

A METHOD AND SET-UP FOR MANUFACTURING AN EMBOSSED SHEET OF MATERIAL AND
OBTAINING A CONTROLLED MATERIAL THICKNESS AND A FILTERING ELEMENT

Technical field of invention

The invention is in the field of manufacturing for the inhalable drug delivery system industry, including smoking products in which medical drugs or nicotine may be dispensed in a gas to a user in various inhalable ways, comprising for example vapor, heated tobacco, and conventional burned tobacco as known from cigarettes and cigars, more specifically in a field of embossing, and relating to a component of a filtering element, and the filtering element as such.

Background of the invention

Numerous prior art references discuss the technical field of the invention specifically for the cigarette industry.

Prior art publication "Basic principle of cigarette design and Function" by Ken Podraza, Philip Morris, Presentation to LSRO 29-30 October 2001 contains a wealth of information about the parameters ruling the manufacturing and the consumption of cigarettes.

A further prior art publication "Effect of cigarette filter components on its efficiency and smoking characteristic of cigarettes", Sobhy Mohammed Mohsen, Abdalla S.M. Ammar, Ateya Fathy, Bioscience Research, January 2018, Pages 325–336, is a further source of information more focused on cigarette filters of cigarettes.

French publication FR 2 418 628 discusses a method and a device for transforming a fibrous sheet of material in order to manufacture a cigarette filter or simple filter. The publication describes how to make a certain topographical profile on the sheet to obtain a filtering structure, whereby the height of the profile may be varied during the process, to vary at the same time a transversal stretching of the sheet, and hence its texture's characteristics, to obtain on one hand an embossed texture or on the other hand a longitudinal creped texture, or any intermediate texture, whereby the characteristics may be varied without any discontinuity. Hence the draft of the resulting filter may be adjusted as needed by suitably adapting the texture.

Since the publications of above prior art documents, smoking and other inhalable drug delivery systems have undergone significant development with a recent multiplication of utilization domains. In addressing an enhanced user experience, much research and development has been centered around the filtering element of a such a device, which currently primarily serves the purpose of filtering the gas generated from the drug containing part of the inhalable drug delivery system. The user then receives a mainstream gas into his mouth by drawing through the filter on the opposite end of the cigarette. Certain cigarettes or other inhalable drug delivery systems incorporate filter elements or towels having absorbent materials dispersed therein, such as activated carbon or charcoal materials in particulate or granular form. For example, a filtering element can possess multiple segments, and at least one of those segments can comprise particles of high carbon-content materials.

Following facts may be retrieved from the reading of both above cited prior art documents "Basic principle of cigarette design and Function" and "Effect of cigarette filter components on its efficiency and smoking characteristic of cigarettes":

Paper cigarette filters offer a higher smoke-component removal efficiency as the conventional cellulose acetate cigarette filters, at a same filter characteristic pressure drop, but this increase comes with a poor visual appearance. A filter pressure drop is the amount of suction that must be used to pull smoke through the filter, at a standardized suction volume (35 ml puff in 2s).

The term "Retention", used at further points in the description of this invention, is alternative way of designating a filtering efficiency, i.e., a percentage of gas components (e.g., particulates) that are removed by the filtering element.

As the pressure drop increases for a given filtering configuration, filtration efficiency increases due to a reduction in a mainstream gas velocity. In the same time, particulate phase materials can be removed to some degree with a filtering element produced of fibrous materials, while gases (CO, NOx) are not removed.

Considering its dynamics, a gas flow velocity shall increase as the gas passes through a constriction section, whereas its static pressure shall decrease in accord with the principle of conservation of mechanical energy (Bernoulli's principle). Thus, any gain in kinetic energy a gas may attained by its increased velocity through a constriction section is balanced by a drop in pressure.

As Bernoulli's principle is invertible, by passing through an expansion section the gas flow velocity shall decrease and its static pressure should rise. Furthermore, if a gas flow presents an alternance of a constriction section and an expansion section, turbulences will appear in the gas flow.

Sustainable substrates (e.g., paper- or cellulosid-based) used to produce sustainable cigarette filters, of filters for other various drug delivery devices may undergo a step of accelerated drying, e.g., using forced air drying, which has a direct impact on their thickness stability.

These sustainable substrates of varying thickness are leading – upon their folding and transforming into a filter rod – to filters with varying filling factors (i.e., impact on gas flow / filtering properties) and also on influences on their mechanical properties, e.g., stiffness.

A grammage of these sustainable substrates may vary for instance between 25 gsm and 100 gsm and their thicknesses vary – typically and according to their fabrication process – between 50 μm and 500 μm . Therefore, the mass density of such substrates may typically be found in the region between 0.1 g/cm³ and 1.0 g/cm³.

The sustainable substrate's grammage gives a much better idea as to the actual thickness of a paper. As a general rule, anything 10–35 gsm is of tissue consistency; 35–70 gsm is lighter textweight, 70–100 gsm is medium textweight, 100–120 gsm is heavy textweight/light cardstock, 120–150 gsm is regular cardstock weight, 150–200 gsm is heavy cardstock, and greater than 200 gsm is super heavy cardstock.

Departing from prior art knowledge, the invention aims at providing a method and an embossing set-up to manufacture a novel embossed sheet of material configured to be folded to obtain a filter element which constitutes an alternative to existing technology, and is applicable for an inhalable drug delivery system in general.

A further problem addressed by the invention is to provide a method and an embossing set-up to manufacture an embossed sheet of material that has a controlled material thickness. This may allow to compensate for a material that is uneven prior to embossing, i.e., has a variable thickness, and to confer an improved control of draft through a filtering element made using the embossed sheet of material.

A further problem addressed by the invention is to provide a filtering element comprising an embossed sheet of material having the controlled material thickness, in order to have a way of controlling a draft of the filtering element and obtain a desired draft for mass production of such filtering elements.

Summary of the invention

In a first aspect, the invention provides a method for manufacturing an embossed sheet of material and obtaining a controlled material thickness, the embossed sheet of material being configured to obtain a filtering element configured for an inhalable drug delivery device, and for filtering a mainstream gas flow passing through the filtering element. The method comprises steps of: providing the sheet of material; embossing the sheet of material at least with embossing features by means of an embossing rollers system in which embossing features formed on a first base surface of a first embossing roller and corresponding embossing features formed on a second base surface of a second embossing roller are in a congruence with each other, and by feeding the sheet of material to a nip between the first embossing roller and the second embossing roller, the embossing features comprising profile embossing features configured for embossing at least an aerodynamic profile on the sheet of material, the embossed aerodynamic profiles being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element; embossing the sheet of material with separating base surface zones located between embossing features, and corresponding to the first base surface and the second base surface. For each embossing feature the corresponding congruence is configured to be such that for a first subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature; thereby configuring a width of the nip between the first and the second embossing rollers, which has a first nip width value for the separating base surface zones, and different nip width values smaller than the first nip width value for embossing features of the first subset of the embossing features; thereby enabling to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones, and different values of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features of the first subset of the embossing features.

In a preferred embodiment, the configuring for each embossing feature of the corresponding congruence is further such that for a second subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal to a value of depth of the recess embossing feature, thereby configuring a width of the nip between the first and second embossing rollers, which has further different nip values greater than or equal to the first nip width value for embossing features of the second subset of the embossing features; thereby enabling to obtain further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features of the second subset of the embossing features.

In a further preferred embodiment, the method for manufacturing the embossed sheet of material further comprises arranging the embossing features in a plurality of stripes, each stripe comprising protrusion features and recess features corresponding to embossing features on each of the first embossing roller and the second embossing roller, and each embossed stripe being oriented longitudinally along a straight line on the sheet of material, the profile embossing features thereby being arranged according to an orientation of the stripe on the embossing rollers.

In a further preferred embodiment, the embossing features further comprise radial embossing features configured to delimitate each stripe on opposite lateral sides of the stripe, on the first and second embossing rollers, and further configured to form longitudinal-delimitation embossed features that delimitate the embossed stripe on the sheet of material, on the opposite lateral sides of the embossed stripe.

In a further preferred embodiment, the radial embossing features are further configured to emboss a folding line into the sheet of material.

