manufacturing a pile layer, which encompasses the following steps: Cutting a flat structure that exhibits bundles encompassing carbon fibers, and is at least partially fixed by means of foreign materials, in particular knitting or sewing threads, or a binder; processing the cut flat structure to partially break open the bundle into single fibers in an opening unit, in particular in a tearing machine; introducing the batch partially broken up as the result of being processed in this way into a pile forming machine, in particular into a carding machine; operating the pile forming machine in such a way as not to completely isolate the bundles into single fibers, but rather to intertwine carbon fibers in the bundles with additional fibers; removing the pile layer from the pile forming machine.

The pile layer according to some embodiments is advantageously distinguished by the fact that it exhibits a percentage of foreign material measuring at most 30%, while the carbon fibers exhibit a percentage by weight of at least 70%. The percentage of carbon fibers here determines first and foremost the strength as well as the quality of the pile layer, wherein the percentage of foreign material contributes to the basis weight of the textile as a whole, but without also significantly influencing the strength and quality. The quality and strength relates in particular to the quality and strength that the pile layer can provide to a composite material into which it is integrated.

In the course of tests performed by the applicant, it was found that the percentage of foreign material stemming from a recycling process can slightly detract from the quality of the pile layer, but that the 70% by weight of carbon

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fibers relative to the overall weight of the total carbon fiber content is high enough to offset such adverse effects. In particular, the percentage of carbon fibers is then sufficient for manufacturing a pile layer that is also able to satisfy the requirements to be met in automotive engineering. Accordingly, a pile layer must reach a minimum strength at a corresponding maximum weight. However, automotive engineering places less stringent requirements on the textile to be manufactured than, for example, aircraft construction in terms of quality and purity. For example, automotive engineering permits relatively lower strengths at a higher overall weight for the textile. However, these lessened requirements on strength or weight in comparison to aircraft construction can already be achieved with a lower percentage of carbon fibers per textile segment, wherein the foreign materials produce no significant adverse effects. In addition, a maximum percentage of foreign materials is still acceptable in reaching the targets established in automotive engineering relative to the basis weights to be achieved.

The pile layer according to some embodiments here exhibits a plurality of bundles encompassing carbon fibers. The bundles typically stem from textiles that were sent to a recycling process to obtain the fibers for manufacturing the pile layer. Accordingly, the recycling process does not require that the fibers be completely broken up into single fibers for purposes of pile layer fabrication. The textiles are typically textiles that exhibit carbon fibers, but can also exhibit no carbon fibers, depending on the area of application.

The process for manufacturing the pile layer according to some embodiments with a pile forming machine can be adjusted in such a way that the introduced bundles need not be resolved into single fibers in the pile forming machine. However, this does not mean that single fibers will not be

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introduced into the pile forming machine aside from bundles. In particular, the bundles can be present in a random arrangement of fibers that has not been solidified or further processed, in which in part isolated fibers protrude from a bundle, and are intertwined with other fibers, wherein other fibers can also be present in the bundle. Depending on the embodiment, the bundle can consist completely of carbon fibers, or just a percentage thereof. The fibers sent to the pile forming machine can here also consist in part of original fibers that were not taken from a recycling process.

In order to prevent a complete resolution of the bundles in the pile forming machine, it is possible to adjust the number of processing steps, or the functional components in the pile forming machine. Also conceivable is a geometric adjustment of the functional components in the pile forming machine.

In both this conjunction and within the framework of the present patent application, a bundle must be understood as an accumulation of fibers that at least partially progress in an essentially parallel direction, wherein the fiber density in the bundle is at least partially elevated by comparison to the fiber density of the environment. Bundles can in this respect also be visually identified very well, since they stand out visually in a readily discernible manner from their environment, and can be easily visually identified as a bundle. In addition, a bundle can also exhibit a cohesion of single fibers, which safeguards the bundle against falling apart into single fibers when exposed to a mechanical stress.

The advantage to the pile layer according to some embodiments is that, while the bundles are also encompassed by the pile layer, the fibers are not resolved into single fibers. This imparts a special strength to the pile layer, in particular

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as relates to a mechanical stress, which acts on the bundles in a longitudinal direction of the fibers. By comparison to isolated fibers that are not further aligned relative to each other, this allows bundles to absorb external forces that act on the fiber composite material to be fabricated later in the direction of their fiber progression to a significantly better degree without failing.

One especially advantageous embodiment of the pile layer is distinguished by the fact that the bundles encompassing carbon fibers are at least partially also obtained from recycling process. For example, it is also conceivable in this embodiment for the bundles to have been obtained at least partially from a recycling process, along with the fibers encompassed by the pile layer. This enables an especially cost-effective fabrication of the pile layer, since fewer manufacturing steps are to be expected. Furthermore, the materials used in the pile layer are sometimes already tailored to each other. On the other hand, the pile layer to be manufactured can also be mixed with original, i.e., as yet unused carbon fibers, so as to offset any potential losses in quality owing to the reused carbon fibers. For example, a percentage of new single carbon fibers having a specific minimum length can be added to the pile layer, so as to elevate the overall fiber length distribution in the pile layer after the recycling process has shortened the carbon fibers during the recycling process. In addition, original carbon fiber bundles can be incorporated in the pile forming process.

The embodiment can also provide that the foreign materials at least partially exhibit foreign fibers, which are not carbon fibers. In particular, such foreign fibers are glass fibers and synthetic fibers, e.g., chemical textile fibers made of polyethylene, polyamide, polyester, polypropylene,

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etc. These fibers are also integrated into the pile layer during the pile forming process. These fibers here preferably become intertwined with the carbon fibers or other fibers encompassed by the pile layer. However, the foreign fibers only contribute negligibly to the strength of the pile layer, since the strength essentially stems from the carbon fibers. This relates in particular to the strength which the pile layer imparts to a fiber composite work piece encompassing it. But since the pile layer according to the embodiment exhibits enough carbon fibers, the required minimum strength can continue to be ensured.

One especially preferred further embodiment of the invention can also provide that the carbon fibers exhibit a predetermined first arrangement relative to each other, which determines a first pattern, and the foreign fibers exhibit a second arrangement relative to each other, which determines a second pattern, wherein the first pattern differs from the second pattern.

Here and below, a pattern is to be understood as a distribution of material density over the surface area to be considered, wherein variations in material density are at least partially present. In particular, these variations in material density are visually discernible, and can be systematically compared.

In particular, the differentiation between the two patterns can be ascertained by means of a flat autocorrelation function. For example, a surface section of the pile layer according to the embodiment, for example a surface section measuring 15 cm by 15 cm, is here selected and divided into smaller surface subunits—e.g., 1.5 mm by 1.5 mm—having the same surface area. Based on the standardized fiber densities prevailing in these surface subunits, a value is assigned to the individual surface subunits from a prescribed scale, for example a scale ranging from -5 to

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+5. Standardization takes place in relation to the overall fiber content in the surface section under examination. A two dimensional integral or two dimensional sum is then calculated over all adjacent surface subunits for each surface subunit, wherein the integral or sum is calculated over a product of the value for the predetermined surface subunit and the values for the adjacent surface subunits. Therefore, the calculation involves a correlation of fiber surface density for the surface subunits themselves, i.e., an autocorrelation of fiber surface density. The value determined in this way is assigned to the respectively predetermined surface subunit, wherein the calculation must be performed accordingly for all other surface subunits.

In order to simplify the calculation, a two-dimensional weight function can also be taken into account, for example which limits the integration or sum to an integration or sum encompassing the next 10 neighbors. However, the number selected cannot be so small as to prevent the integration or sum from extending to possibly repeating patterns for the carbon fiber density, for example caused by the corresponding arrangement of bundles in the pile layer. The results obtained from the individual calculations are then standardized once again, so that they can be made comparable relative to each other for all surface subunits. Standardization also makes it possible to correspondingly take edge effects into account too, which can arise given surface subunits lying close to the edge of the selected and examined surface section measuring about 15 cm by 15 cm.

Given a repetition of patterns, for example of carbon fibers, which are arranged in bundles spaced apart at more or less constant intervals in the pile layer, the values for the autocorrelation function will deviate from zero or another baseline value, which indicates that no repeating regularities arise, i.e., the distribution of values is

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purely random. As a consequence, the autocorrelation function is able to account for regularities in a pattern. However, these regularities must differ from a strictly static sequence of values. If the patterns are purely random, i.e., these patterns come about only as the result of a purely statistically random distribution of the individual values, the autocorrelation function will yield a baseline value or zero for all surface subunits. The baseline value depends on the scale values selected in advance, i.e., the baseline value denoting that a purely random distribution is present also depends among other things on the initially chosen scale.

