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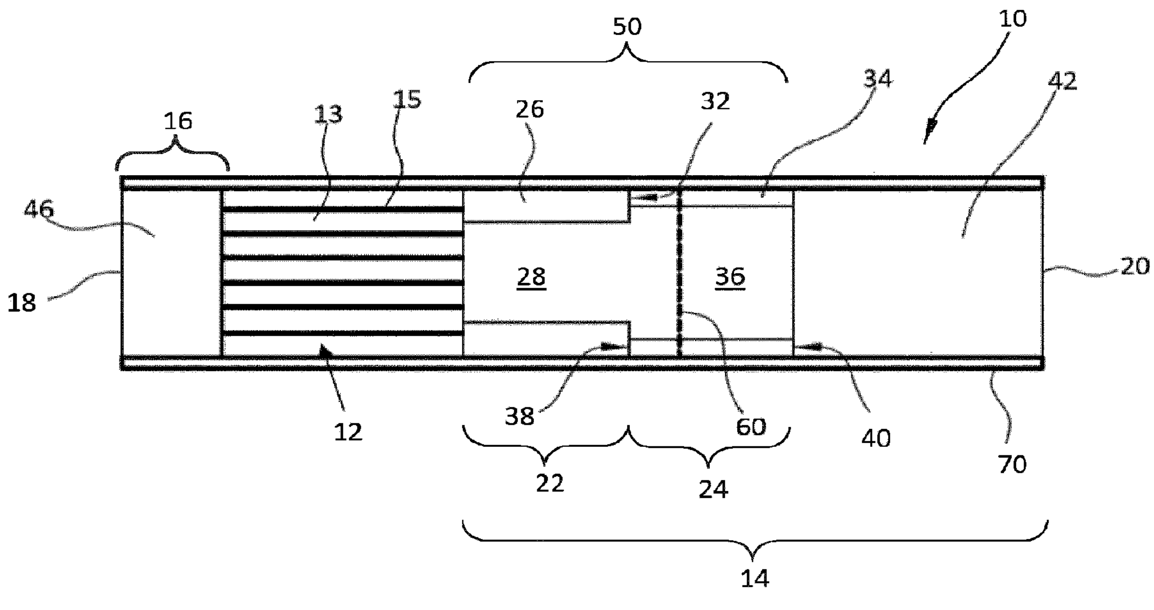

Figure 1

(57) Abrégé/Abstract:
There is provided an aerosol-forming substrate for use in a heated aerosol-generating article, the aerosol-forming substrate comprising a co-laminated sheet comprising a layer of aerosol-forming material and a layer of carbon-based thermally conductive material.

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Abstract:

There is provided an aerosol-forming substrate for use in a heated aerosol-generating article, the aerosol-forming substrate comprising a co-laminated sheet comprising a layer of aerosol-forming material and a layer of carbon-based thermally conductive material.

THERMALLY ENHANCED AEROSOL-FORMING SUBSTRATE

The present disclosure relates to an aerosol-forming substrate. The present disclosure also relates to a rod comprising the aerosol-forming substrate, an aerosol-generating article, and an aerosol-generating system as well as methods of making an aerosol-forming substrate, rod and aerosol-generating article.

A typical aerosol-generating system comprises an aerosol-generating device and an aerosol-generating article comprising an aerosol-forming substrate. In use, the aerosol-generating device interacts with the aerosol-generating article to heat the aerosol-forming substrate and cause the aerosol-forming substrate to release volatile compounds. These compounds then cool to form an aerosol which is inhaled by a user.

Known aerosol-forming substrates typically have relatively low thermal conductivities. This may be undesirable, particularly in aerosol-generating systems in which a blade is inserted into the aerosol-forming substrate and heated in order to heat the aerosol-forming substrate. This is because the low thermal conductivity of the aerosol-forming substrate may lead to a relatively large temperature gradient in the aerosol-forming substrate during use. This may mean that portions of the aerosol-forming substrate which are located furthest from the blade do not reach a high temperature and so do not release as many volatile compounds as they would if the aerosol-forming substrate had a higher thermal conductivity. In other words, the low thermal conductivity of the aerosol-forming substrate may undesirably result in a low usage efficiency of the aerosol-forming substrate.

Further, known aerosol-forming substrates are typically not heatable to operating temperatures by induction. This means that, for inductive heating, a separate susceptor element is typically required. This can increase costs. In addition, this can lead to the same issues as discussed above. For example, where an inductively heated susceptor element is placed in a central position in the substrate, portions of the aerosol-forming substrate which are located furthest from the susceptor element may not reach a high temperature and therefore may not release many volatile compounds.

Attempts have been made to increase the thermal conductivity of aerosol-forming substrates. However, to date, these attempts have been inadequate in one or more respects.

It is an aim of the present invention to provide an improved aerosol-forming substrate, for example an aerosol-forming substrate having an increased thermal conductivity. It is also an aim of the present invention to provide such an aerosol-forming substate having increased thermal conductivity while also having improved tensile strength.

According to the present disclosure there is provided an aerosol-forming substrate. The aerosol-forming substrate may be suitable for use in a heated aerosol-generating article. The aerosol-forming substrate may comprise a co-laminated sheet. The co-laminated sheet may comprise a layer of aerosol-forming material. The co-laminated sheet may comprise a layer of carbon-based thermally conductive material.

Thus, according to a first aspect of the present disclosure, there is provided an aerosol-forming substrate for use in a heated aerosol-generating article, the aerosol-forming substrate comprising a co-laminated sheet comprising a layer of aerosol-forming material and a layer of carbon-based thermally conductive material.

As used herein, the term “carbon-based thermally conductive material” is used to refer to a material comprising carbon, for example materials comprising or consisting of one or more of graphite, expanded graphite, graphene, carbon nanotubes and charcoal.