In a further preferred embodiment, the radial embossing features are further configured to form a plurality of enclosing walls on the first embossing roller and on the second embossing roller, describing at least an enclosure around one or a plurality of the profile embossing features, and, for each enclosure, an enclosure opening in the enclosure connecting the enclosure to a successive enclosure in the orientation direction of the stripe, the enclosure having a corresponding maximum enclosure expansion section area in the orientation direction of the stripe and the enclosure opening having a corresponding enclosure opening constriction section area in the orientation direction of the stripe which is smaller than the corresponding maximum enclosure expansion section area. The radial embossing features are further configured to define at least one alternance of the enclosure opening constriction section area and the maximum enclosure expansion section area in the orientation direction of the stripe, formed by the enclosure opening and the enclosure respectively, with a cross-section area ratio between the maximum enclosure expansion section area and the enclosure opening constriction section area of the profile in a range from 15:1 to 2:1.

In a further preferred embodiment, the embossed embossing features comprise at least one from a list comprising a recessed shape in the sheet of material and a protrusion in the sheet of material.

In a further preferred embodiment, the sheet of material may be either woven or not-woven and comprises any material from a list comprising paper, a cellulose-based material, wool, plant- or animal-based fibrous material.

In a further preferred embodiment, the profile embossing features are further configured to produce a height of the aerodynamic profile that is in a range of 1 to 15 times of a thickness of the sheet of material.

In a further preferred embodiment, the embossing of the sheet of material is configured to be a wallpaper-like embossing producing an uninterrupted and repeating pattern of embossed aerodynamic features.

In a further preferred embodiment, each one of the profile embossing features as a height in a range between 0,1 mm and 2,5 mm.

In a further preferred embodiment, the method for manufacturing the embossed sheet of material further comprises a step of adjusting the width of the nip to the first nip width value by providing a shoulder at each extremity of the first and second embossing rollers, the shoulders being configured to produce the first nip width value when at each extremity of the first and the second embossing rollers the shoulders from the first embossing roller are in contact with corresponding ones of the shoulder from the second embossing roller.

In a further preferred embodiment, the step of adjusting the width further comprises providing pressuring means configured to exert pressure between the first embossing roller and the second embossing roller, and enable a maintaining of the controlled material thickness.

In a further preferred embodiment, the first nip width value is chosen in function of a predetermined grammage of the sheet of material, and of a desired value for the first value of the material thickness.

In a further preferred embodiment, the sheet of material has a grammage in a range between 10 gsm and 100 gsm and a thickness in a range between 0,02 mm and 1,5 mm.

In a further preferred embodiment, a ratio between the controlled material thickness of the embossed sheet and an initial thickness of the material sheet prior to embossing is in a range of 1:1 to 1:5.

In a further preferred embodiment, a ratio between a statistic standard deviation of the initial thickness of the sheet of material and a statistic standard deviation of the controlled material thickness of the embossed sheet is between 1:1 and 1:3.

In a further preferred embodiment, the method for manufacturing the embossed sheet of material further comprises a step of heating the sheet of material prior to embossing.

In a further preferred embodiment, at least one of the first and the second embossing rollers is maintained at a constant temperature in a range of 20°C to 60°C.

In a second aspect, the invention provides an embossing set-up for manufacturing an embossed sheet of material and obtaining a controlled material thickness, configured to obtain a filtering element configured for an inhalable drug delivery device, and for filtering a mainstream gas flow passing through the filtering element. The set-up comprises features of: an embossing rollers system in which embossing features formed on a first base surface of a first embossing roller and corresponding embossing features formed on a second base surface of a second embossing roller are in a congruence with each other, the embossing system being configured to emboss the sheet of material in a nip between the first embossing roller and the second embossing roller, the embossing features comprising profile embossing features configured for embossing at least an aerodynamic profile on the sheet of material, the embossed aerodynamic profile being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element. The embossing rollers system further comprises for embossing the sheet of material, separating base surface zones located between embossing features, and corresponding to the first base surface and the second base surface. the corresponding congruence of each of the embossing features is configured to enable that for a first subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature; thereby

configuring a width of the nip between the first and the second embossing rollers, which has a first nip width value for the separating base surface zones, and different nip width values smaller than the first nip width value for embossing features of the first subset of the embossing features; thereby enabling to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones, and a different value of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features of the first subset of the embossing features.

In a further preferred embodiment, the corresponding congruence of each the embossing features is further configured to enable that for a second subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal to a value of depth of the recess embossing feature, thereby configuring a width of the nip between the first and second embossing rollers, which has further different nip values greater than or equal to the first nip width value for embossing features of the second subset of the embossing features; thereby enabling to obtain further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features of the second subset of the embossing features.

In a further preferred embodiment, the embossing rollers system is further configured to emboss the sheet of material with a plurality of stripes, each stripe comprising protrusion features and recess features corresponding to embossing features on each of the first embossing roller and the second embossing roller, and each embossed stripe being oriented longitudinally along a straight line on the sheet of material, the profile embossing features being arranged according to an orientation of the stripe on the embossing rollers.

In a further preferred embodiment, the embossing features further comprise radial embossing features configured to delimitate each stripe on opposite lateral sides of the stripe, on the first and second embossing rollers, and further configured to form longitudinal delimitation embossed features that delimitate the embossed stripe on the sheet of material, on opposite lateral sides of the embossed stripe.

In a further preferred embodiment, the radial embossing features are further configured to emboss a folding line into the sheet of material.

In a further preferred embodiment, the radial embossing features are further configured to form a plurality of enclosing walls on the first embossing roller and on the second embossing rollers describing at least an enclosure around one or a plurality of the profile embossing features, and, for each enclosure, an enclosure opening in the enclosure connecting the enclosure to a successive enclosure in the orientation direction of the stripe, the enclosure having a corresponding maximum enclosure expansion section area in the orientation direction of the stripe and the enclosure opening having a corresponding enclosure opening constriction section area in the orientation direction of the stripe which is smaller than the corresponding maximum enclosure expansion section area. The radial embossing features are further configured to define at least one alternance of the enclosure opening constriction section area and the maximum enclosure expansion section area in the orientation direction of the stripe, formed by the enclosure opening and the enclosure respectively, with a cross-section area ratio between the maximum enclosure expansion section area and the enclosure opening constriction section area of the profile in a range from 15:1 to 2:1.

In a further preferred embodiment, the embossed embossing features comprise at least one from a list comprising a recessed shape in the sheet of material and a protrusion in the sheet of material.

In a further preferred embodiment, the sheet of material may be either woven or non-woven and comprises any material from a list comprising paper, a cellulose-based material, wool, plant- or animal-based fibrous material.

In a further preferred embodiment, the profile embossing features are further configured to produce a height of the aerodynamic profile that is in a range of 1 to 15 times of a thickness of the sheet of material.

In a further preferred embodiment, the embossing rollers system and the embossing features are configured for embossing of the sheet of material to be a wallpaper-like embossing producing an uninterrupted and repeating pattern of embossed aerodynamic features.

In a further preferred embodiment, each one of the profile embossing features as a height in a range between 0,1 mm and 2,5 mm.

In a further preferred embodiment, the embossing set-up further comprises a shoulder at each extremity of the first and the second embossing rollers enabling an adjusting of the width of the nip

to the first nip width value, the shoulders being configured to produce the first nip width value when at each extremity of the first and the second embossing rollers the shoulders from the first embossing roller are in contact with corresponding ones of the shoulder from the second embossing roller.

In a further preferred embodiment, the embossing set-up further comprises pressuring means configured to exert pressure between the first embossing roller and the second embossing roller, and to enable a maintaining of controlled material thickness.

In a further preferred embodiment, the first nip width value is chosen in function of a predetermined grammage of the sheet of material, and of a desired value for the first value of the material thickness.

In a further preferred embodiment, the sheet of material has a grammage in a range between 10 gsm and 100 gsm and a thickness in a range between 0,02 mm and 1,5 mm.

In a further preferred embodiment, a ratio between the controlled material thickness of the embossed sheet and an initial thickness of the material sheet prior to embossing is in a range of 1:1 to 1:5.

In a further preferred embodiment, a ratio between a statistic standard deviation of the initial thickness of the sheet of material and a statistic standard deviation of the controlled material thickness of the embossed sheet is between 1:1 and 1:3.

In a further preferred embodiment, the embossing set-up further comprises a step of heating the sheet of material prior to embossing.

In a further preferred embodiment, at least one of the first and the second embossing rollers is maintained at a constant temperature in a range of 20°C to 60°C.