Various patterns are obtained when the flat autocorrelation function for the distribution of carbon fibers is now compared with the flat autocorrelation function for the distribution of foreign materials or foreign fibers. A pattern differs when the standardized and summated values for all comparable surface subunits deviate by more than 5% on average. Other mathematically sensible or technically reasonable methods are possible to distinguish how the two arrangements of surface subunits or the patterns deviate. Also suitable for this purpose in particular is to calculate the mathematical or complex order for a pattern in the surface area.

As an alternative, the two patterns can also be compared using a simplified examination approach. As will be explained in detail in the figures section, this is preferred in particular when the foreign material density or foreign fiber density is so low that only a percentage of the surface subunits for the foreign material density or foreign fiber density exhibits an overlap with the surface subunits, while other surface subunits can have no overlap. Additional explanations regarding this simplified, and in most instances preferred, method of comparison may be gleaned from the figures section.

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The diversity of patterns reveals a varied distribution of single fibers in a selected surface section. If the foreign materials or foreign fibers that behave differently from the carbon fibers or the bundles encompassing carbon fibers in the pile manufacturing process are typically stochastically distributed, the bundles that encompass carbon fibers are typically increasingly distributed uniformly over the entire surface area of the pile layer, in part spaced apart at regular intervals. This circumstance also stems from the fact that the bundles exhibit an elevated tendency to be uniformly distributed over the entire surface area during the pile forming process in the pile forming machine when exposed to a mechanical stress. By contrast, the foreign fibers that are sometimes encountered in far fewer numbers in the pile layer can also be randomly distributed over the surface area of the pile layer, but are at times present in vastly lower concentrations. In addition, these single fibers behave differently while being mechanically processed in a pile forming machine, so that they typically exhibit a different distribution. Furthermore, the foreign fibers can also be conjoined with individual carbon fibers or carbon fiber agglomerates, thereby potentially also partially preventing a free movement independently of the remaining carbon fibers during the pile forming process. In addition, the foreign fibers can exhibit a completely different length distribution than the carbon fibers. Therefore, it must be expected that the pattern of carbon fibers in the pile layer will distinctly differ from the patterns of foreign materials or foreign fibers.

Another further development of some embodiments can also provide that the first pattern exhibit a higher order than the second pattern. The order is here determined based on the mathematical aspects to be applied in conjunction with patterns and complex arrangements. Determining the order

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within the meaning of a complex order here enables a generalization of the aspects described above for calculating an autocorrelation. Logical procedures for calculating the order are known to the expert, and can be applied accordingly to the case at hand.

A further embodiment of the present invention can also provide that at least 10% of the foreign fibers have a tensile strength that is 1.5 times, in particular 2 times, lower by comparison to the carbon fibers. However, the lower strength of the foreign fibers only diminishes the strength of the pile layer or the fiber composite material fabricated therewith to a slight extent, if at all, since the carbon fibers are present in sufficient amounts. In particular for applications in automotive engineering, the very small, yet possible losses in strength are insignificant.

Another embodiment can also provide that at least a portion of the foreign fibers are sewing or knitting threads. Accordingly, sewing or knitting threads originally provided to fix a textile to be reused, i.e., recycled, can be relayed to the pile forming process along with the carbon fibers encompassed by this textile, without having to be separated out of the carbon fibers or carbon fiber bundles. This reduces the manufacturing outlay on the one hand, and also ensures the production of a relatively more cost-effective pile layer.

It can also be provided that at least a portion of the foreign fibers exhibit a different color by comparison to the carbon fibers. On the one hand, this makes it easy to identify locations where accumulations of foreign fibers arise, which could potentially detract from the quality, while on the other hand, the foreign fibers can also be removed from the pile layer after the fact as needed in a targeted manner, should this become necessary. First and

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foremost to avoid visual impairments, consideration can be given to removing the foreign fibers from the pile layer composite.

An embodiment can also provide that at least a portion of the foreign fibers exhibits a crimp. Fibers with a crimp are better anchored with the surrounding carbon fibers, so that an additional local solidification can be achieved for the pile layer. The latter is especially advantageous when, after it has been manufactured, the pile layer is exposed to a mechanical stress during further processing that might at times cause damage to the pile layer as the result of handling.

Another embodiment can also provide that at least a portion of the foreign fibers be approx. 50%, preferably even 100%, longer on average than the carbon fibers in the bundle. For example, solidifying threads derived from the recycling process can still be present in the pile layer. Solidifying threads include in particular knitting threads or sewing threads that can be used to solidify carbon fiber textiles, but were not additionally isolated during the recycling process. Since these threads are typically also significantly less brittle than carbon fibers, these threads are not shortened to as great an extent as carbon fibers, even when processed in a mill, in particular a hammer mill. In addition, these threads typically already have a greater length when present in the textile object to be reused.

Another embodiment that builds on the preceding one can provide that the foreign fibers are glass fibers and/or polyester fibers. In particular in conjunction with carbon fibers, the latter are preferred auxiliary fibers, which are readily used especially in textile structures intended for preliminary solidification. In particular, polyester fibers are preferably used for sewing or knitting

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individual textile layers. Other fibers are also possible, including polyamide fibers, polyethylene fibers, polypropylene fibers or the like.

Another embodiment of the invention can also provide that the foreign substances at least partially exhibit a chemical binder, in particular a resin. Therefore, the embodiment does not require that a binder be removed from the fiber surface or completely removed before relaying the fibers to a pile forming process. Rather, percentages of this binder can be integrated into the pile layer, but without having to diminish the strength requirements placed on the fiber composite material to be subsequently manufactured. The binder can instead even help to pre-solidify the fibers in the pile layer, so that the pile layer can exhibit an improved cohesion of fibers, for example. As a consequence, this type of pile layer is easier to handle, and can be exposed to a stronger mechanical stress, for example when subsequently processed. Furthermore, it is possible for the binder to be identical with the resin used to later treat the pile layer, so as to fabricate a fiber composite material. As an alternative, the binder can also be chemically compatible with another resin, which serves to subsequently manufacture a fiber composite material by means of the pile layer.

Another embodiment can also provide that the plurality of bundles encompassing carbon fibers be no longer than 15 cm, and in particular no longer than 10 cm. As the length incrementally shortens, the relative bundle content in the pile layer can be improved while keeping the fiber content constant. However, this incrementally improves the strength provided to the pile layer by the bundles. It may here also be necessary that the bundles exhibit sections having a suitable orientation in preferably one predetermined direction, so as to achieve a direction-specific improvement in strength. However, this sometimes requires

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that the bundles not drop below a minimum length. In another embodiment, it may thus be advantageous for the curved bundles not to dip further below a lower length of about 2 cm.

A preferred embodiment can also provide that the bundles encompass at least 200, preferably at least 500, and especially preferably at least 1000 carbon fibers. This makes it possible to increase the strength given to the pile layer by a possible alignment of the bundles, as a result of which an improved, directionally dependent strength is also imparted to the fiber composite material to be subsequently manufactured, for example. In addition, this makes it possible to reuse carbon fiber textiles from a recycling process, which typically exhibit strands comprising more than 1000 fibers per strand. In a suitable process, the latter are prepared in a carbon fiber textile to be reused in such a way as to break open the strands to a minimum number of fibers. By subsequently being processed in a pile forming machine, the strands or bundles can in part be broken up even further, but not to more of an extent than to leave behind a number of fibers in the pile layer according to the embodiment.

Another embodiment can also provide that a pile layer exhibit a mass per unit area (weight per unit area) of at most 50 g/m², and no less than 10 g/m², preferably between 35 g/m² and 25 g/m². Such pile layers are especially desired in particular in the automobile industry, since they exhibit a sufficient strength in the fiber composite material to be subsequently manufactured, while allowing a very large reduction in the weight of the component. In particular the masses per unit area according to the embodiment enable an efficient use of the valuable raw material, carbon fibers, while at the same time ensuring compliance with the minimal requirements placed on

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strength. Therefore, the ratio between required strength and the present weight is especially advantageous.

The present disclosure further provides an embodiment involving a nonwoven or nonwoven material, which exhibits at least two pile layers according to an embodiment of the invention, which in particular are needled together. By processing at least two pile layers into a nonwoven or nonwoven material, the strength-enhancing properties of the pile layers can be improved yet again. In particular, the directional or orientation properties can be tailored to each other by suitably orienting the at least two pile layers in relation to each other. For example, the one pile layer can be arranged with a first orientation, while the second pile layer is arranged relative to another, second orientation that differs from the first orientation. This makes it possible to define several preferred directions within a nonwoven or nonwoven layer. The bundles here already exhibit a preliminary orientation, and thereby also impart a suitable orientation to the pile layer. Some embodiments are intended to prevent the bundles from breaking up into single fibers as the result of needling.