A layer of carbon-based thermally conductive material comprising or consisting of at least one of graphite and expanded graphite may be particularly preferred. The layer of carbon-based thermally conductive material may be referred to as a carbon material or a carbon-containing material.

Advantageously, the layer of carbon-based thermally conductive material may increase the thermal conductivity of the aerosol-forming substrate. This may provide a more even temperature distribution throughout the substrate during use. This may result in a greater proportion of the aerosol-forming substrate reaching a sufficiently high temperature to release volatile compounds, and thus a higher usage efficiency of the aerosol-forming substrate. Alternatively, or in addition, the increased thermal conductivity of the substrate may allow a heater, for example a heating blade configured to heat the substrate, to operate at a lower temperature and thus require less power.

Advantageously, layer of carbon-based thermally conductive materials such as those listed above, particularly materials comprising graphite and expanded graphite, may have a high thermal conductivity and a low density, and so are able to substantially improve the thermal conductivity of the aerosol-forming substrate without significantly increasing the density of the aerosol-forming substrate. It may be advantageous to avoid significantly increasing the density of the aerosol-forming substrate. This is because an increase in density may increase the weight, and therefore the transport costs, for a given volume of the substrate.

As used herein, the term ‘sheet’ denotes a laminar element having a width and length substantially greater than the thickness thereof. The width of a sheet may be greater than 10 mm, preferably greater than 20, 30, 40, 50, 60, 70, 80, 90, 100 millimeter. The width of the sheet may be less than 300, 250, 200, 150 millimeter. As will be described, the co-laminated sheet may undergo a processing step such as gathering. In such cases, the “width” of the sheet may refer to the width of the sheet prior to gathering.

As used herein, the term "co-laminated sheet" denotes a single sheet formed from two or more layers of material in intimate contact with one another. In particular, the co-laminated sheet may comprise a layer of aerosol-forming material in intimate contact with a layer of thermally-conducting material. The intimate contact between the layer of aerosol-forming material and the layer of carbon-based thermally conductive material means that heat may be transported throughout the layer of aerosol-forming material by the layer of aerosol-forming material by conduction. This improves the thermally conductivity of the aerosol-forming substrate.

The layer of carbon-based thermally conductive material may have a length and a width that is similar or the same as the length and width of the layer of aerosol-forming material.

The layer of carbon-based thermally conductive material may be in contact with the layer of aerosol-forming material across substantially the entirety of a surface of the thermally conductive material.

The layers of the co-laminated sheet may form a single sheet.

The co-laminated sheet may comprise more than one layer of aerosol-forming material. The co-laminated sheet may comprise more than one layer of thermally-conducting material. The or each layer of aerosol-forming material may be sandwiched between layers of thermally conductive material. Alternatively or additionally, the or each layer of thermally conductive material may be sandwiched between layers of aerosol-forming material.

The co-laminated sheet may comprise one or more additional layers comprising a material other than the carbon-based thermally conductive material and the aerosol-forming material.

The or each layer of thermally conductive material may be in the form of a film or foil. A film or foil is thin and so only a small volume of the aerosol-forming substrate may be taken up by the layer or layers of thermally conductive material. However, because the thermally conductive layer may be provided as a layer, which may advantageously extend throughout the aerosol-forming substrate, the thermal conductivity of the substrate is improved throughout the substrate.

The or each layer of thermally conductive material may be flexible. The or each layer of aerosol-forming material may be flexible. In this way, the co-laminated sheet may also be flexible. This may be particularly advantageous when the co-laminated sheet is gathered to form a rod of an aerosol-forming substrate, as will be described below. The gathered co-laminated sheet preferably extends along substantially the entire length of the rod and across substantially the entire transverse cross-sectional area of the rod.

The or each layer of thermally conductive material may have a thickness less than 10, 5, 3, 2, 1, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.09, 0.08, 0.07, 0.06, 0.05, 0.04, 0.03 or 0.02 millimeter.

The or each layer of thermally conductive material may have a thickness of between 10 and 0.02, or 5 and 0.02, 3 and 0.02, 2 and 0.02, 1 and 0.02, 0.9 and 0.02, 0.8 and 0.02, 0.7 and 0.02, 0.6 and 0.02, 0.5 and 0.02, 0.4 and 0.02, 0.3 and 0.02, 0.2 and 0.02, 0.1 and 0.02, 0.09 and 0.02, 0.08 and 0.02, 0.07 and 0.02, 0.06 and 0.02, 0.05 and 0.02, 0.04 and 0.02 millimeter.

Preferably, the layer of carbon-based thermally conductive material may comprise or consist of carbon fibres, graphite or graphene.

Even more preferably, the layer of carbon-based thermally conductive material may comprise or consist of expanded graphite.

Optionally, the layer of carbon-based thermally conductive material may comprise both graphite and expanded graphite.

The layer of carbon-based thermally conductive material may consist of a flexible graphite or a flexible graphite and expanded graphite foil or film.

The layer of carbon-based thermally conductive material may have a density lower than or equal to a density of the aerosol-forming material.

The layer of thermally conductive material may have a density which is at least 1, 2, 5, 10, 15, 20, 25, or 30 % less than a density of the aerosol-forming material.

The aerosol-forming substrate may have a density of less than 1050, 1000, 950, 900, 850, 800, 850, 800, 750, 700, or 650 kg/m3.

The aerosol-forming substrate may have a density of between 500 and 900 kg/m^3, for example between 600 and 800 kg/m^3.

The layer of carbon-based thermally conductive material may have a density less than 3, 2, 1.8, 1.5, 1.2, 1, 0.8, 0.5, 0.2, 0.1, 0.05, 0.02 grams per centimetre cubed (g / cm^3).

The layer of carbon-based thermally conductive material may have a density greater than 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 0.8, 1, 1.2, 1.5 or 1.8 grams per centimetre cubed (g / cm^3).