In a third aspect, the invention provides a filtering element configured for an inhalable drug delivery device, and for filtering a mainstream gas flow passing through the filtering element. The filtering element comprises an embossed sheet of material, with a controlled material thickness, wherein the sheet of material is embossed at least with embossing features by means of an embossing rollers system in which the embossing features formed on a first base surface of a first embossing roller and

corresponding embossing features formed on a second base surface of a second embossing roller are in a congruence with each other, and by feeding the sheet of material to a nip between the first embossing roller and the second embossing roller, the embossing features comprising profile embossing features configured for embossing at least an aerodynamic profile on the sheet of material, the embossed aerodynamic profile being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element. The sheet of material is further embossed with separating base surface zones located between embossing features, and corresponding to the first base surface and the second base surface. The corresponding congruence of each of the embossing features is configured to be such that for a first subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature; thereby configuring a width of the nip between the first and the second embossing rollers, which has a first nip width value for the separating base surface zones, and different nip width values smaller than the first nip width value for embossing features of the first subset of the embossing features; thereby enabling to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones, and a different value of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features of the first subset of the embossing features.

In a further preferred embodiment, the configuring for each embossing feature of the corresponding congruence is further such that for a second subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal to a value of depth of the recess embossing feature, thereby configuring a width of the nip between the first and second embossing rollers, which has further different nip values greater of equal to the first nip width value for embossing features of the second subset of the embossing features; thereby enabling to obtain further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features of the second subset of the embossing features.

In a further preferred embodiment, the embossed sheet of material is configured to comprise a plurality of stripes, each stripe comprising protrusion features and recess features corresponding to embossing features on each of the first embossing roller and the second embossing roller, and each

embossed stripe being oriented longitudinally along a straight line on the sheet of material, the profile embossing features thereby being arranged according to an orientation of the stripe on the embossing rollers.

Brief description of the figures

The invention will be better understood through the detailed description of preferred embodiments and in reference to the figures, wherein

Figure 1 illustrates an embossing set-up for manufacturing an embossed sheet of material and obtaining a controlled material thickness, the sheet of material being configured to be folded and obtain a filtering element, according to an example embodiment of the invention;

Figure 2 illustrates an embossing set-up with a detail on the embossed sheet of material with a controlled material thickness, according to a further example embodiment of the invention;

Figure 3 schematically illustrates an obtaining of filtering elements using an embossed sheet of material issued from the method of manufacturing according to a further example embodiment of the invention;

Figures 4a and 4b schematically illustrates example embodiments for embossing rollers with and without a toothed wheel at an extremity, according to example embodiments of the invention;

Figure 5 schematically illustrates a set of embossing rollers with ring-shaped shoulders at extremities of the rollers, according to an example embodiment of the invention;

Figure 6 illustrates the set of embossing rollers from Figure 5 in a different perspective;

Figure 7 illustrates the set of embossing rollers from Figure 6 in a variant with radial recesses replacing ring-shaped shoulder, according to an example embodiment of the invention;

Figure 8 illustrates an example of a manufactured embossed sheet of material with embossed features and embossed separating base surface zones according to an example of the invention;

Figures 9a and 9b illustrate respectively a cross-section through a set of embossing rollers together with an example of the embossed sheet of material produced therewith, wherein the embossing rollers have shoulders in contact, according to example embodiments of the invention;

Figures 10a and 10b illustrate respectively a cross-section through a set of embossing rollers together with an example of the embossed sheet of material produced therewith, wherein the embossing rollers have radial recesses at their extremities, according to example embodiments of the invention;

Figures 11a and 11b illustrate respectively a cross-section through a set of embossing rollers together with an example of the embossed sheet of material produced therewith, wherein the embossing rollers have radial recesses at their extremities, according to example embodiments of the invention;

Figures 12a and 12b illustrate further examples of embossings in which the material is controlled through embossing, according to the invention;

Figure 13 illustrates a further example of an embossed sheet of material manufactured according to the invention;

Figures 14a and 14b illustrate further examples of embossed sheets of material according to the invention;

Figure 15 illustrates a further example of an embossed sheet of material according to the invention;

Figure 16 schematically illustrates how a filtering element, in this case a cigarette filter, may be mounted to a tobacco containing section in order to obtain a cigarette according to prior art;

Figures 17 schematically illustrates a structure of an inhalable drug delivery device; and

Figure 18 contains a flowchart illustrating a preferred embodiment of the method for manufacturing the embossed sheet of material and obtaining a controlled material thickness according to the invention.

Same references are used to reference same or similar feature illustrated throughout the figures.

Detailed description of preferred embodiments

As previously mentioned, the invention is in the field of manufacturing for the inhalable drug delivery system industry, including smoking products in which medical drugs or nicotine may be dispensed in a gas to a user in various inhalable ways, comprising for example vapor, heated tobacco, and conventional burned tobacco as known from cigarettes and cigars, more specifically in a field of embossing, relating to a component of a filtering element, and to the filtering element as such. Accordingly, the filtering element be configured to filter the gas, i.e., a mainstream gas flow. In one example, the filtering element may correspond to a cigarette filter used in a tobacco cigarette and the mainstream gas flow produced to be filtered is from smoke of burned tobacco. In a further example,

the filter element may correspond to a non-burning cigarette filter used in a non-burning tobacco cigarette, in which case the mainstream gas flow produced to be filtered results from heating the tobacco. Various other embodiments, in which for example nicotine would be included in some other gas, for example vapour, the filter element would be configured to filter the corresponding mainstream gas flow and possibly retain particles that need not be included in the inhaled filtered gas administrated to a user.

The inventive device and method result from ecology-motivated research which for example aims to replace conventional cellulose acetate cigarette filters with other categories of suitable, sustainable sheet-materials, more preferably with filters made of paper-based materials, or any material from a list comprising paper, wool, plant- or animal-based fibrous material.

The invention provides a method and a device configured for manufacturing a sheet of material, and obtaining a controlled material thickness, that may be used as a component of a filtering element and that comprises embossed features for influencing a flow of the mainstream gas flow traversing the filtering element. The embossed features have a direct impact on slowing / speeding of the mainstream gas flow and, in that manner, reducing or enhancing the retention of particulates from the gas in fibers of the sheet of material, whereas a constancy of the controlled material thickness of the embossed sheet material has a direct positive impact on the reduction of the statistic variations of the filtering elements obtained through folding of the embossed sheet of material.

Preferably the sheet of material is a cellulose-based material, or any material from a list comprising paper, wool, plant- or animal-based fibrous material.

Furthermore, several classes may be distinguished regarding the sheet of material to be embossed, like the (i) woven sheets of materials including paper and paper-hybrid substrates, mainly containing interlaced fibers, as well as (ii) various non-woven sheets of material such as these described in the patent applications WO 2010112024 or US 10076135.

Referring to **Figure 1** this illustrates an embossing set-up **100** according to an example embodiment of the invention. The embossing set-up **100** is configured for manufacturing an embossed sheet of material **200**, and obtaining a controlled material thickness. The embossed sheet of material is configured to be folded and to obtain a filtering element configured for filtering a mainstream gas flow passing through the filtering element (filtering element and mainstream gas flow not illustrated in **Figure 1**). Without further tools attached to it, the embossing set-up **100** may also be denoted as an offline embossing system. The embossing set-up **100** comprises embossing rollers, i.e., a first embossing roller **101** and a second embossing roller **102**, and is configured to realize embossing of embossing features (embossing features not illustrated in **Figure 1**) on the sheet of material **103**. The first embossing roller **101** and the second embossing roller **102** may optionally be mounted in a quick exchange device **104** and are configured to cooperate with each other to emboss in a nip **105** the

sheet of material **103** fed between the first embossing roller **101** and the second embossing roller **102**. A synchronization of the first embossing roller **101** and the second embossing roller **102** may be implemented in various manners, one of which is suggested in the illustration of **Figure 1**, and is not limitative for the embossing set-up **100**, which comprises toothed wheels on the extremities of the rollers, which cooperate with each other. Other embodiments for synchronization may for example involve a servo-control mechanism (not illustrated) which controls angular positions of each roller relative to the other roller, or a combination of toothed wheels and the servo-control mechanism.

As a result of the embossing, the embossed sheet of material **200** is obtained with a plurality of embossed features (not individually shown in **Figure 1**, and represented as dots on the surface of the embossed sheet of material **200** for a better reading). For further explanations, a zone **106**, which will subsequently be examined in the description, e.g., in relation to examples illustrated in **Figure 8**, is identified on the embossed sheet of material **200**.