Another preferred embodiment of the nonwoven material can also provide that it exhibit a pile layer according to the embodiments described previously, which is needled for solidification purposes. Needling causes the fibers encompassed by the pile layer to become further intertwined, in particular intertwined on a local level, thereby producing a local solidification. If the pile layer is needled with a sufficient number of sufficiently dense stitches, a distinctly improved strength can be imparted to the entire pile layer structure.

Another embodiment of a nonwoven or nonwoven material can also provide that the orientation of the curved bundles in

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a pile layer deviate from the orientation of the curved bundles in another pile layer by at least 5° , in particular differing by an angle of 15° , 30° , 45° , 60° , 75° or 90° . In particular, this makes it easy to generate preferred directions within the nonwoven or nonwoven material with a defined angular deviation. This proves very advantageous within the framework of processing in automotive vehicle construction, since the preferred directions can be suitably tailored relative to the applications.

Another embodiment of the invention can also provide that at least two pile layers are needled together or one pile layer is needled for solidification purposes, wherein on average at least 1 needling puncture, preferably at least 5 needling punctures, are present on an area of 1 cm^2 . The designated area relates to the area of the pile layer or pile layers processed via needling, which preferably represents the entire area of the pile layer or pile layers. Introducing the needling punctures solidifies the pile layer or pile layers on the one hand, so as to improve handling thereof. The needling process here produces above all a local solidification, as already explained above. Due to the selected density of the needling punctures, the embodiment ensures that the number of local solidifications is high enough to yield a solidification that extends over the entire selected area of the pile layer(s). This becomes possible in particular when, given a uniform distribution of the pile layer or pile layers into respective subunits of 1 cm^2 , each subunit exhibits the number of needling punctures according to the embodiment. In addition, the needling punctures provide a sufficient number of openings in the pile layer or pile layers to enable a more efficient impregnation with a liquid resin or a polymer. This is because the openings make it possible to efficiently relay the resin or polymer over the entire needling thickness, and hence, as stipulated in the embodiment, over the entire thickness of the pile layer(s). This reduces the

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impregnation time for one, and hence also the manufacturing time for components that encompass the pile layer(s).

Some embodiments can also provide that a resin-impregnated component exhibit a pile layer described above, or a nonwoven described above, or a nonwoven material described above, wherein the component is designed in particular as a vehicle component. Such components can exhibit the described pile layers, nonwovens or nonwoven materials separately or in conjunction with other textile structures. In particular, it is possible for the described pile layers, nonwovens or nonwoven materials to be encompassed by the component in conjunction with a structure and/or a fabric, wherein the structure and/or fabric is furnished primarily to absorb stresses. It is further also possible for the components of a vehicle exhibiting the described pile layers, nonwovens or nonwoven materials not to be provided to ensure the passive safety of a vehicle. In particular, these components are preferably designed as parts of the outer skin of a vehicle. The component can be impregnated with resin, wherein a complete impregnation or even just a partial impregnation can be achieved. In addition, the resin-impregnated component can be hardened. The resin impregnation according to the embodiment must also include a suitable polymer impregnation.

An especially preferred embodiment of the method can also provide that the method not encompass the step of separating the foreign materials, or not encompass the step of partially separating the foreign materials. This cuts the number of steps for preparing the amount of material or fiber to be processed into a pile layer, since it omits the step of separating or partially separating foreign materials, in particular foreign fibers. While the foreign materials are thus also integrated into the pile layer and increase its basis weight, the foreign

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materials, in particular the foreign fibers, have only a negligible, if any, bearing on the strength in the fiber composite material to be subsequently manufactured, so that the carbon fibers that are also still present can ensure a
5 sufficient and desired strength.

It can further also be provided that bundles encompassing carbon fibers and obtained in a recycling procedure may be used for fabricating a pile layer, in particular for manufacturing a pile layer described above, while implementing a method
10 described as conforming with the invention or embodiment.

Various embodiments of the pile layer, nonwoven or nonwoven material and the manufacturing process for fabricating a pile layer according to the invention will be used below to explain embodiments of the invention in detail based on figures. The
15 depicted embodiments do not represent a limitation with respect to the entirety of the invention. In particular, the features described below are each respectively being described both in isolation and in conjunction with the features described above. As a consequence, embodiments of the invention extend to every
20 technically possible combination of features that is suitable from the standpoint of embodiments of the present invention.

Shown on:

Fig. 1a is a first embodiment of a pile layer according to the invention, top view;

25 Fig. 1b is the percentage of carbon fiber in the pile layer according to Fig. 1a, isolated view;

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Fig. 1c is the percentage of foreign fiber in the pile layer according to Fig. 1a, isolated view;

Fig. 2 is a schematic view of the percentage of foreign fibers according to Fig. 1c in conjunction with a flat distribution for characterizing the pattern or order of the pattern of foreign fibers;

Fig. 3 is a first embodiment of a nonwoven or nonwoven material according to the invention, top view;

Fig. 4 is a flowchart for illustrating the sequence of individual steps, which are encompassed by an embodiment of the manufacturing method according to the invention.

For the sake of completeness, let it here be noted that the embodiments shown are only schematic representations. In particular the dimensions and proportions for a specific object of the invention can deviate from those in the illustrations depicted.

Fig. 1 presents a first embodiment of a pile layer 1 according to the invention with a plurality of bundles 2 that encompass carbon fibers 10. While the bundles here exhibit a preferred curved progression, they can also have any other technically possible progression. The curvature of the present bundles is the result of being processed with a carding machine. The bundles 2 are intertwined with other fibers encompassed by the pile layer 1, which can also be carbon fibers 10, thereby making it possible to prepare a pile layer 1 that is strong enough, for example, that it can be removed from the pile forming machine as a complete structure, or undergo further mechanical processing.

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In addition to the percentage of carbon fibers depicted in an isolated view on Fig. 1b, the pile layer 1 according to Fig. 1a also encompasses a number of foreign materials 20, in particular in the form of foreign fibers 20, which are shown in bold. These foreign materials 20 or foreign fibers 20 are again depicted in an isolated view on Fig. 1c. The foreign materials 20 or foreign fibers 20 are here each randomly arranged. In particular, the progression of the foreign material 20 or foreign fiber progression exhibits no regularity. In addition, the individual foreign materials 20 or foreign fibers 20 also have a purely random arrangement relative to each other.

However, matters are different with respect to the carbon fibers 10, in particular those encompassed by the bundles 2. As evident from the depiction on Fig. 1b, the bundles exhibit a relatively similar, curved progression. The latter is characterized by a vertex area, which has the largest curvature in the progression of a bundle. The vertex area is situated between the bundle ends, wherein the bundle end areas exhibit only a relatively slight curvature by comparison to the vertex area. The bundle end areas are sometimes not even curved at all.

Due to the curved progression, the bundles 2 also exhibit a preferred direction not just roughly in the direction of fiber progression at the bundle end areas, but also roughly in the direction tangential to the vertex area. Therefore, the curved progression ensures that the bundles 2 exhibit a preferred direction not just with respect to force absorption, but also another preferred direction that deviates from it, in particular running perpendicular to the first preferred direction.

Within the framework of the present invention, the curvature of a bundle 2 is determined from the averaged directional progression of all fibers in the bundle 2. For

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purposes of this determination, the fibers in a bundle are acquired in terms of their individual spatial position, wherein the average position is calculated from comparable sections of individual fibers in the bundle 2. In particular in areas where the fibers in the bundle 2 are tightly packed over a circular cross section, the average progression essentially corresponds with that of the fiber located in the middle of the bundle 2 in relation to the cross section. However, if the fibers are fanned out, as will sooner typically be the case at the bundle ends, it will be possible to calculate the average progression of the bundle 2 by averaging the layers of all comparable sections of the individual fibers. Based upon established deliberations, the expert can calculate the average so as to determine the average progression.

As may also be gleaned from the depiction on Fig. 1b, the bundles 2 exhibit a comparable orientation. In the present case, this means that the vertex areas of the bundles 2 are oriented to one side of the pile layer 1, while the individual bundle ends of the respective bundles 2 point to the opposite side of the pile layer 1.

In addition, the distances between the individual bundles 2 and the respective immediately adjacent bundles 2 only vary to a negligible extent for all bundles 2. This relates both to the distances between the respectively adjacent bundles 2 laterally as shown on Fig. 1b, as well as to the distances from the next bundles 2 above or below a bundle 2 in the respective illustration.

As a result, a pattern can be derived from the arrangement of individual bundles 2 on Fig. b that cannot be discerned in the arrangement of foreign materials according to Fig. 1c.