The layer of carbon-based thermally conductive material may have a density between 0.01 and 3, 0.01 and 2, 0.01 and 1.8, 0.01 and 1.5, 0.01 and 1.2, 0.01 and 1, 0.01 and 0.8, 0.01 and 0.5, 0.02 and 3, 0.02 and 2, 0.02 and 1.8, 0.02 and 1.5, 0.02 and 1.2, 0.02 and 1, 0.02 and 0.8, 0.02 and 0.5, 0.01 and 3, 0.05 and 2, 0.05 and 1.8, 0.05 and 1.5, 0.05 and 1.2, 0.05 and 1, 0.05 and 0.8, 0.05 and 0.5 g/cm3, 0.1 and 3, 0.1 and 2, 0.1 and 1.8, 0.1 and 1.5, 0.1 and 1.2, 0.1 and 1, 0.1 and 0.8, 0.1 and 0.5, 0.2 and 3, 0.2 and 2, 0.2 and 1.8, 0.2 and 1.5, 0.2 and 1.2, 0.2 and 1, 0.2 and 0.8, 0.2 and 0.5, 0.5 and 3, 0.5 and 2, 0.5 and 1.8, 0.5

and 1.5, 0.5 and 1.2, 0.5 and 1, 0.5 and 0.8, 0.8 and 3, 0.8 and 2, 0.8 and 1.8, 0.8 and 1.5, 0.8 and 1.2, 0.8 and 1 grams per centimetre cubed (g / cm3).

Advantageously, the use of lower density layer of thermally conductive material may result in a lower density substrate. This may reduce the weight, and therefore the transport costs, for a given volume of the substrate.

The layer of carbon-based thermally conductive material may have a tensile strength greater than 1, 2, 3, 4, 5, 6, 7, 8 or 9 Megapascal (MPa).

Providing an aerosol-forming substrate in the form of a co-laminated sheet comprising such a layer of carbon-based thermally conductive material may advantageously increase the tensile strength of the substrate overall. Furthermore, the layer of carbon-based thermally conductive material may provide support for the layer aerosol-forming material. As such, there may be no need for a rod of aerosol-generating substrate to comprise an additional support layer. In some embodiments, during the manufacture of the aerosol-forming substrate, the aerosol-forming material may advantageously be cast directly onto the layer of carbon-based thermally conductive material.

The layer of carbon-based thermally conductive material may consist of a foil or film comprising at least 90%, 95%, 97%, 99%, 99.5% 99.9% graphite or expanded graphite by weight.

The layer of carbon-based thermally conductive material may comprise or consist of a reconstituted carbon-based material, preferably a reconstituted sheet of graphite or expanded graphite, even more preferably a reconstituted graphite or expanded graphite film or foil.

The reconstituted carbon-based material may comprise thermally conductive particles. Each thermally conductive particle of the thermally conductive particles may have a thermal conductivity of at least 1 Watt per metre Kelvin [W/(mK)] in at least one direction at 25 degrees Celsius. Some or all of the thermally conductive particles comprise carbon, for example at least 10, 30, 50, 70, 90, 95, 98, or 99 wt % carbon. Optionally, some or all of the thermally conductive particles comprise one or more of graphite, expanded graphite, graphene, carbon nanotubes and charcoal. Optionally, some or all of the thermally conductive particles are graphite particles. Optionally, some or all of the thermally conductive particles are expanded graphite particles. Optionally, some or all of the thermally conductive particles are graphene particles. Advantageously, such materials may have relatively high thermal conductivities.

The reconstituted carbon-based material may comprise at least 10%, 20%, 30%, 40%, 50%, 60%, 70% by weight thermally conductive particles. The reconstituted carbon-based may comprise less than 90%, 95%, 80% by weight of thermally conductive particles.

The reconstituted carbon-based material may comprise an aerosol former. The reconstituted carbon-based material may comprise the aerosol former on a dry weight basis of between 7 and 60 wt %.

The reconstituted carbon-based material may comprise fibres. The layer of reconstituted carbon-based material may comprise the fibres on a dry weight basis if between 2 and 20 wt %. Optionally, the fibres are cellulose fibres. Advantageously, cellulose fibres are not overly costly and can increase the tensile strength of the substrate.

Optionally, each of the fibres has three mutually perpendicular dimensions, a largest dimension of the three dimensions being at least 1.5, 2, 3, 5, 10, or 20 times larger than a smallest dimension of the three dimensions. Optionally, each of the fibres has three mutually perpendicular dimensions, a largest dimension of the three dimensions being at least 1.5, 2, 3, 5, 10, or 20 times larger than a second largest dimension of the three dimensions.

The reconstituted carbon-based material may comprise a binder. The reconstituted carbon-based material may comprise the binder, on a dry weight basis, between 2 and 10 wt %. Optionally, the substrate comprises, on a dry weight basis, at least 4, 6, or 8 wt % of the binder. Optionally, the substrate comprises, on a dry weight basis, no more than 8, 6, or 4 wt % of the binder. Optionally, the substrate comprises, on a dry weight basis, between 4 and 10, 6 and 10, 8 and 10, 2 and 8, 4 and 8, 6 and 8, 2 and 6, 4 and 6, 2 and 4 wt % of the binder. It may be particularly preferable for the substrate to comprise, on a dry weight basis, between 2.1 and 10 wt % of the binder.

Suitable binders are well-known in the art and include, but are not limited to, natural pectins, such as fruit, citrus or tobacco pectins; guar gums, such as hydroxyethyl guar and hydroxypropyl guar; locust bean gums, such as hydroxyethyl and hydroxypropyl locust bean gum; alginate; starches, such as modified or derivatized starches; celluloses, such as methyl, ethyl, ethylhydroxymethyl and carboxymethyl cellulose; tamarind gum; dextran; pullalon; konjac flour; xanthan gum and the like. It may be particularly preferable for the binder to be or comprise guar. It may be particularly preferable for the binder to comprise or consist of one or more of carboxymethyl cellulose or hydroxypropyl cellulose or a gum such as guar gum.