An optional bobbin dispensing device (not illustrated) may be configured to carry a bobbin with a web of sheet of material **103** and unwind it out towards the embossing set-up **100**. A product bobbin device (not illustrated) may also optionally be provided to rewind the web of embossed sheet of material **200** for later use in a filtering element manufacturing.

The sheet of material **103** may for example be provided in the form of a web of sheet material, either woven or non-woven, which may for example comprise cellulose-based material, or any material from a list comprising paper, wool, plant- or animal-based fibrous material.

Further concerning the sheet of material **103**, this preferably comprises fibers with a cut length in a first range of 0,5 mm to 6,0 mm, and with a diameter in a second range of 10 μm to 500 μm , the fibers being randomly distributed to deliver an air permeability. A sheet of material's air permeability is configured with filtration capabilities of substances present in a gas, e.g., cigarette or any other gas as mentioned for example in the previously presented gases.

A further preferred embodiment of the embossing set-up **100** according to the invention may be part of an online production process as illustrated in **Figure 2**, the embossing set-up **100** then being part of an online production line for manufacturing a filter element of length **L** (filter element and length not represented in **Figure 2**). The online production line further comprises for example a compacting device **201** comprising a funnel **202** into which the embossed sheet of material **200** is fed, folded and formed into a filter rod **203** output by the compacting device **201**. Hence the embossed sheet of material **200** is compacted with the funnel **202**. The filter rod **203** may be pulled by means of a pulling jig **204** to a further process step **206** of cutting illustrated under reference **300** in **Figure 3**. The further process step involves cutting the filter rod **203** into individual pieces comprising, as an example, two filter elements **301** each, having the length **L**, by means of a cutting device **302**. As previously described in **Figure 1** as being an option, the production line may comprise the bobbin dispensing

device **205** configured to carry the bobbin with the web of sheet of material **103** and unwind it out towards the embossing set-up **100**. A magnified view **207** on initial sheet of material **103** before embossing, schematically shows inhomogeneities **208** of the material thickness, while a further magnified view **209** schematically shows an example embossing **210** on the embossed sheet of material **200** with the controlled material thickness.

Referring again to **Figure 3**, this further illustrates a magnified view of a section **303** at an extremity of one of the filter elements **301** in which the embossed sheet of material **200** is folded and compacted to fit in a cylindrical wrapper **304**, also represented as a section of the cylindrical wrapper **304**. Foldings of the embossed sheet of material **200** appear to be in a plurality of angles. A detailed view **305** of a part of the section **303**, in which the view is slightly from an angle, schematically illustrates how the embossed sheet of material **200** is folded and packed in a manner of an accordion. In the view **305** a material thickness **306** is represented to be the same all over, and while this may be desired to be in this manner, there may also be embossed features (not shown in the **Figure 3**) in which the material thickness may be different.

As will be explained hereinbelow throughout the description, the invention provides a solution to obtain a controlled material thickness, while at the same time embossing features of different kinds in the sheet of material.

Referring now to **Figure 4a**, this illustrates an example embodiment for any one of embossing rollers **101** and **102**, which comprises a rotation axis **400**, a roller surface **401** and a toothed wheel **402** at one extremity of the embossing roller **101**, **102**, enabling the embossing roller **101**, **102** to be driven by a motor assembly having a corresponding toothed wheel (not represented in **Figure 4a**). The roller surface **401** may carry embossing features (not represented) which protrude from or recess in a base surface (not explicitly represented) of the embossing roller **101**, **102**. Examples of embossing features will be given hereinbelow.

Referring now to **Figure 4b**, this shows a further example embodiment for any one of embossing rollers **101** and **102**, which is similar to that of **Figure 4a**, except that it doesn't comprise any toothed wheel. In this example the embossing roller **101**, **102**, is typically driven by a servo motor mechanism (not represented) that directly rotates the rotation axis **400**.

Figure 5 represents a set of embossing rollers **501**, **502**, bearing protrusion and recess embossing features (not illustrated in **Figure 5**), each comprising at a corresponding extremity a toothed wheel **503**, **504**, the teeth of which intertwine to synchronously drive the embossing rollers **501**, **502**, to rotate about respective rotation axes **505**, **506**. The embossing rollers **501**, **502**, further each comprise two ring-shaped shoulders **507**, **508**, one towards each extremity of the respective embossing roller **501**, **502**, and configured such that a ring-shaped shoulder on one embossing roller faces a corresponding ring-shaped shoulder of the opposite embossing roller. The ring-shaped shoulders **507**, **508**, are

generally designed to form a ring which centered on the rotation axis of the embossing roller, whose circumference protrudes from a base surface of the embossing roller where it is located. This level of detail is not illustrated in **Figure 5** to maintain a better readability.

Figure 6 represents the set of embossing rollers **501**, **502**, of **Figure 5** but in a different perspective, together with two magnified views **509**, **510**, of areas where the ring-shaped shoulders **507** and **508** are resting on each other as may be the case during embossing. This is substantiated by distance **511** between the ring-shaped shoulders **507** and **508** being 0, while a nip **512** is maintained between the embossing rollers **501** and **502** with a determined nip width value n separating a base surface **514** of the embossing roller **501** from an opposite base surface **513** of the embossing roller **502**. The base surfaces are schematically represented and in the views **509** and **510** do not comprise any embossing features in the example of **Figure 6**. The determined nip width value n of the nip **512** enables to insert a sheet of material in it (sheet of material not represented) for embossing.

In a further example represented in **Figure 7** the ring-shaped shoulders of **Figure 6** may be replaced by radial recesses **701** and **702**, which each form recesses in the embossing rollers **501** and **502** respectively as compared to the base surfaces **513** and **514**. Hence, when the embossing rollers **501** and **502** are pressured one towards the other, as is depicted by arrows **705** in the radial recesses **701** and **702**, their base surfaces **513** and **514** may be coming into contact such that a distance **703** tends to become similar to that of a sheet of material inserted therein for embossing (not illustrated in **Figure 7**), and a distance **704** between radial recesses **701** and **702** facing each other from one embossing roller to the other is greater than 0. The pressure depicted by the arrows **705** may be exerted by pressuring means comprised in the embossing set-up (not illustrated in **Figure 7** as is well known in the prior art, for example by hydraulic pressuring means).

Figure 8 depicts an upper view of an example of a manufactured embossed sheet of material **800** with embossed features in reference to surface **106** in **Figures 1** and **2**, in which a controlled material thickness is obtained. The embossed features comprise embossed profile embossing features **801**, a magnified view **803** of which shows various shapes and sizes. The embossed profile embossing features **801** are configured to obtain at least an aerodynamic profile on the sheet of material **800**, which may be obtained for example by a determined number of the embossed profile embossing features **801**, in various shapes (segment(s), arc of circle) and/or sizes, the embossed aerodynamic profiles being configured for an end product, namely a filtering element (not illustrated in **Figure 8**), to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element. The sheet of material further comprises embossed separating base surface zones **802** located between embossed profile embossing features **801**. The embossed separating base surface zones **802** result from embossing with separating base surface zones located between profile embossing features of the embossing rollers (not illustrated in **Figure 8**, and corresponding to the first base surface and the second base surface of the embossing rollers (not illustrated either). The embossed profile embossing

features **801** result from embossing features formed on a first base surface of a first embossing roller and corresponding embossing features formed on a second base surface of a second embossing roller, which are in a congruence with each other (not illustrated in **Figure 8**) and for which the congruence is configured by adjusting heights of protrusion and depths of recesses of the embossing features as will be explained in further examples herein below. The example of **Figure 8** is intended to show a possible layout of embossed profile embossing features **801** and embossed separating base surface zones **802** on an embossed sheet of material **800**.

Figure 9a illustrates a cross-section view **909** through a set of embossing rollers together with an example of the embossed sheet of material **907** produced therewith according to an example embodiment of the invention. In the cross-section view **909**, the first embossing roller **501** and the second embossing roller **502** are seen in cross-section. A magnified view **911** of one extremity of the set of embossing rollers from view **909** details that the shoulders of the rollers are in contact in a similar manner as in **Figure 6**. The cross-section view **909** shows a nip corresponding to separating base surface zones **906** located between embossing features **901**, **902**, **903**, and corresponding to a first base surface and a second base surface of the first embossing roller **501** and the second embossing roller **502**. The cross-section view **909** further shows nips corresponding to a first subset of embossing features **901**, **902**, **903**. The embossing features **901**, **902**, **903** are formed on the first base surface of the first embossing roller **501** and corresponding embossing features **901**, **902**, **903** are formed on the second base surface of the second embossing roller **502**, and are in a congruence with each other.