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In order to determine this pattern more precisely, the examined surface section of the pile layer 1, for example a surface section measuring 20 cm by 20 cm, can very easily be divided into respectively identical surface subsections. This is schematically denoted on Fig. 2. In the present case, the depicted surface section was divided into a checkerboard pattern of 32 by 32 surface subsections. Depending on foreign material density or foreign fiber density in a respective surface subsection, a value can now be assigned to the respective surface subsections. The foreign material density and foreign fiber density must here be standardized to the overall [material] density or overall fiber density. In the simplest case, a value of 1 could be assigned if percentages of foreign materials or foreign fibers were present in the surface subsection. However, this simple breakdown only makes sense given a high enough number of surface subsections that exhibit no percentages of foreign material or foreign fibers in the distribution. Otherwise, a finer breakdown is called for in most instances. As already described above, for example, such a breakdown could involve using a scale of -5 to +5, and assigning an integral value as a function of foreign material density or foreign fiber density, wherein the lowest density would be rated -5, and the highest density +5.

If a comparable approach were now also to be taken with respect to carbon fiber distribution as shown on Fig. 1b (not depicted in any greater detail here), the result would be a varying distribution of standardized fiber densities. Accordingly, a different value would in most instances be assigned to the individual comparable surface subunits than in the case of the foreign material density or foreign fiber distribution. In order to now compare the patterns for carbon fiber distribution according to Fig. 1b and foreign material distribution according to Fig. 1c, the individual values for the respectively corresponding

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surface subunits can be compared to each other. This comparison could be performed mathematically by subtracting the values for the respectively comparable surface subunits from each other.

If both patterns were now to be identical, subtraction would yield a value of zero for each surface subunit. However, the more varied the patterns, the more different the individual values yielded by subtracting the surface subunits. This results in a gauge for the disparity between the patterns to be compared. From a practical standpoint, it could be determined that the two patterns differ if the subtracted values for all respective comparable surface subunits exceed an average limit. For example, the patterns could differ if the sum of all subtracted values for all surface subunits standardized to the overall number of surface subunits exceeds a predetermined value. This value must be determined in a reasonable manner in accordance with the scale graduation selected above. For example, it could measure 0.1 in a scale ranging from -5 to +5.

In the present case, determining the differences between the patterns for both examined surface sections is relatively easy, since the distribution of carbon fibers 10 clearly differs from the distribution of foreign materials 20 or foreign fibers 20. In each instance, this difference can already be discerned with the naked eye. This holds true in particular because the distribution of foreign materials 20 or foreign fibers 20 does not even cover numerous surface subunits of the examined surface section. However, if most or even all surface subunits are covered, a simple comparison of patterns by subtracting the values for the respective comparable surface subsections can at times produce a false picture. In addition, certain patterns may not be immediately obvious, since the patterns are scarcely perceptible in the amount of existing carbon fibers 10 or foreign materials 20. In this respect, it may

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be appropriate to use a more refined method of pattern comparison. For example, as already described above, the flat autocorrelation for all surface subunits can be calculated, which is sometimes better able to have existing pattern regularities included in the calculation.

Both introduced methods are each equivalent in terms of comparing patterns within the framework of the present invention, wherein the simpler method is preferably to be used given a foreign material distribution if at least 5% of the identified surface subsections of a surface section chosen for purposes of pattern comparison are unable to show any foreign materials in the overlap.

Fig. 3 shows a first embodiment of a nonwoven or nonwoven material according to the invention, which consists of two plies of a pile layer 1 fabricated through doubling. If a nonwoven fabric is present, the latter can have been solidified by needling the two plies of the pile layers 2. In an embodiment, the two pile layers 2 are arranged relative to each other in such a way that their respective preferred directions are turned by a specific angle in relation to one another. In this way, the strength-enhancing properties that may be derived from the preferred directions of the individual pile layers 2 can be adjusted in a directionally specific manner. A relative arrangement of the two pile layers 1 to each other can preferably involve turning by an angle of 15°, 30°, 45°, 60°, 75° and 90°. In the present case, the relative arrangement of the two pile layers 1 has them turned by about 45° relative to each other.

Fig. 4 relates to a flowchart for illustrating the progression of individual steps, which are encompassed by an embodiment of the method according to the invention for manufacturing a pile layer. According to the latter, it is necessary to cut a flat structure, which exhibits bundles 2

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encompassing carbon fibers 10, and is fixed at least partially by foreign materials 20, in particular by knitting threads. Cutting can here be understood in its most general form, and also encompasses a blanking step, for example. In addition, it is necessary that the cut flat structure be processed, in particular in a hammer mill, so as to partially break up the bundles 2 into single fibers; also encompassed is a step of introducing the batch partially broken up during this processing step into a pile forming machine, in particular into a carding machine. The pile forming machine is subsequently operated so as to not completely isolate the bundles 2 into single fibers, while still intertwining carbon fibers 10 in the bundles 2 with other fibers. The pile layer fabricated in this way is then removed from the pile forming machine. In particular, the method does not also encompass the step of separating the foreign materials 20 or foreign fibers 20.

In a further manufacturing method, the pile layers can subsequently also be processed into nonwovens or nonwoven materials. Needling, stitching or knitting can also be considered for solidifying several pile layers 1 laid on top of each other. The curved bundles 2 encompassed by the pile layers 1 must here only be partially damaged, if at all.

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Reference numbers:

1	Pile layer
2	Bundle
10	Carbon fiber
5 20	Foreign material/foreign fiber

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CLAIMS:

1. A pile layer, which exhibits a plurality of bundles partially broken up into single fibers and encompassing carbon fibers, as well as foreign materials, wherein
- 5 the carbon fibers comprise at least 70% by weight of the overall weight of the pile layer, and the foreign materials comprise no more than 30%, but not less than 2%, wherein the foreign materials are derived from a recycling process.
2. The pile layer according to claim 1, wherein the
- 10 bundles encompassing the carbon fibers are at least partially also derived from a recycling process.
3. The pile layer according to claim 1 or 2, wherein the foreign materials at least partially exhibit foreign fibers, which are not carbon fibers.
- 15 4. The pile layer according to claim 3, wherein the carbon fibers exhibit a predetermined first arrangement relative to each other, which determines a first pattern, and the foreign fibers exhibit a second arrangement relative to each other, which determines a second pattern, wherein the
- 20 first pattern differs from the second pattern.
5. The pile layer according to claim 3 or 4, wherein at least 10% of the foreign fibers have a tensile strength that is 1.5 times lower by comparison to the carbon fibers.
6. The pile layer according to any one of claims 3 to 5,
- 25 wherein at least a portion of the foreign fibers are sewing or knitting threads.

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7. The pile layer according to any one of claims 3 to 6, wherein at least a portion of the foreign fibers exhibit a different color by comparison to the carbon fibers.

8. The pile layer according to any one of claims 3 to 7, wherein at least a portion of the foreign fibers is approx. 50% longer on average than the carbon fibers in the bundle.

9. The pile layer according to any one of claims 1 to 8, wherein the foreign materials at least partially exhibit a chemical binder.

10. The pile layer according to any one of claims 1 to 9, wherein the plurality of bundles encompassing carbon fibers are no longer than 15 cm.

11. The pile layer according to any one of claims 1 to 10, wherein the bundles encompass at least 200 carbon fibers.

12. The pile layer according to any one of claims 1 to 11, wherein the pile layer exhibits a mass per unit area of at most 50 g/m², and no less than 10 g/m².

13. A nonwoven or nonwoven material that exhibits at least two pile layers according to any one of claims 1 to 12.

14. A nonwoven material that exhibits a pile layer according to any one of claims 1 to 12, which is needled for solidification purposes.

15. The nonwoven or nonwoven material according to claim 13 or 14, wherein at least two pile layers are needled

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together or one pile layer is needed for purposes of solidification, wherein on average at least 1 needling puncture is present on an area of 1 cm².

16. A method for manufacturing a pile layer, encompassing
5 the following steps:

cutting a flat structure that exhibits bundles encompassing carbon fibers, and is at least partially fixed by means of foreign materials;

10 processing the cut flat structure to partially break open the bundle into single fibers in an opening unit;

introducing the batch partially broken up as the result of being processed in this way into a pile forming machine;

15 operating the pile forming machine in such a way as not to completely isolate the bundles into single fibers, but rather to intertwine carbon fibers in the bundles with additional fibers; and

removing the pile layer from the pile forming machine.