Optionally, the thermally conductive particles are substantially homogeneously distributed throughout the layer of thermally conductive material. Optionally, the aerosol former is substantially homogeneously distributed throughout the layer of thermally conductive material. Optionally, the fibres are substantially homogeneously distributed throughout the layer of thermally conductive material. Optionally, the binder is substantially homogeneously distributed throughout the layer of thermally conductive material. Advantageously, a homogenous distribution of components of the substrate may result in the substrate have more spatially uniform properties. For example, substantially homogeneously distributed thermally conductive particles may result in the substrate having a substantially uniform thermal conductivity. As another example, substantially homogeneously distributed binder or fibres may result in the substrate having a substantially uniform tensile strength.

Advantageously, one or both of the fibres and the binder may increase a tensile strength of the reconstituted carbon-based material. The increased tensile strength may allow the production of a sheet of reconstituted carbon-based material which does not easily tear. The increased tensile strength may allow the production of a reconstituted carbon-based material using existing production machinery.

The thermally conductive particles may each have a “particle size”. The meaning of the term “particle size” and a method of measuring particle size is set out later.

The thermally conductive particles may be characterised by a particle size distribution. The particle size distribution may have number D10, D50 and D90 particle sizes. The number D10 particle size is defined such that 10% of the particles have a particles size less than or equal to the number D10 particle size. Similarly, the number D50 particle size is defined such that 50% of the particles have a particles size less than or equal to the number D50 particle size. Thus, the number D50 particle size may be referred to as a median particle size. The number D90 particle size is defined such that 90% of the particles have a particles size less than or equal to the number D90 particle size. Thus, if there were 1,000 particles in the distribution and the particles were order by ascending particle size, one would expect the number D10 particle size to be roughly equal to the particle size of the 100^{th} particle, the number D50 particle size to be roughly equal to the particle size of the 500^{th} particle, and the number D90 particle size to be roughly equal to the particle size of the 900^{th} particle.

The particle size distribution may have volume D10, D50 and D90 particle sizes. The volume D10 particle size is defined such that 10% of the sum of the volumes of all of the particles is accounted for by the sum of the volumes of the particles having a particles size less than or equal to the volume D10 particle size. Similarly, the volume D50 particle size is defined such that 50% of the sum of the volumes of all of the particles is accounted for by the sum of the volumes of the particles having a particles size less than or equal to the volume D50 particle size. And the volume D90 particle size is defined such that 90% of the sum of the volumes of all of the particles is accounted for by the sum of the volumes of the particles having a particles size less than or equal to the volume D90 particle size.

Optionally, the thermally conductive particles have a particle size distribution having a number D10 particle size, wherein the number D10 particle size is at least 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, or 500 microns.

Optionally, the thermally conductive particles have a particle size distribution having a number D10 particle size, wherein the number D10 particle size is no more than 1,000, 500, 200, 100, 50, 20, 10, 5, 2, 1, 0.5, or 0.2 microns.

A compromise has to be made when deciding the sizes of the particle. Larger thermally conductive particles may advantageously increase the thermal conductivity of the reconstituted carbon-based material, and so the aerosol-forming substrate comprising that reconstituted carbon-based material, more than smaller thermally conductive particles. However, larger thermal conductive particles may reduce the space available for aerosol-forming material in the substrate.

Optionally, the thermally conductive particles have a particle size distribution having a number D50 particle size, wherein the number D50 particle size is at least 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, or 500 microns.

Optionally, the thermally conductive particles have a particle size distribution having a number D50 particle size, wherein the number D50 particle size is no more than 1,000, 500, 200, 100, 50, 20, 10, 5, 2, 1, 0.5, or 0.2 microns.

Optionally, the thermally conductive particles have a particle size distribution having a number D90 particle size, wherein the number D90 particle size is at least 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, or 500 microns.

Optionally, the thermally conductive particles have a particle size distribution having a number D90 particle size, wherein the number D90 particle size is no more than 1,000, 500, 200, 100, 50, 20, 10, 5, 2, 1, 0.5, or 0.2 microns.

Optionally, the thermally conductive particles have a particle size distribution having a number D10 particle size and a number D90 particle size, wherein the number D90 particle size is no more than 50, 40, 30, 20, 10, or 5 times the number D10 particle size.

Optionally, the thermally conductive particles have a particle size distribution having a number D10 particle size and a number D90 particle size, wherein the number D90 particle size is at least 1.5, 2, 3, 5, 10, or 20 times the number D10 particle size.

A compromise must be made in relation to the particle size distribution. A tighter particle size distribution, for example characterised by a smaller ratio between the D90 and D10 particle sizes, may advantageously provide a more uniform thermal conductivity throughout the reconstituted carbon-based material. This is because there will be less variation in particle size in different locations in the substrate. This may advantageously allow for more efficient usage of the aerosol-forming material throughout the aerosol-forming substrate. However, a tighter particle size distribution may disadvantageously be more difficult and expensive to achieve. The inventors have found that the particle size distributions described above may provide an optimal compromise between these two factors.

Optionally, the thermally conductive particles have a particle size distribution having a volume D10 particle size, wherein the volume D10 particle size is at least 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, or 500 microns.

Optionally, the thermally conductive particles have a particle size distribution having a volume D10 particle size, wherein the volume D10 particle size is no more than 1,000, 500, 200, 100, 50, 20, 10, 5, 2, 1, 0.5, or 0.2 microns

Optionally, the thermally conductive particles have a particle size distribution having a volume D50 particle size, wherein the volume D50 particle size is at least 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, or 500 microns.

Optionally, the thermally conductive particles have a particle size distribution having a volume D50 particle size, wherein the volume D50 particle size is no more than 1,000, 500, 200, 100, 50, 20, 10, 5, 2, 1, 0.5, or 0.2 microns.