For the first subset of the embossing features, the congruence for each embossing feature is configured to be such that corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature. Thereby a width of the nip between the first and the second embossing rollers is configured, which has a first nip width value for the separating base surface zones **906**, and different nip width values smaller than the first nip width value for embossing features **901**, **902**, **903** of the first subset of the embossing features. Further thereby, this enables to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones **906**, and different values of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features **901**, **902**, **903** of the first subset of the embossing features.

View **907** shows a detail from a sheet of material embossed according to the invention, in which, using same reference numbers as for the embossing features and for the separating base surface features from the embossing rollers, embossed separated base surface zones **906** and embossings from the embossing features **901**, **902**, **903** are shown; the embossings from embossing features **901** and **902** may be called protrusion features, whereas the embossings from embossed features **903** are in the

opposite direction and may be called recess features. Furthermore, a dashed line **912** suggests the location of the cross-section view depicted in **909**.

The embossing features **902** and **903** are profile embossing features, which are configured for embossing at least an aerodynamic profile (referenced **902** and **903** in view **907**) on the sheet of material, the embossed aerodynamic profiles being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element (filtering element and gas flow not illustrated in the Figure).

The embossing features **901** are radial embossing features configured to delimitate stripes on opposite lateral sides of the stripe, on the first and second embossing rollers, and further configured to form longitudinal-delimitation embossed features that delimitate the embossed stripe on the sheet of material, on the opposite lateral sides of the embossed stripe. Each stripe comprises protrusion features and recess features corresponding to embossing features **902** and **903** on each of the first embossing roller and the second embossing roller, and each embossed stripe being oriented longitudinally along a straight line on the sheet of material, the profile embossing features thereby being arranged according to an orientation of the stripe on the embossing rollers.

Referring now to **Figure 9b**, this illustrates a cross-section view **910** through a set of embossing rollers together with an example of the embossed sheet of material **908** produced therewith according to an example embodiment of the invention. In the cross-section view **910**, the first embossing roller **501** and the second embossing roller **502** are again seen in cross-section. A magnified view **911** of one extremity of the set of embossing rollers from view **910** details that the shoulders are in contact in a similar manner as in **Figure 6**. Cross section view **910** shows a nip corresponding to separating base surface zones **906** located between embossing features **907**, **902**, **903**, and corresponding to a first base surface and a second base surface of the first embossing roller **501** and the second embossing roller **502**. Cross-section view **910** further shows nips corresponding to the first subset of embossing features **902**, **903** and nips corresponding to a second subset of embossing features **907**. The embossing features **907**, **902**, **903** are formed on the first base surface of the first embossing roller **501** and corresponding embossing features **907**, **902**, **903** are formed on the second base surface of the second embossing roller **502**, and are in a congruence with each other.

The nature of the first subset of embossing features has already been described in relation for **Figure 9a**.

For the second subset of the embossing features, the congruence for each embossing feature is configured to be such that corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal a value of depth of the recess embossing feature. Thereby a width of the nip

between the first and the second embossing rollers is configured, which, as previously explained in relation to **Figure 9a**, has the first nip width value for the separating base surface zones **906**, and further different nip width values greater than or equal to the first nip width value for embossing features **907** of the second subset of the embossing features. Further thereby, this enables to obtain the controlled material thickness of the embossed sheet of material with respectively the first value of the material thickness when the sheet of material is embossed with the separating base surface zones **906**, and further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features **907** of the second subset of the embossing features.

View **908** shows a detail from a sheet of material embossed according to the invention, in which, using same reference numbers as for the embossing features and for the separating base surface features from the embossing rollers, embossed separated base surface zones **906** and embossings from the embossing features **907**, **902**, **903** are shown; the embossings from embossing features **907** and **902** may be called protrusion features, whereas the embossings from embossed features **903** are in the opposite direction and may be called recess features. Furthermore, a dashed line **913** suggests the location of the cross-section view depicted in **910**.

The embossing features **902** and **903** are profile embossing features, which are configured for embossing at least an aerodynamic profile (referenced **902** and **903** in view **908**) on the sheet of material, the embossed aerodynamic profiles being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element (filtering element and gas flow not illustrated in the Figure).

The embossing features **907** are radial embossing features configured to delimitate stripes on opposite lateral sides of the stripe, on the first and second embossing rollers, and further configured to form longitudinal-delimitation embossed features that delimitate the embossed stripe on the sheet of material, on the opposite lateral sides of the embossed stripe. Each stripe comprises protrusion features and recess features corresponding to embossing features **902** and **903** on each of the first embossing roller and the second embossing roller, and each embossed stripe being oriented longitudinally along a straight line on the sheet of material, the profile embossing features thereby being arranged according to an orientation of the stripe on the embossing rollers.

Figure 10a illustrates a cross-section view **1009** through a set of embossing rollers together with an example of the embossed sheet of material **1007** produced therewith according to an example embodiment of the invention. In the cross-section view **1009**, the first embossing roller **501** and the second embossing roller **502** are seen in cross-section. A magnified view **1011** of one extremity of the set of embossing rollers from view **1009** details that radial recesses are at extremities of the rollers,

and the rollers are pressured toward each other in a similar manner as in **Figure 7**. The cross-section view **1009** shows a nip corresponding to separating base surface zones **1006** located between embossing features **1001**, **1002**, **1003**, and corresponding to a first base surface and a second base surface of the first embossing roller **501** and the second embossing roller **502**. The cross-section view **1009** further shows nips corresponding to a first subset of embossing features **1001**, **1002**, **1003**. The embossing features **1001**, **1002**, **1003** are formed on the first base surface of the first embossing roller **501** and corresponding embossing features **1001**, **1002**, **1003** are formed on the second base surface of the second embossing roller **502**, and are in a congruence with each other.

For the first subset of the embossing features, the congruence for each embossing feature is configured to be such that corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature. Thereby a width of the nip between the first and the second embossing rollers is configured, which has a first nip width value for the separating base surface zones **1006**, and different nip width values smaller than the first nip width value for embossing features **1001**, **1002**, **1003** of the first subset of the embossing features. Further thereby, this enables to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones **1006**, and different values of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features **1001**, **1002**, **1003** of the first subset of the embossing features.

View **1007** shows a detail from a sheet of material embossed according to the invention, in which, using same reference numbers as for the embossing features and for the separating base surface features from the embossing rollers, embossed separated base surface zones **1006** and embossings from the embossing features **1001**, **1002**, **1003** are shown; the embossings from embossing features **1001** and **1002** may be called protrusion features, whereas the embossings from embossed features **1003** are in the opposite direction and may be called recess features. Furthermore, a dashed line **1012** suggests the location of the cross-section view depicted in **1009**.

Referring now to **Figure 10b** this illustrates a cross-section view **1010** through a set of embossing rollers together with an example of the embossed sheet of material **1008** produced therewith according to an example embodiment of the invention. In the cross-section view **1010**, the first embossing roller **501** and the second embossing roller **502** are again seen in cross-section. A magnified view **1011** of one extremity of the set of embossing rollers from view **1010** details that radial recesses are at extremities of the rollers, and the rollers are pressured toward each other in a similar manner as in **Figure 7**. The cross-section view **1010** shows a nip corresponding to separating base surface zones **1006** located between embossing features **1007**, **1002**, **1003**, and corresponding to a first base surface and a second base surface of the first embossing roller **501** and the second embossing roller **502**. The cross-section view **1010** further shows nips corresponding to the first

subset of embossing features **1002**, **1003** and nips corresponding to a second subset of embossing features **1007**. The embossing features **1007**, **1002**, **1003** are formed on the first base surface of the first embossing roller **501** and corresponding embossing features **1007**, **1002**, **1003** are formed on the second base surface of the second embossing roller **502**, and are in a congruence with each other.

The nature of the first subset of embossing features has already been described in relation for **Figure 10a**.

For the second subset of the embossing features, the congruence for each embossing feature is configured to be such that corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal a value of depth of the recess embossing feature. Thereby a width of the nip between the first and the second embossing rollers is configured, which, as previously explained in relation to **Figure 10a**, has the first nip width value for the separating base surface zones **1006**, and further different nip width values greater than or equal to the first nip width value for embossing features **1007** of the second subset of the embossing features. Further thereby, this enables to obtain the controlled material thickness of the embossed sheet of material with respectively the first value of the material thickness when the sheet of material is embossed with the separating base surface zones **1006**, and further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features **1007** of the second subset of the embossing features.