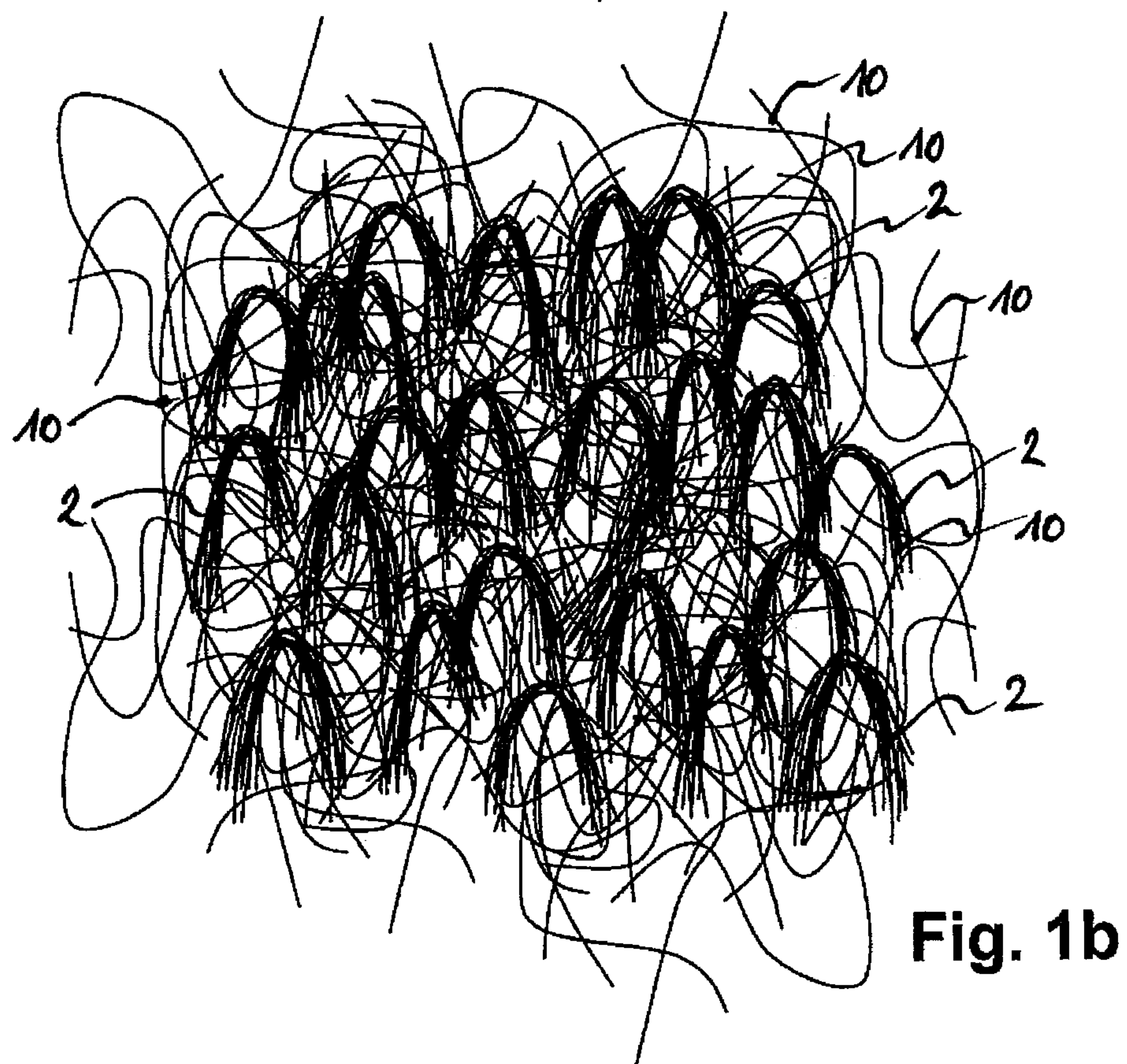
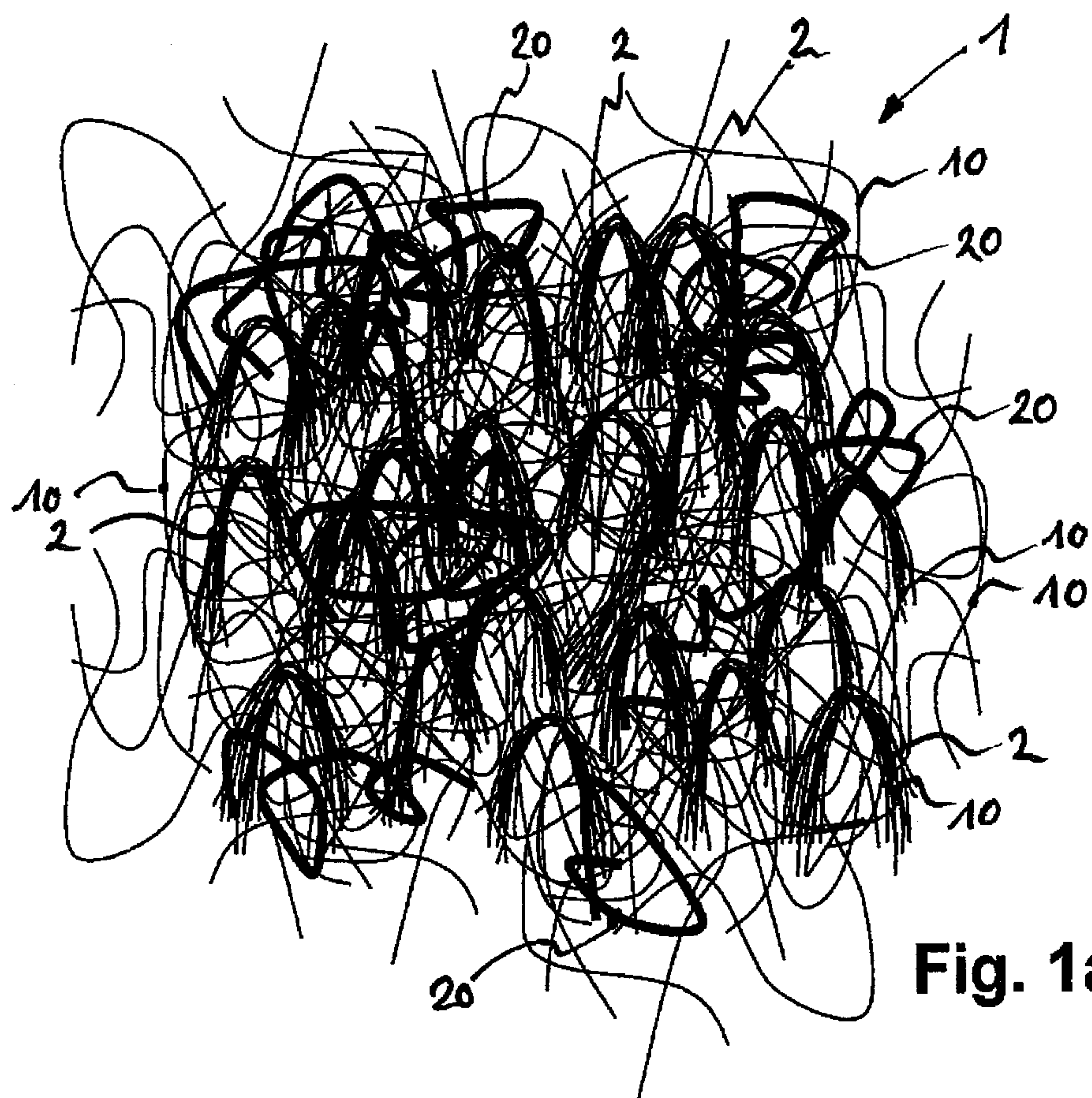
20 17. The method for manufacturing a pile layer according to claim 16, wherein the method does not encompass a step of separating the foreign materials, or does not encompass a step of partially separating the foreign materials.

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18. The method for manufacturing a pile layer according to claim 16 or 17, wherein the bundles encompassing carbon fibers are obtained in a recycling procedure.

19. A resin-impregnated component, encompassing a pile
5 layer according to any one of claims 1 to 12 or a nonwoven or nonwoven material according to any one of claims 13 to 15.