Optionally, the thermally conductive particles have a particle size distribution having a volume D90 particle size, wherein the volume D90 particle size is at least 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, or 500 microns.

Optionally, the thermally conductive particles have a particle size distribution having a volume D90 particle size, wherein the volume D90 particle size is no more than 1,000, 500, 200, 100, 50, 20, 10, 5, 2, 1, 0.5, or 0.2 microns.

It may be particularly preferably for the thermally conductive particles have a particle size distribution having a volume D10 particle size between 1 and 20 microns. Alternatively, or in addition, it may be particularly preferably for the thermally conductive particles have a particle size distribution having a volume D90 particle size between 50 and 300 microns, or between 50 and 200 microns.

Optionally, the thermally conductive particles have a particle size distribution having a volume D10 particle size and a volume D90 particle size, wherein the volume D90 particle size is no more than 50, 40, 30, 20, 10, or 5 times the volume D10 particle size.

Optionally, the thermally conductive particles have a particle size distribution having a volume D10 particle size and a volume D90 particle size, wherein the volume D90 particle size is at least 1.5, 2, 3, 5, 10, or 20 times the volume D10 particle size.

As explained above, a compromise must be made in relation to the particle size distribution, and the inventors have found that the particle size distributions above may provide an optimal compromise.

Optionally, each of the thermally conductive particles has a particle size of at least 0.01, 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, or 500 microns. Optionally, each of the thermally conductive particles has a particle size of no more than 1,000, 500, 300, 200, 100, 50, 20, 10, 5, 2, 1, 0.5, or 0.2 microns. It may be particularly preferable for each of the thermally conductive particles to have a particle size of at least 1 micron. Alternatively, or in addition, it may be particularly preferable for each of the thermally conductive particles to have a particle size of no more than 300 microns. Particles smaller than 1 micron may be difficult to handle during manufacturing. Particles greater than 300 microns may take up a rather large amount of space in the substrate which could be used for aerosol-forming material. Thus, it may be particularly advantageous for each of the thermally conductive particles to have a particle size of at least 1 micron, or a particle size of no more than 300 microns, or both.

Optionally, each of the thermally conductive particles has three mutually perpendicular dimensions, a largest dimension of the three dimensions being no more than 10, 8, 5, 3, or 2 times larger than a smallest dimension of the three dimensions. Optionally, each of the thermally conductive particles has three mutually perpendicular dimension, a largest dimension of the three dimensions being no more than 10, 8, 5, 3, or 2 times larger than a second largest dimension of the three dimensions. Optionally, each of the thermally conductive particles is substantially spherical. Advantageously, the orientation of substantially spherical particles may not affect the thermal conductivity of the substrate as much as the orientation of non-spherical particles. Thus, the use of more spherical particles may result in less variability between different substrates where the orientations of the particles is not controlled. In addition, substantially spherical particles may be easier to characterise.

Optionally, the thermally conductive particles comprise at least 10, 20, 50, 100, 200, 500, or 1000 particles. Advantageously, a greater number of particles in the aerosol-forming substrate may allow the thermal conductivity of the substrate to be more uniform.

Optionally, the substrate comprises, on a dry weight basis, at least 20, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 or 85 wt % of the thermally conductive particles. Optionally, the substrate comprises, on a dry weight basis, no more than 85, 80, 75, 70, 65, 60, 55, 50, 45, 40, 35, 30, 25, 20, or 15 wt % of the thermally conductive particles. Optionally, the substrate comprises, on a dry weight basis, between 10 and 90, 20 and 90, 30 and 90, 40 and 90, 50 and 90, 60 and 90, 70 and 90, 80 and 90, 10 and 80, 20 and 80, 30 and 80, 40 and 80, 50 and 80, 60 and 80, 70 and 80, 10 and 70, 20 and 70, 30 and 70, 40 and 70, 50 and 70, 60 and 70, 10 and 60, 20 and 60, 30 and 60, 40 and 60, 50 and 60, 10 and 50, 20 and 50, 30 and 50, 40 and 50, 10 and 40, 20 and 40, 30 and 40, 10 and 30, 20 and 30, or 10 and 20 wt % of the thermally conductive particles. It may be particularly preferable for the substrate to comprise, on a dry weight basis, between 50 and 90, or more preferably between 60 and 90, or even more preferably between 65 and 85, wt % of the thermally conductive particles.

A comprise must be made in relation to the weight percent of thermally conductive particles in the substrate. Increasing the weight percent of particles in the aerosol-forming substrate may advantageously increase the thermal conductivity of the substrate. However, increasing the weight percent of particles in the aerosol-forming substrate may also reduce the available space for one or more of the aerosol former, binder, and fibres, so could result in a substrate which forms less aerosol, or which has less tensile strength.

The layer of carbon-based thermally conductive material not comprise tobacco. The layer of carbon-based thermally conductive material may not comprise nicotine.

The layer of carbon-based thermally conductive material may be formed by a casting process.

The co-laminated sheet may comprise or have the form of a gathered sheet. The carbon-based thermally conductive material may have sufficient tensile strength to withstand the gathering process while providing supporting for the aerosol-forming material layer.

The layer of carbon-based thermally conductive material may have a thermal conductivity of greater than 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 or 1500 W/(mK). The thermal conductivity may be a thermal conductivity as measured at 25 °C.

The layer of carbon-based thermally conductive material may exhibit anisotropic thermal conductivities. The layer of carbon-based thermally conductive material may lie in or define a plane. The thermal conductivity of the layer of carbon-based thermally conductive material in-plane may be greater than 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 or 1500 W/mK. The thermal conductivity may be a thermal conductivity as measured at 25 °C.

Advantageously, increasing the thermal conductivity of the layer of thermally conductive material may increase the thermal conductivity of the aerosol-forming substrate.

Expanded graphite may have a density less than 2, 1.8, 1.5, 1.2, 1, 0.8, or 0.5, 0.2, 0.1, 0.05, 0.02 grams per centimetre cubed (g / cm^3).