View **1008** shows a detail from a sheet of material embossed according to the invention, in which, using same reference numbers as for the embossing features and for the separating base surface features from the embossing rollers, embossed separated base surface zones **1006** and embossings from the embossing features **1007**, **1002**, **1003** are shown; the embossings from embossing features **1007** and **1002** may be called protrusion features, whereas the embossings from embossed features **1003** are in the opposite direction and may be called recess features. Furthermore, a dashed line **1013** suggests the location of the cross-section view depicted in **1010**.

Figure 11a and **Figure 11b** illustrate further examples of the invention, in which embossing rollers with radial recesses as shown in magnified views **1100** and **1106** are used. **Figure 11a** depicts an isometric view **1101** from the surface of the first embossing roller **501**, and a cross-section view of embossing features **1103** in which respectively corresponding protrusion and recess embossing features **1104**, **1105** present on the embossing rollers **501** and **502** are shown, and the magnified view **1100**, in which the recessed radii of the embossing rollers **501** and **502** are evidenced. **Figure 11b** depicts an isometric view **1107** from the surface of a further first embossing roller **501**, a cross-section view of embossing features **1109** in which respectively corresponding protrusion and recess

embossing features **1110**, **1111** present on the embossing rollers **501** and **502** are shown, and the magnified view **1106**, in which the recessed radii of the embossing rollers **501** and **502** are evidenced. In both examples, the first embossing roller **501** and the second embossing roller **502** are pressured towards each other, which enables a maintaining of the controlled thickness of the embossed sheet of material. The embossing features **1104** and **1110** belong to the second subset of the embossing features as discussed for **Figures 9b** and **10b**, because the congruence for each embossing feature is configured to be such that corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal a value of depth of the recess embossing feature, in this particular example the value of height appear to be equal to the value of depth. Thereby a width of the nip between the first and the second embossing rollers is configured, in which further different nip width values equal to the first nip width value for embossing features **1104**, **1100** of the second subset of the embossing features. Further thereby, this enables to obtain the controlled material thickness of the embossed sheet of material with respectively the first value of the material thickness when the sheet of material is embossed with the separating base surface zones, and further different values of the material thickness equal to the first value of the material thickness when the sheet of material is embossed with embossing features **1104**, **1100** of the second subset of the embossing features.

Examples of controlling a material thickness through embossing different sheets of materials and with different distributions of protrusion and recessed embossed features are illustrated by means of **Figure 12a** and **Figure 12b**, which illustrate respectively an upper view a zone of the sheet of material embossed according to the invention. **Figure 12a** shows a zone **1200** of sheet of material embossed according to invention, which contains an embossed base surface zone **1201**, embossed protrusion embossing features **1202** and **1203**, and embossed recessed embossing features **1204**. Thickness measurements were carried out in 20 different points of the embossed base surface **1201** of the embossed sheet of material and a mean value and the corresponding standard deviation were calculated. **Figure 12b** shows a zone **1205** of a sheet of material embossed according to invention, which contains an embossed base surface zone **1207** and embossed protrusion embossing features **1202** and **1206**. Thickness measurements were carried out in 20 different points of the base surface **1201** of the embossed sheet of material and a mean value and the corresponding standard deviation were calculated.

In one example, a sheet of material to produce a cigarette filter, having a grammage of 35 gsm and a mean thickness value of 320 μm , exhibited a standard deviation of its mean material thickness of 15 μm prior to its embossing according to the invention. After the embossing with an embossing linear force of 7,3 kN/m applied between the embossing rollers **501** and **502** (not shown in **Figure 12a**), the base surface **1201** exhibited a mean material thickness of 125 μm and a standard deviation of its mean material thickness of 7 μm .

In a further example, a sheet of material to produce a cigarette filter, having a grammage of 62 gsm and a mean thickness value of 395 μm , which exhibited a standard deviation of its mean material thickness of 36 μm prior to its embossing, was embossed with a linear force of 11,6 kN/m applied between the embossing rollers **501** and **502** (not shown in **Figure 12a** and **Figure 12b**), according to the invention, to obtain embossed sheets **1200**, **1205** of material of controlled thickness, as in **Figure 12a** and **Figure 12b**, respectively. After the embossing, the base surface **1201** exhibited a mean material thickness of 104 μm and a standard deviation of its mean material thickness of 14 μm , whereas the base surface **1207** exhibited a mean material thickness of 113 μm and a standard deviation of its mean material thickness of 18 μm .

Further different examples of embossing according of the invention, to obtain an embossed sheet of material with a controlled thickness, showed that the ratio between the material thickness of the embossed sheet of material and the material thickness of the non-embossed sheet of material varies with a ratio in a range from of 1:1 to 1:5, whereas the ratio between the standard deviation of the material thickness of the embossed sheet of material and the standard deviation of the material thickness of the non-embossed sheet of material varies in range of 1:1 to 1:3

Figure 13 illustrates an example of realization of the invention, and contains a detailed view from a sheet of material **1300** embossed according to the invention, which shows embossed base surface zones **1302** and embossed protrusion embossing features **1301**, arranged in an array-like manner described by the dimensional parameters p and l . **Figure 13** further illustrates in a cross-section view **1304** along a line **1303** of the embossed sheet of material **1300**, an embossed height h_1 and material thicknesses **1305** and **1306** of the embossed sheet of material in zones corresponding respectively to the base surface zones **1302** and to the protrusion features **1301**. In this example the material thickness **1306** obtained after embossing with protrusion features **1301** is smaller than the material thickness **1305** obtained after embossing with base surface feature zones **1302**.

Figure 14a illustrates a further example of realization of the invention, and contains a detailed view from a sheet of material **1400** embossed according to the invention, which shows an embossed base surface zone **1401** and both embossed protrusion and recess embossed radial features **1403** and **1402**, separated by a distance l , whereas each embossed radial feature defines a plurality of enclosures **1411**, which are longitudinally distributed along the embossed radial feature and separated from each other by a distance p . **Figure 14a** further includes a cross-section view **1410** along a line **1408** of the embossed sheet of material **1400**, in which a height h_1 of the protrusions **1403** and a depth h_2 of the recesses **1402** are illustrated. Furthermore, a material thickness **1405** and **1404** of the embossed sheet of material in zones respectively corresponding to the embossed base surface zone **1401**, and to the embossed protrusion features **1403** or embossed recess features **1402** is depicted.

As an option, **Figure 14b** illustrates a further example of realization of the invention, and contains a detailed view from a sheet of material **1406** embossed according to the invention, which shows a base

surface **1401** and embossed protrusion radial features **1403**, separated by a distance l , whereas each embossed radial feature **1403** defines a plurality of enclosures **1413**, which are longitudinally distributed along the corresponding embossed radial feature and separated by a distance p . **Figure 14b** further includes a cross-section view **1412** of the embossed sheet of material along a line **1409**, in which a height h_r of an embossed protrusion feature is illustrated. Furthermore, material thicknesses **1407** and **1408** of the embossed sheet of material **1406** in zones corresponding to the embossed base surface zones **1407** and to the embossed protrusion features **1403**.

Figure 15 illustrates a further example of realization of the invention, and contains a detailed view from a sheet of material **1500** embossed according to the invention, which shows a base surface zone **1501** and embossed segments **1502**, arranged in an array-like manner described by the dimensional parameters p and l . **Figure 15** further illustrates in a cross-section view **1504** taken along a line **1503** of the embossed sheet of material **1500**, the embossed height h_r and material thicknesses **1506** and **1505** of the embossed sheet of material in zones corresponding both to the embossed base surface zones and to the embossed segments **1502**.

Figure 16 schematically illustrates how a cigarette filter **1601** -type filtering element from a double filter **301** may be mounted to a tobacco containing section **1603** in order to obtain a cigarette **1605** according to prior art. Part **(A)** shows the double filter **301**. Part **(B)** shows the double filter **301** positioned between tobacco containing sections **1603**, and a filter paper **1602** being wound and glued around the double filter **301** and partly over a part of each tobacco containing section **1603**, resulting in a double cigarette **1604** shown in part **(C)**. Part **(D)** shows one of cigarettes **1605** obtained after cutting a double cigarette **1604** in a middle **1606** thereof.