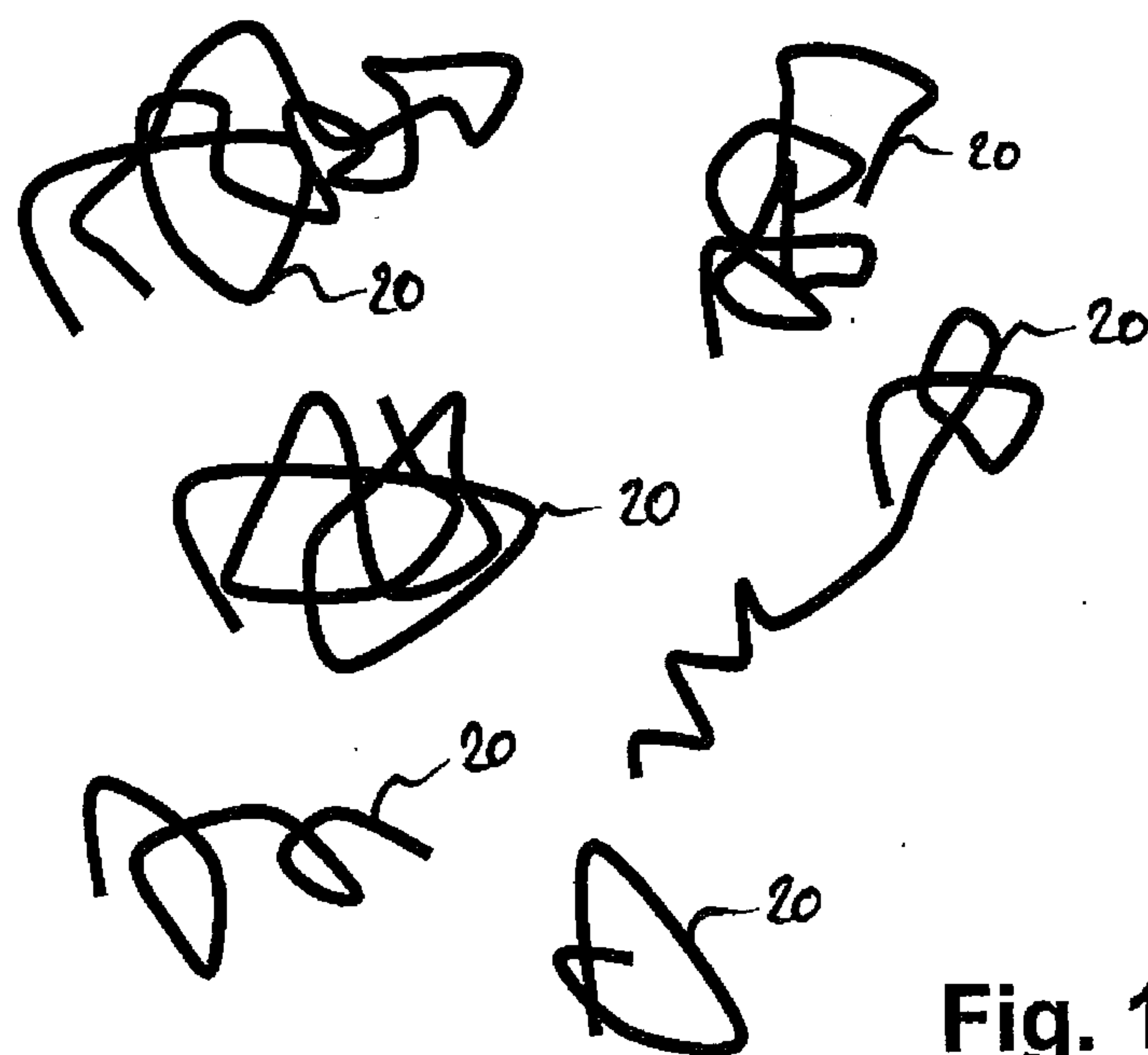


Fig. 1c

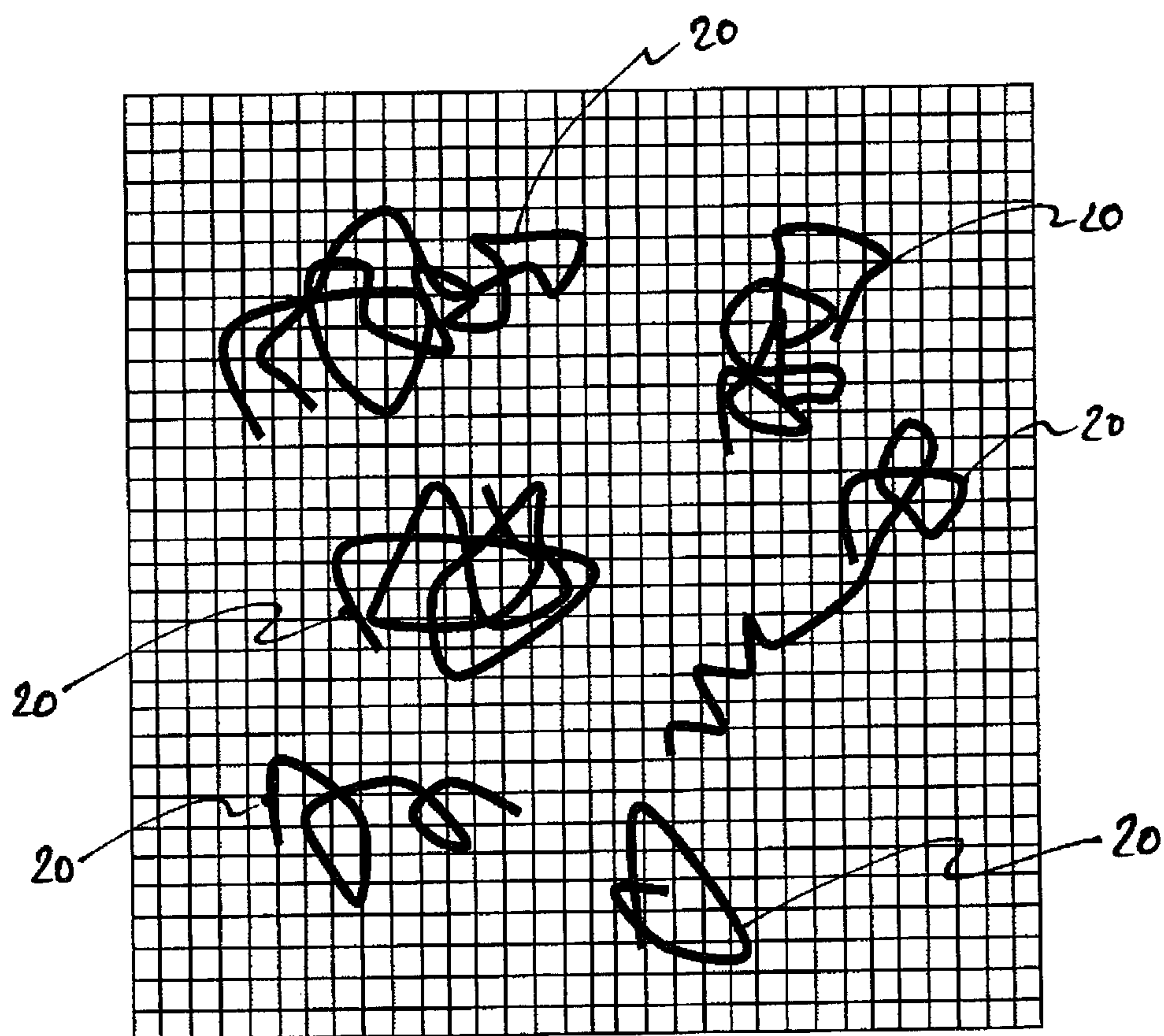


Fig. 2