Expanded graphite may have a density greater than 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 0.8, 1, 1.2, 1.5 or 1.8 grams per centimetre cubed (g / cm^3).

Expanded graphite may have a density between 0.01 and 3, 0.01 and 2, 0.01 and 1.8, 0.01 and 1.5, 0.01 and 1.2, 0.01 and 1, 0.01 and 0.8, 0.01 and 0.5, 0.02 and 3, 0.02 and 2, 0.02 and 1.8, 0.02 and 1.5, 0.02 and 1.2, 0.02 and 1, 0.02 and 0.8, 0.02 and 0.5, 0.01 and 3, 0.05 and 2, 0.05 and 1.8, 0.05 and 1.5, 0.05 and 1.2, 0.05 and 1, 0.05 and 0.8, 0.05 and 0.5 g/cm^3, 0.1 and 3, 0.1 and 2, 0.1 and 1.8, 0.1 and 1.5, 0.1 and 1.2, 0.1 and 1, 0.1 and 0.8, 0.1 and 0.5, 0.2 and 3, 0.2 and 2, 0.2 and 1.8, 0.2 and 1.5, 0.2 and 1.2, 0.2 and 1, 0.2 and 0.8, 0.2 and 0.5, 0.5 and 3, 0.5 and 2, 0.5 and 1.8, 0.5 and 1.5, 0.5 and 1.2, 0.5 and 1, 0.5 and 0.8, 0.8 and 3, 0.8 and 2, 0.8 and 1.8, 0.8 and 1.5, 0.8 and 1.2, 0.8 and 1 grams per centimetre cubed (g / cm^3).

The layer of carbon-based thermally conductive material may comprise more than 10, 30, 50, 70, 80, 90, 95, 98, 99, 99.5, or 99.9% carbon by weight. The layer of carbon-based thermally conductive material may consist of carbon except for trace quantities of impurities.

The layer of carbon-based thermally conductive material may make up less than or equal to 90, 80, 70, 60, 50, 20, 10, or 5 weight percent of the aerosol-forming substrate. The layer of carbon-based thermally conductive material may make up more than or equal to 0.1, 0.2, 0.5, 1, 2, 3, 5, 10, 20, 30, 40 or 50 weight percent of the aerosol-forming substrate. The layer of carbon-based thermally conductive material may make up between 20 and 90, 20 and 90, 30 and 90, 40 and 90, 20 and 80, 30 and 80, 40 and 80, 20 and 70, 30 and 70, 40 and 70, 20 and 60, 30 and 60, 40 and 60, 20 and 50, 30 and 50 weight percent of the aerosol-forming substrate.

Advantageously, the inventors have found that such weight percentages provide an optimal compromise between increasing the thermal conductivity of the aerosol-forming substrate and maintaining enough aerosol-forming material to form an adequate quantity of aerosol.

The layer of aerosol-forming material may have a thermal conductivity of between 0.1 W/mK to 0.2 W/mK. This may be the case if the aerosol-forming material is a standard homogenised tobacco. Thus, in some embodiments the aerosol-forming material may have a thermal conductivity of less than 0.2 W/mK, for example when measured at 25 °C, and the layer of carbon-based thermally conductive material may have a thermal conductivity of greater than, and preferably much greater than, 0.22 W/mK, for example when measured at 25 °C. The layer of carbon-based thermally conductive material may have a thermal conductivity as high as 1700 W/mK, for example as found in commercial graphite foil along its planar direction.

These thermal conductivities may be measured when a moisture content of the materials is between 0 and 20, or 5 and 15, for example around 10%. This thermal conductivity may be measured when the material comprises between 0 and 20, or 5 and 15, for example around 10 wt % water. The moisture or water content of the material may be measured using a titration method. The moisture or water content of the material may be measured using the Karl Fisher method.

The aerosol-forming material is preferably configured to generate an aerosol on heating, for example on heating to a temperature of between 120 degrees Centigrade and 395 degrees Centigrade. In some embodiments the layer of carbon-based thermally conductive material is not configured to generate an aerosol on heating, for example on heating to a temperature of between 120 degrees Centigrade and 350 degrees Centigrade. Thus, in these embodiments, the layer of carbon-based thermally conductive material is not an aerosol-forming material. The role of the carbon-based thermally conductive material in such embodiments is to facilitate the transfer of heat to allow aerosol generation from the aerosol-forming material to be optimised.

The aerosol-forming material may comprise one or more organic materials such as tobacco. The aerosol-forming material may comprise one or more of herb leaf, tobacco leaf, fragments of tobacco ribs, reconstituted tobacco, homogenised tobacco, extruded tobacco and expanded tobacco. Preferably, the aerosol-forming material may be formed from homogenised tobacco. Preferably, the aerosol-forming material comprises tobacco and an aerosol-former. Preferably, the aerosol-forming material is configured to generate an aerosol when heated to a temperature of between 120 degrees Centigrade and 395 degrees Centigrade. The aerosol-forming material may be a homogenised tobacco material comprising an aerosol former such as glycerine or propylene glycol. The first material may further comprises fibres and a binder to improve the structure of the first material.

Advantageously, one or both of the fibres and the binder may increase a tensile strength of the aerosol-forming material. The increased tensile strength may allow the production of a co-laminated sheet of the aerosol-forming substrate which does not easily tear. The increased tensile strength may allow the production of a co-laminated sheet of the aerosol-forming substrate using existing production machinery.

The aerosol-forming material may comprise one or more aerosol-formers. Suitable aerosol-formers are well known in the art and include, but are not limited to, one or more aerosol-formers selected from: polyhydric alcohols, such as propylene glycol, polyethylene glycol, triethylene glycol, 1, 3-butanediol and glycerine; esters of polyhydric alcohols, such as glycerol mono-, di- or triacetate; and aliphatic esters of mono-, di- or polycarboxylic acids, such as dimethyl dodecanedioate and dimethyl tetradecanedioate. It may be particularly preferable for the aerosol-former to be or comprise glycerine. Optionally, the aerosol-forming substrate comprises one or both of glycerine and glycerol.