Figure 17 schematically illustrates the structure of an inhalable drug delivery system **1700A** and **1700B**, according to the prior art. Part **(A)** depicts a delivery system comprising a drug containing component **1701** and a filtering element **1702** fabricated using a sheet of material embossed according to the invention. Part **(B)** depicts an inhalable drug delivery system comprising the drug containing component **1701**, a cooling component **1703**, and of the filtering element **1702** fabricated using a sheet of material embossed according to the invention.

Figure 18 contains a flowchart illustrating a preferred embodiment of the method for manufacturing the embossed sheet of material and obtaining a controlled material thickness according to the invention. A sheet of material **1800** is provided **1801** for embossing, and in embossed step **1802** embossed with at least embossing features by means of an embossing rollers system in which embossing features formed on a first base surface of a first embossing roller and corresponding embossing features formed on a second base surface of a second embossing roller are in a congruence with each other, and fed to a nip between the first embossing roller and the second embossing roller. The embossing features comprise profile embossing features configured for embossing at least an aerodynamic profile on the sheet of material, the embossed aerodynamic

profiles being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element. In a further embossing step **1805** the sheet of material is embossed with separating base surface zones located between profile embossing features, and corresponding to the first base surface and the second base surface. For each embossing feature the corresponding congruence is configured to be such that for a first subset **1803** of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature, thereby configuring a width of the nip between the first and the second embossing rollers, which has a first nip width value for the separating base surface zones, and different nip width values smaller than the first nip width value for embossing features of the first subset of the embossing features, thereby enabling to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones, and different values of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features of the first subset of the embossing features. For a second subset **1804** of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal to a value of depth of the recess embossing feature, thereby configuring a width of the nip between the first and second embossing rollers, which has further different nip values greater than or equal to the first nip width value for embossing features of the second subset of the embossing features, thereby enabling to obtain further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features of the second subset of the embossing features. As a result of these steps, an embossed sheet of material **1806** is obtained with a controlled material thickness.

Claims

1. A method for manufacturing an embossed sheet of material and obtaining a controlled material thickness, the embossed sheet of material being configured to obtain a filtering element configured for an inhalable drug delivery device, and for filtering a mainstream gas flow passing through the filtering element, the method comprising steps of:
providing the sheet of material;
embossing the sheet of material at least with embossing features by means of an embossing rollers system in which embossing features formed on a first base surface of a first embossing roller and corresponding embossing features formed on a second base surface of a second embossing roller are in a congruence with each other, and by feeding the sheet of material to a nip between the first embossing roller and the second embossing roller, the embossing features comprising profile embossing features configured for embossing at least an aerodynamic profile on the sheet of material, the embossed aerodynamic profiles being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element;
embossing the sheet of material with separating base surface zones located between embossing features, and corresponding to the first base surface and the second base surface;
configuring for each embossing feature the corresponding congruence to be such that
for a first subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature;
thereby configuring a width of the nip between the first and the second embossing rollers, which has a first nip width value for the separating base surface zones, and different nip width values smaller than the first nip width value for embossing features of the first subset of the embossing features;
thereby enabling to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones, and different values of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features of the first subset of the embossing features.
2. The method for manufacturing the embossed sheet of material, according to claim 1, wherein the configuring for each embossing feature of the corresponding congruence is further such that

for a second subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal to a value of depth of the recess embossing feature,

thereby configuring a width of the nip between the first and second embossing rollers, which has further different nip values greater than or equal to the first nip width value for embossing features of the second subset of the embossing features;

thereby enabling to obtain further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features of the second subset of the embossing features.

3. The method for manufacturing the embossed sheet of material according to any one of claims 1 and 2, further comprising arranging the embossing features in a plurality of stripes, each stripe comprising protrusion features and recess features corresponding to embossing features on each of the first embossing roller and the second embossing roller, and each embossed stripe being oriented longitudinally along a straight line on the sheet of material, the profile embossing features thereby being arranged according to an orientation of the stripe on the embossing rollers.
4. The method for manufacturing the embossed sheet of material according to any one of claims 1 to 3, wherein the embossing features further comprise radial embossing features configured to delimitate each stripe on opposite lateral sides of the stripe, on the first and second embossing rollers, and further configured to form longitudinal-delimitation embossed features that delimitate the embossed stripe on the sheet of material, on the opposite lateral sides of the embossed stripe.
5. The method for manufacturing the embossed sheet of material according to claim 4, wherein the radial embossing features are further configured to emboss a folding line into the sheet of material.
6. The method for manufacturing of any one of claims 4 to 5, further wherein the radial embossing features are further configured
 - to form
 - a plurality of enclosing walls on the first embossing roller and on the second embossing roller, describing at least an enclosure around one or a plurality of the profile embossing features,
 - and, for each enclosure,
 - an enclosure opening in the enclosure connecting the enclosure to a successive enclosure in the orientation direction of the stripe,

the enclosure having a corresponding maximum enclosure expansion section area in the orientation direction of the stripe and the enclosure opening having a corresponding enclosure opening constriction section area in the orientation direction of the stripe which is smaller than the corresponding maximum enclosure expansion section area, and

to define at least one alternance of the enclosure opening constriction section area and the maximum enclosure expansion section area in the orientation direction of the stripe, formed by the enclosure opening and the enclosure respectively, with a cross-section area ratio between the maximum enclosure expansion section area and the enclosure opening constriction section area of the profile in a range from 15:1 to 2:1.

7. The method for manufacturing of any one of claims 1 to 6, wherein the embossed embossing features comprise at least one from a list comprising a recessed shape in the sheet of material and a protrusion in the sheet of material.
8. The method for manufacturing of any one of claims 1 to 7, wherein the sheet of material may be either woven or not-woven and comprises any material from a list comprising paper, a cellulose-based material, wool, plant- or animal-based fibrous material.
9. The method for manufacturing of any one of the claims 1 to 8, whereby the profile embossing features are further configured to produce a height of the aerodynamic profile that is in a range of 1 to 15 times of a thickness of the sheet of material.
10. The method for manufacturing according to any one of the claims 1 to 9, further wherein the embossing of the sheet of material is configured to be a wallpaper-like embossing producing an uninterrupted and repeating pattern of embossed aerodynamic features.
11. The method for manufacturing of any one of claims 1 to 10, whereby each one of the profile embossing features as a height in a range between 0,1 mm and 2,5 mm.
12. The method for manufacturing the embossed sheet of material according to any one of claims 1 to 11, further comprising a step of adjusting the width of the nip to the first nip width value by providing a shoulder at each extremity of the first and second embossing rollers, the shoulders being configured to produce the first nip width value when at each extremity of the first and the second embossing rollers the shoulders from the first embossing roller are in contact with corresponding ones of the shoulder from the second embossing roller.

13. The method for manufacturing the embossed sheet of material according to any one of claims 1 to 12, wherein the step of adjusting the width further comprises providing pressuring means configured to exert pressure between the first embossing roller and the second embossing roller, and enable a maintaining of the controlled material thickness.
14. The method for manufacturing the embossed sheet of material according to any one of claims 1 to 13, wherein the first nip width value is chosen in function of a predetermined grammage of the sheet of material, and of a desired value for the first value of the material thickness.
15. The method for manufacturing the embossed sheet of material according to any one of the preceding claims, wherein the sheet of material has a grammage in a range between 10 gsm and 100 gsm and a thickness in a range between 0,02 mm and 1,5 mm.
16. The method for manufacturing the embossed sheet of material according to any one of claims 1 to 15, wherein a ratio between the controlled material thickness of the embossed sheet and an initial thickness of the material sheet prior to embossing is in a range of 1:1 to 1:5.
17. The method for manufacturing the embossed sheet of material according to any one of claims 1 to 15, wherein a ratio between a statistic standard deviation of the initial thickness of the sheet of material and a statistic standard deviation of the controlled material thickness of the embossed sheet is between 1:1 and 1:3.
18. The method for manufacturing the embossed sheet of material according to any one of claims 1 to 17, further comprising a step of heating the sheet of material prior to embossing.
19. The method for manufacturing the embossed sheet of material according to any one of claims 1 to 18, wherein at least one of the first and the second embossing rollers is maintained at a constant temperature in a range of 20°C to 60°C.
20. An embossing set-up for manufacturing an embossed sheet of material and obtaining a controlled material thickness, configured to obtain a filtering element configured for an inhalable drug delivery device, and for filtering a mainstream gas flow passing through the filtering element, comprising features of:
an embossing rollers system in which embossing features formed on a first base surface of a first embossing roller and corresponding embossing features formed on a second base surface of a second embossing roller are in a congruence with each other, the embossing system being configured to emboss the sheet of material in a nip between the first embossing roller and the second embossing roller, the embossing features

comprising profile embossing features configured for embossing at least an aerodynamic profile on the sheet of material, the embossed aerodynamic profile being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element;

the embossing rollers system further comprising for embossing the sheet of material, separating base surface zones located between embossing features, and corresponding to the first base surface and the second base surface;

the corresponding congruence of each of the embossing features being configured to enable that

for a first subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature;

thereby configuring a width of the nip between the first and the second embossing rollers, which has a first nip width value for the separating base surface zones, and different nip width values smaller than the first nip width value for embossing features of the first subset of the embossing features;

thereby enabling to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones, and a different value of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features of the first subset of the embossing features.