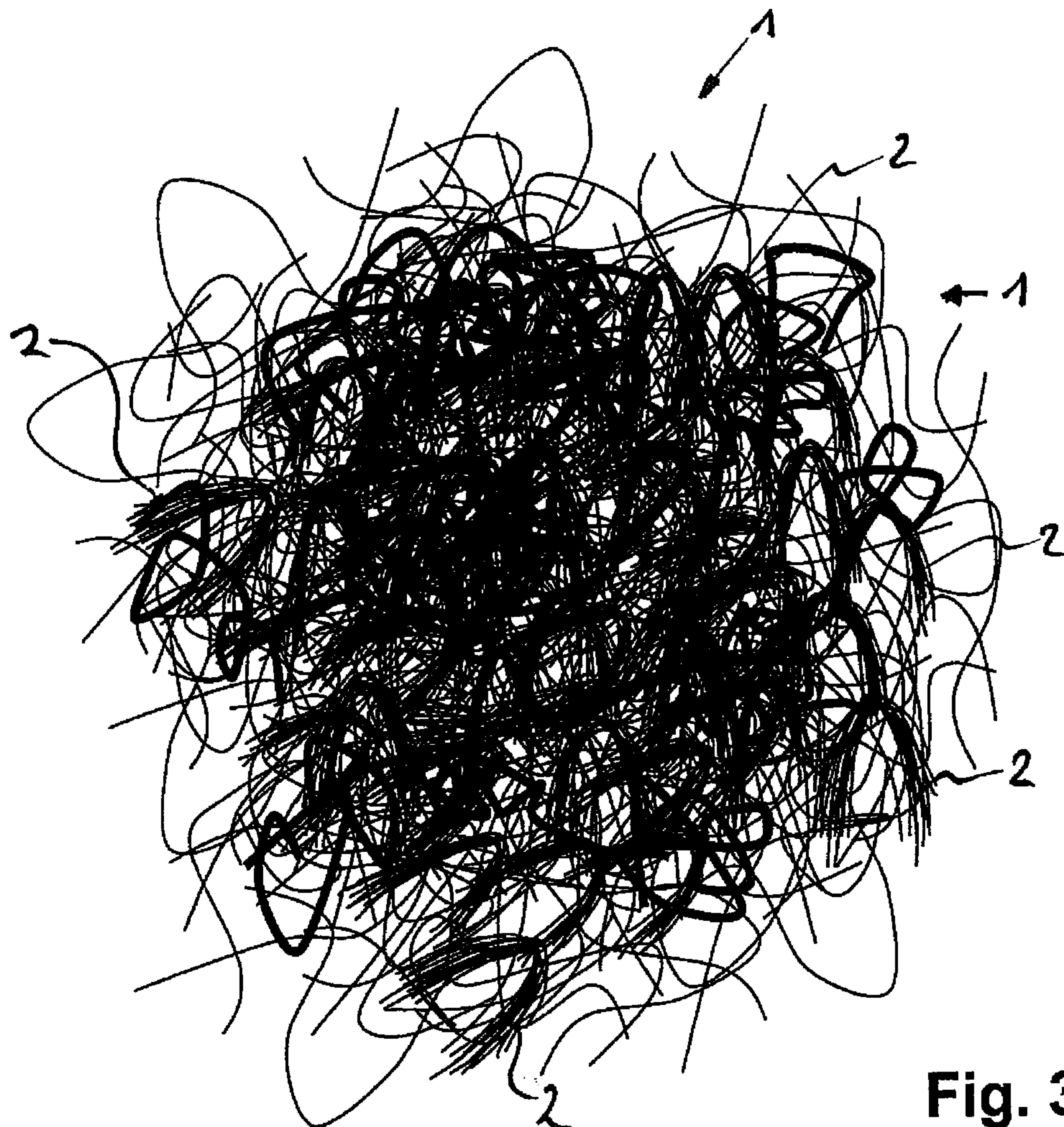
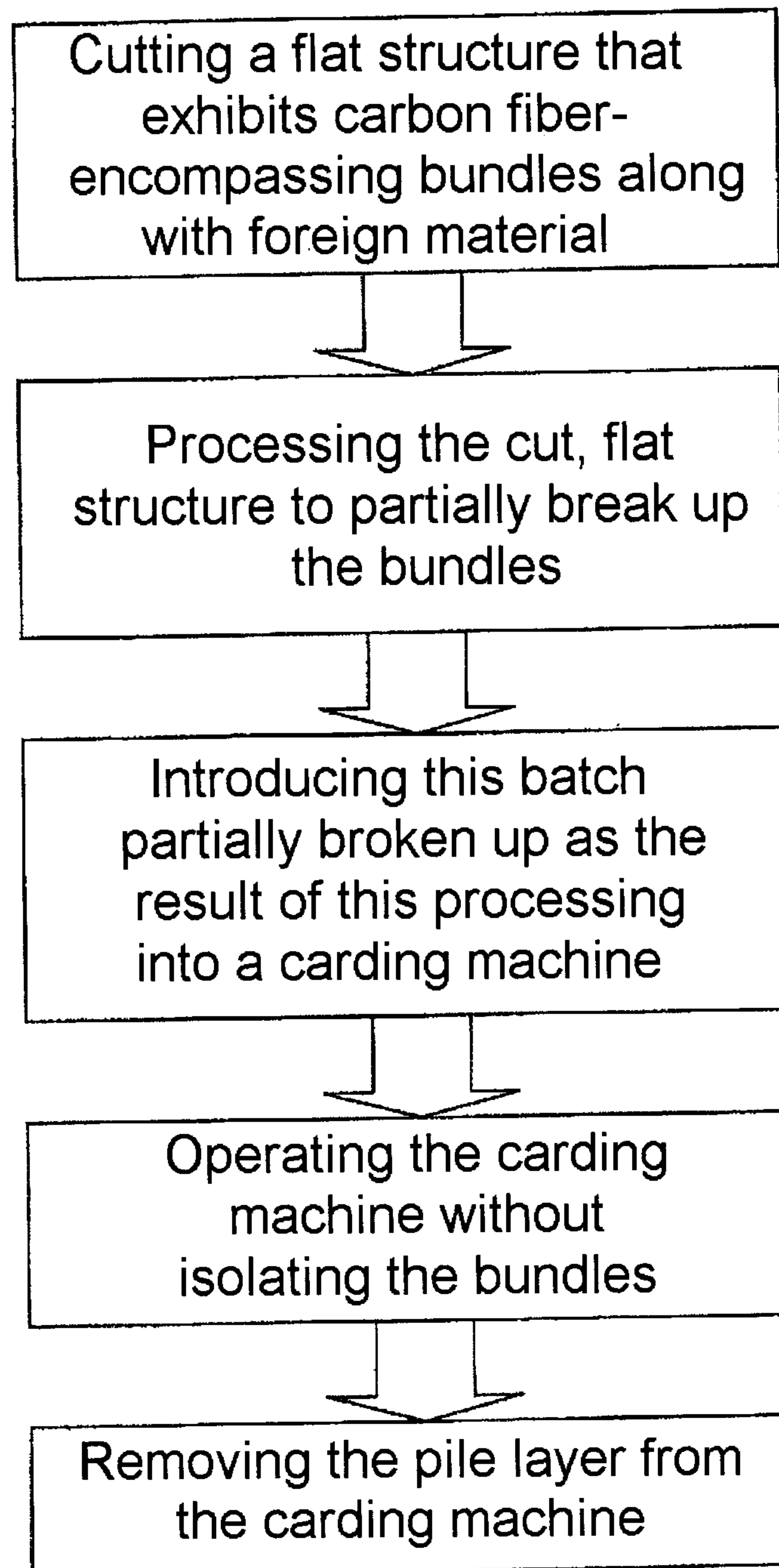
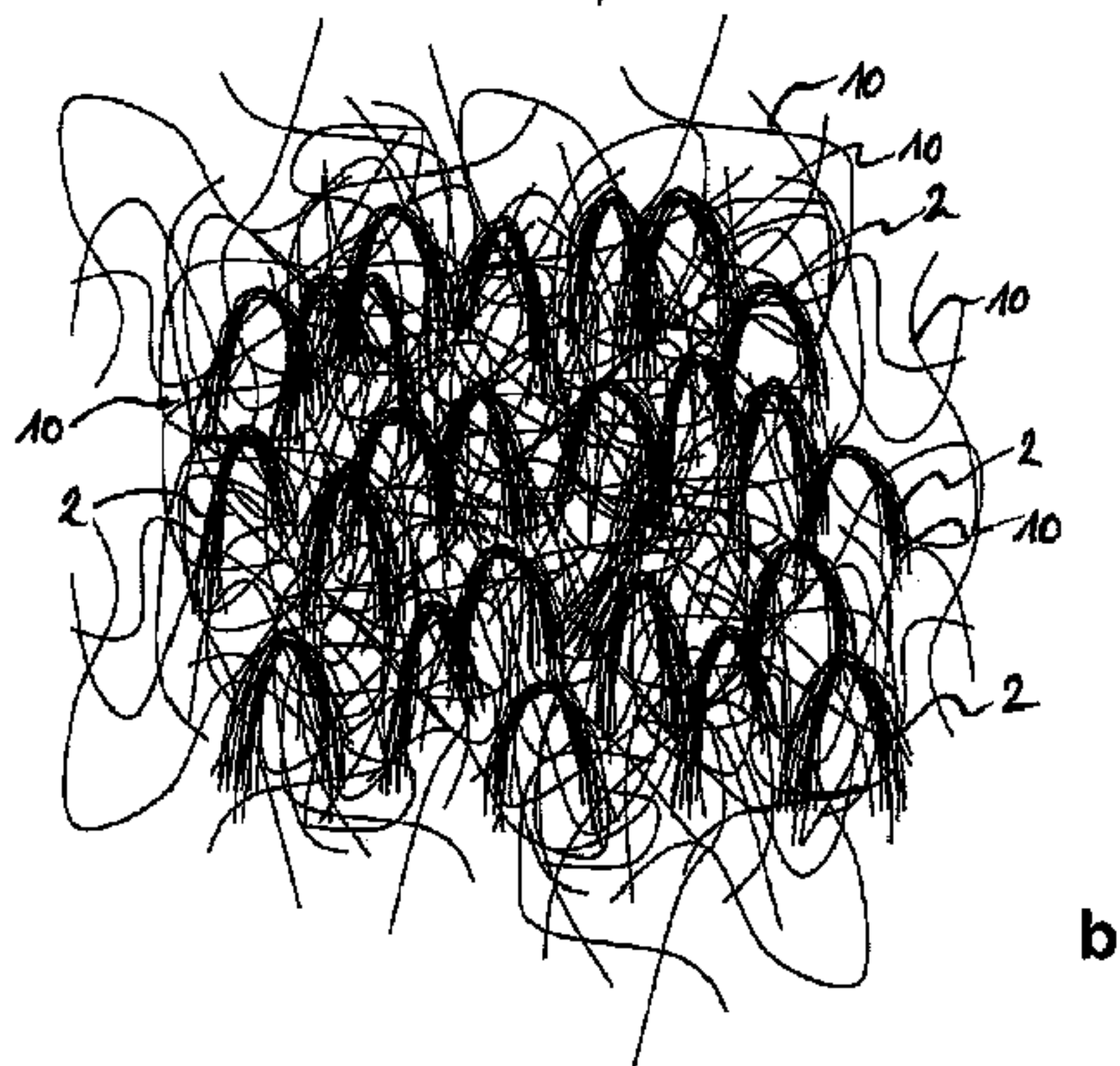