Optionally, the substrate comprises, on a dry weight basis, at least 10, 15, 20, 25, 30, 35, 40, 45, 50, or 55 wt % of the aerosol former. Optionally, the substrate comprises, on a dry weight basis, no more than 55, 50, 45, 40, 35, 30, 25, 20, or 15 wt % of the aerosol former. Optionally, the substrate comprises, on a dry weight basis, between 7 and 60, 10 and 60, 20 and 60, 30 and 60, 40 and 60, 50 and 60, 7 and 50, 10 and 50, 20 and 50, 30 and 50, 40 and 50, 7 and 40, 10 and 40, 20 and 40, 30 and 40, 7 and 30, 10 and 30, 20 and 30, 7 and 20, 10 and 20, or 7 and 10 wt % of the aerosol former. It may be particularly preferable for the substrate to comprise, on a dry weight basis, between 15 and 25 wt % of the aerosol former.

Optionally, the substrate comprises, on a dry weight basis, at least 2, 4, 6, 8, 10, 12, 14, 16 or 18 wt % of the fibres. Optionally, the substrate comprises, on a dry weight basis, no more than 20, 18, 16, 14, 12, 10, 8, 6, or 4 wt % of the fibres. Optionally, the substrate comprises, on a dry weight basis, between 4 and 20, 6 and 20, 8 and 20, 10 and 20, 12 and 20, 14 and 20, 16 and 20, 18 and 20, 2 and 18, 4 and 18, 6 and 18, 8 and 18, 10 and 18, 12 and 18, 14 and 18, 16 and 18, 2 and 16, 4 and 16, 6 and 16, 8 and 16, 10 and 16, 12 and 16, 14 and 16, 2 and 14, 4 and 14, 6 and 14, 8 and 14, 10 and 14, 12 and 14, 2 and 12, 4 and 12, 6 and 12, 8 and 12, 10 and 12, 2 and 10, 4 and 10, 6 and 10, 8 and 10, 2 and 8, 4 and 8, 6 and 8, 2 and 6, 4 and 6, or 2 and 4 wt % of the fibres. It may be particularly preferable for the substrate to comprise, on a dry weight basis, between 2.1 and 9.8 wt % of the fibres.

The aerosol-former may be glycerine. The aerosol-forming substrate may comprise at least 1, 2, 5, 10, or 15 weight percent glycerine. For example, the aerosol-forming substrate may comprise between 12 and 25 weight percent glycerine.

The aerosol-forming material may comprise fibres, preferably between 2 and 20 wt % of fibres. The aerosol-forming material may comprise a binder, preferably between 2 and 10 wt % of a binder.

Optionally, the substrate comprises, on a dry weight basis, at least 2, 4, 6, 8, 10, 12, 14, 16 or 18 wt % of the fibres. Optionally, the substrate comprises, on a dry weight basis, no more than 20, 18, 16, 14, 12, 10, 8, 6, or 4 wt % of the fibres. Optionally, the substrate comprises, on a dry weight basis, between 4 and 20, 6 and 20, 8 and 20, 10 and 20, 12 and 20, 14 and 20, 16 and 20, 18 and 20, 2 and 18, 4 and 18, 6 and 18, 8 and 18, 10 and 18, 12 and 18, 14 and 18, 16 and 18, 2 and 16, 4 and 16, 6 and 16, 8 and 16, 10 and 16, 12 and 16, 14 and 16, 2 and 14, 4 and 14, 6 and 14, 8 and 14, 10 and 14, 12 and 14, 2 and 12, 4 and 12, 6 and 12, 8 and 12, 10 and 12, 2 and 10, 4 and 10, 6 and 10, 8 and 10, 2 and 8, 4 and 8, 6 and 8, 2 and 6, 4 and 6, or 2 and 4 wt % of the fibres. It may be particularly preferable for the substrate to comprise, on a dry weight basis, between 2.1 and 9.8 wt % of the fibres.

Optionally, the fibres are cellulose fibres. Advantageously, cellulose fibres are not overly costly and can increase the tensile strength of the substrate.

Optionally, each of the fibres has three mutually perpendicular dimensions, a largest dimension of the three dimensions being at least 1.5, 2, 3, 5, 10, or 20 times larger than a smallest dimension of the three dimensions. Optionally, each of the fibres has three mutually perpendicular dimensions, a largest dimension of the three dimensions being at least 1.5, 2, 3, 5, 10, or 20 times larger than a second largest dimension of the three dimensions.

Optionally, the substrate comprises, on a dry weight basis, at least 4, 6, or 8 wt % of the binder. Optionally, the substrate comprises, on a dry weight basis, no more than 8, 6, or 4 wt % of the binder. Optionally, the substrate comprises, on a dry weight basis, between 4 and 10, 6 and 10, 8 and 10, 2 and 8, 4 and 8, 6 and 8, 2 and 6, 4 and 6, 2 and 4 wt % of the binder. It may be particularly preferable for the substrate to comprise, on a dry weight basis, between 2.1 and 10 wt % of the binder.

Suitable binders are well-known in the art and include, but are not limited to, natural pectins, such as fruit, citrus or tobacco pectins; guar gums, such as hydroxyethyl guar and hydroxypropyl guar; locust bean gums, such as hydroxyethyl and hydroxypropyl locust bean gum; alginate; starches, such as modified or derivatized starches; celluloses, such as methyl, ethyl, ethylhydroxymethyl and carboxymethyl cellulose; tamarind gum; dextran; pullalon; konjac flour; xanthan gum and the like. It may be particularly preferable for the binder to be or comprise guar. It may be particularly preferable for the binder to comprise or consist of one or more of carboxymethyl cellulose or hydroxypropyl cellulose or a gum such as guar gum.