21. The embossing set-up for manufacturing the embossed sheet of material, according to claim 20, wherein the corresponding congruence of each the embossing features is further configured to enable that
- for a second subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal to a value of depth of the recess embossing feature,
- thereby configuring a width of the nip between the first and second embossing rollers, which has further different nip values greater than or equal to the first nip width value for embossing features of the second subset of the embossing features;
- thereby enabling to obtain further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features of the second subset of the embossing features.

22. The embossing set-up for manufacturing the embossed sheet of material, according to any one of claims 20 and 21, the embossing rollers system being further configured to emboss the sheet of material with a plurality of stripes, each stripe comprising protrusion features and recess features corresponding to embossing features on each of the first embossing roller and the second embossing roller, and each embossed stripe being oriented longitudinally along a straight line on the sheet of material, the profile embossing features being arranged according to an orientation of the stripe on the embossing rollers.
23. The embossing set-up for manufacturing an embossed sheet of material of any one of claims 20 to 22, in which the embossing features further comprise radial embossing features configured to delimitate each stripe on opposite lateral sides of the stripe, on the first and second embossing rollers, and further configured to form longitudinal delimitation embossed features that delimitate the embossed stripe on the sheet of material, on opposite lateral sides of the embossed stripe.
24. The embossing set-up of claim 23, wherein the radial embossing features are further configured to emboss a folding line into the sheet of material.
25. The embossing set-up according to any one of claims 23 to 24, further wherein:
the radial embossing features are further configured
to form
a plurality of enclosing walls on the first embossing roller and on the second
embossing rollers describing at least an enclosure around one or a plurality of
the profile embossing features,
and, for each enclosure,
an enclosure opening in the enclosure connecting the enclosure to a
successive enclosure in the orientation direction of the stripe,
the enclosure having a corresponding maximum enclosure expansion section
area in the orientation direction of the stripe and the enclosure
opening having a corresponding enclosure opening constriction
section area in the orientation direction of the stripe which is smaller
than the corresponding maximum enclosure expansion section area,
and
to define at least one alternance of the enclosure opening constriction section area
and the maximum enclosure expansion section area in the orientation
direction of the stripe, formed by the enclosure opening and the enclosure
respectively, with a cross-section area ratio between the maximum enclosure
expansion section area and the enclosure opening constriction section area of
the profile in a range from 15:1 to 2:1.

26. The embossing set-up of any one of claims 20 to 25, wherein the embossed embossing features comprise at least one from a list comprising a recessed shape in the sheet of material and a protrusion in the sheet of material.
27. The embossing set-up of any one of claims 20 to 26, wherein the sheet of material may be either woven or non-woven and comprises any material from a list comprising paper, a cellulose-based material, wool, plant- or animal-based fibrous material.
28. The embossing set-up of any one of the claims 20 to 27, whereby the profile embossing features are further configured to produce a height of the aerodynamic profile that is in a range of 1 to 15 times of a thickness of the sheet of material.
29. The embossing set-up of any one of the claims 20 to 28, further wherein the embossing rollers system and the embossing features are configured for embossing of the sheet of material to be a wallpaper-like embossing producing an uninterrupted and repeating pattern of embossed aerodynamic features.
30. The embossing set-up of any one of the claims 20 to 29, whereby each one of the profile embossing features as a height in a range between 0,1 mm and 2,5 mm.
31. The embossing set-up according to any one of claims 20 to 30, further comprising a shoulder at each extremity of the first and the second embossing rollers enabling an adjusting of the width of the nip to the first nip width value, the shoulders being configured to produce the first nip width value when at each extremity of the first and the second embossing rollers the shoulders from the first embossing roller are in contact with corresponding ones of the shoulder from the second embossing roller.
32. The embossing set-up according to any one of claims 20 to 31, further comprising pressuring means configured to exert pressure between the first embossing roller and the second embossing roller, and to enable a maintaining of controlled material thickness.
32. The embossing set-up according to any one of claims 20 to 31, wherein the first nip width value is chosen in function of a predetermined grammage of the sheet of material, and of a desired value for the first value of the material thickness.
33. The embossing set-up according to any one of claims 20 to 32, wherein the sheet of material has a grammage in a range between 10 gsm and 100 gsm and a thickness in a range between 0,02 mm and 1,5 mm.

34. The embossing set-up according to any one of claims 20 to 33, wherein a ratio between the controlled material thickness of the embossed sheet and an initial thickness of the material sheet prior to embossing is in a range of 1:1 to 1:5.
35. The embossing set-up according to any one of claims 20 to 33, wherein a ratio between a statistic standard deviation of the initial thickness of the sheet of material and a statistic standard deviation of the controlled material thickness of the embossed sheet is between 1:1 and 1:3.
36. The embossing set-up according to any one of claims 20 to 35, further comprising a step of heating the sheet of material prior to embossing.
37. The embossing set-up according to any one of claims 20 to 36, wherein at least one of the first and the second embossing rollers is maintained at a constant temperature in a range of 20°C to 60°C.
38. A filtering element configured for an inhalable drug delivery device, and for filtering a mainstream gas flow passing through the filtering element, comprising an embossed sheet of material, with a controlled material thickness, wherein
the sheet of material is embossed at least with embossing features by means of an embossing rollers system in which the embossing features formed on a first base surface of a first embossing roller and corresponding embossing features formed on a second base surface of a second embossing roller are in a congruence with each other, and by feeding the sheet of material to a nip between the first embossing roller and the second embossing roller, the embossing features comprising profile embossing features configured for embossing at least an aerodynamic profile on the sheet of material, the embossed aerodynamic profile being configured to modify in a determined manner flow properties for the mainstream gas flow passing through the filtering element by creating a gas flow turbulence occurrence in the filtering element;
the sheet of material is further embossed with separating base surface zones located between embossing features, and corresponding to the first base surface and the second base surface;
the corresponding congruence of each of the embossing features is configured to be such that for a first subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature greater than a value of depth of the recess embossing feature;
thereby configuring a width of the nip between the first and the second embossing rollers, which has a first nip width value for the separating base surface zones,

and different nip width values smaller than the first nip width value for embossing features of the first subset of the embossing features; thereby enabling to obtain the controlled material thickness of the embossed sheet of material with respectively a first value of the material thickness when the sheet of material is embossed with the separating base surface zones, and a different value of the material thickness smaller than the first value of the material thickness when the sheet of material is embossed with embossing features of the first subset of the embossing features.

39. The filtering element according to claim 38, wherein the configuring for each embossing feature of the corresponding congruence is further such that for a second subset of the embossing features, corresponding protrusion and recess embossing features located respectively on different embossing rollers have a value of height of the protrusion embossing feature smaller than or equal to a value of depth of the recess embossing feature, thereby configuring a width of the nip between the first and second embossing rollers, which has further different nip values greater of equal to the first nip width value for embossing features of the second subset of the embossing features; thereby enabling to obtain further different values of the material thickness greater than or equal to the first value of the material thickness when the sheet of material is embossed with embossing features of the second subset of the embossing features.
40. The filtering element according to any one of claims 38 and 39, further wherein the embossed sheet of material is configured to comprise a plurality of stripes, each stripe comprising protrusion features and recess features corresponding to embossing features on each of the first embossing roller and the second embossing roller, and each embossed stripe being oriented longitudinally along a straight line on the sheet of material, the profile embossing features thereby being arranged according to an orientation of the stripe on the embossing rollers.