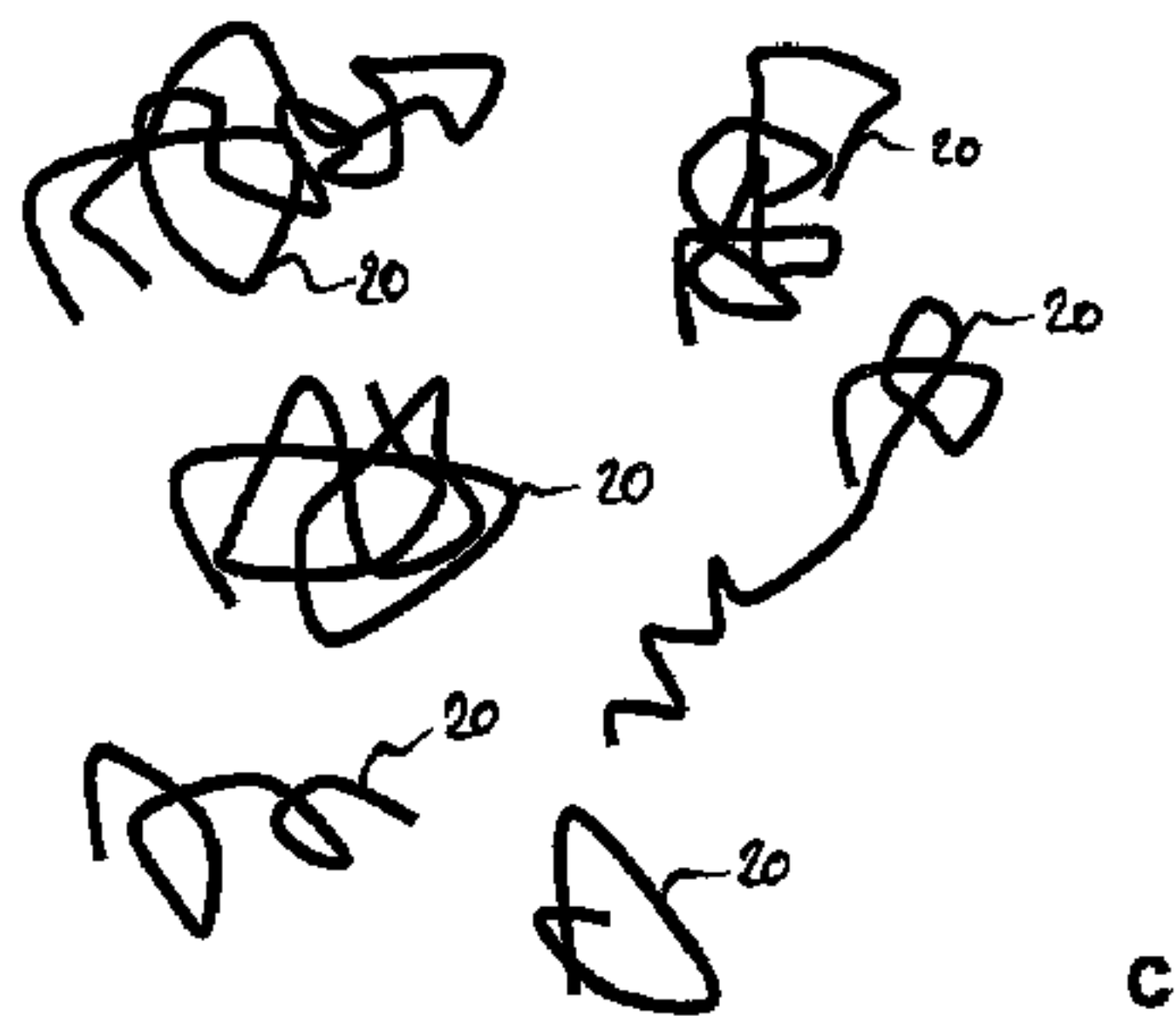
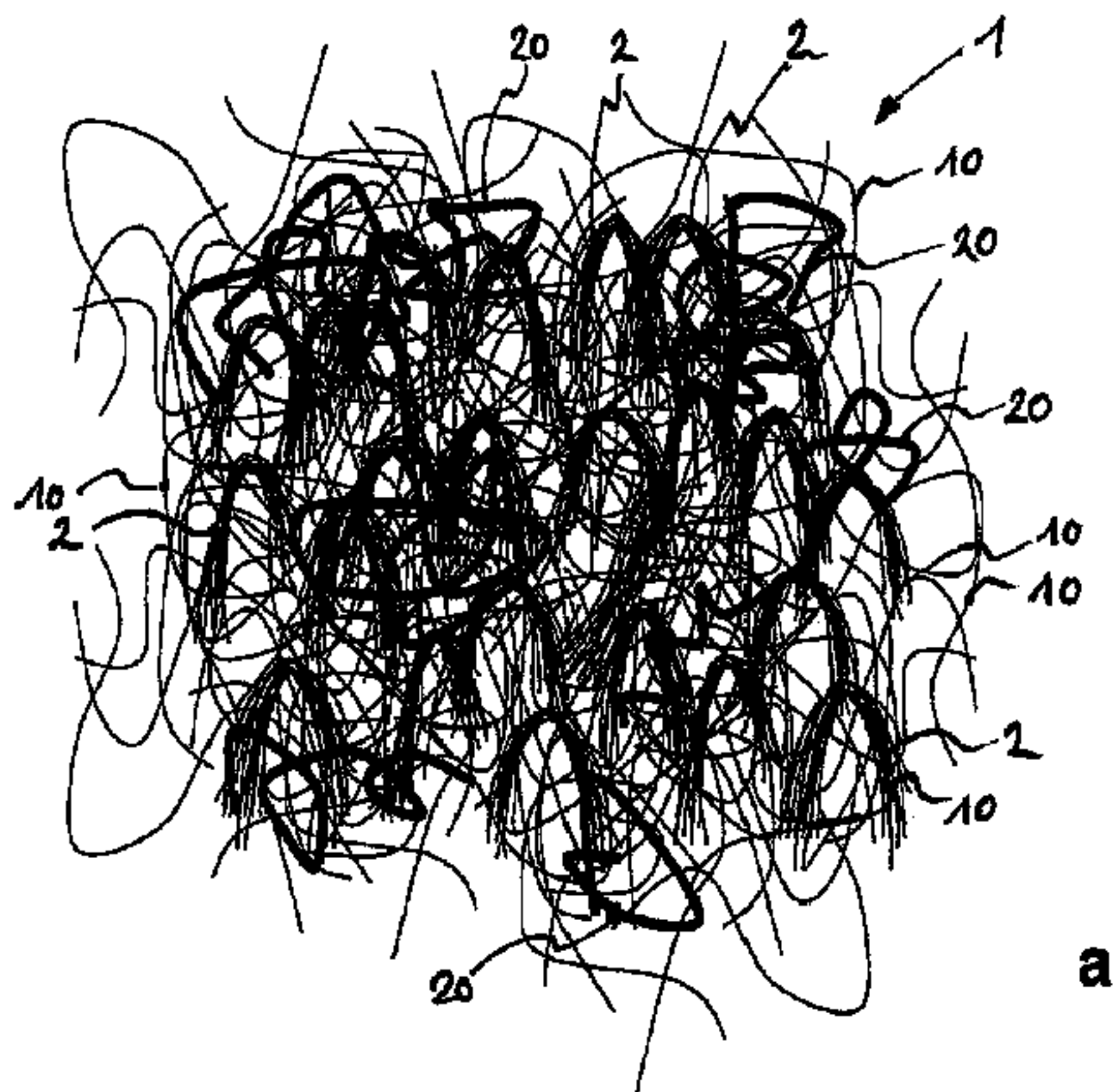


Fig. 3

**Fig. 4**



a

c

b