The aerosol-forming material may comprise nicotine. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, at least 0.01, 1, 2, 3, or 4 wt % nicotine. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, no more than 5, 4, 3, 2, or 1 wt % nicotine. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, between 0.01 and 5, 1 and 5, 2 and 5, 3 and 5, 4 and 5, 0.01 and 4, 1 and 4, 2 and 4, 3 and 4, 0.01 and 3, 1 and 3, 2 and 3, 0.01 and 2, 1 and 2, 0.01 and 1 wt % nicotine. It may be particularly preferable for the aerosol-forming substrate to comprise, on a dry weight basis, between 0.5 and 3 wt % nicotine.

Optionally, the nicotine is substantially homogeneously distributed throughout the aerosol-forming material.

Optionally, the aerosol-forming material comprises an acid. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, at least 0.01, 1, 2, 3, or 4 wt % of the acid. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, no more than 5, 4, 3, 2 or 1 wt % of the acid. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, between 0.01 and 5, 1 and 5, 2 and 5, 3 and 5, 4 and 5, 0.01 and 4, 1 and 4, 2 and 4, 3 and 4, 0.01 and 3, 1 and 3, 2 and 3, 0.01 and 2, 1 and 2, 0.01 and 1 wt % of the acid. It may be particularly preferable for the aerosol-forming substrate to comprise, on a dry weight basis, between 0.5 and 3wt % of acid.

Optionally, the acid comprises or consists of one or more of fumaric acid, lactic acid, benzoic acid, and levulinic acid.

Optionally, the acid is substantially homogeneously distributed throughout the aerosol-forming material.

Optionally, the aerosol-forming material comprises at least one botanical. Optionally, the substrate comprises, on a dry weight basis, at least 0.01, 1, 2, 5, 10, or 15 wt % of the at least one botanical. Optionally, the substrate comprises, on a dry weight basis, no more than

20, 15, 10, 5, 2 or 1 wt % of the at least one botanical. Optionally, the substrate comprises, on a dry weight basis, between 0.01 and 20, 1 and 20, 2 and 20, 5 and 20, 10 and 20, 15 and 20, 0.01 and 15, 1 and 15, 2 and 15, 5 and 15, 10 and 15, 0.01 and 10, 1 and 10, 2 and 10, 5 and 10, 0.01 and 5, 1 and 5, 2 and 5, 0.01 and 2, 1 and 2, 0.01 and 1 wt % of the at least one botanical. It may be particularly preferable for the substrate to comprise, on a dry weight basis, between 5 and 15 wt % of the at least one botanical.

Optionally, the at least one botanical comprises or consists of one or both of clove and 16omprise16s.

Optionally, the at least one botanical is substantially homogeneously distributed throughout the aerosol-forming material.

Optionally, the aerosol-forming material comprises at least one flavourant. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, at least 0.1, 1, 2, or 5 wt % of the at least one flavourant. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, no more than 10, 5, 2 or 1 wt % of the at least one flavourant. Optionally, the aerosol-forming substrate comprises, on a dry weight basis, between 0.1 and 10, 1 and 10, 2 and 10, 5 and 10, 0.1 and 5, 1 and 5, 2 and 5, 0.1 and 2, 1 and 2, 0.1 and 1 wt % of the at least one flavourant. It may be particularly preferable for the substrate to comprise, on a dry weight basis, between 0.5 and 4.0 wt % of the at least one flavourant.

Optionally, the at least one flavourant is present as a coating, for example a coating on one or more other components of the aerosol-forming substrate. Alternatively, or in addition, the at least one flavourant is substantially homogeneously distributed throughout the aerosol-forming former.

Optionally, the aerosol-forming material comprises at least one organic material such as tobacco. Optionally, the at least one organic material comprises one or more of herb leaf, tobacco leaf, fragments of tobacco ribs, reconstituted tobacco, homogenised tobacco, extruded tobacco and expanded tobacco. Optionally, the at least one organic material is substantially homogeneously distributed throughout the aerosol-forming material.

The aerosol-forming substrate may comprise, on a dry weight basis, less than 10, 5, 3, 2, or 1 wt % tobacco. Optionally, the aerosol-forming substrate is a tobacco-free aerosol-forming substrate.

The aerosol-forming material may comprise, or may be in the form of, one or more sheets, for example one or more gathered sheets. The or each sheet, for example gathered sheet, may have a width of at least about 10, 25, 50, or 100 millimetres. The or each sheet, for example gathered sheet, may have a length of at least about 3, 5 or 10 millimetres. The or each sheet, for example gathered sheet, may have a thickness of at least about 100, 150 or 200 microns. The or each sheet, for example gathered sheet, may have a thickness of less than about 500, 400 or 300 microns. The or each sheet, for example gathered sheet, may have a thickness between 100 and 500, 170 and 400, or 200 and 300 microns. The or each sheet, for example gathered sheet, may have a thickness of around 235 microns.

According to a second aspect there is provided a rod. The rod may be a rod for an aerosol-generating article. The rod may comprise or be formed by an aerosol-forming substrate. In other words, there may be provided a rod of aerosol-forming substrate. The rod may comprise a gathered sheet of aerosol-forming substrate.

The rod may comprise a wrapper circumscribing the gathered sheet of aerosol-forming substrate. Preferably, the aerosol-forming substrate is an aerosol-forming substrate according to the first aspect. As such, the rod may be formed by gathering the co-laminated sheet of the first aspect.

A susceptor element may be located within the rod of aerosol-forming substrate. The susceptor element may be an elongate susceptor element. The susceptor element may extend longitudinally within the rod of aerosol-forming substrate. The rod may be substantially cylindrical, for example right cylindrical, in shape. The susceptor element may be positioned in a radially central position within the rod of aerosol-forming substrate. The susceptor element may extend along a central, longitudinal axis of the rod of aerosol-forming substrate.

The susceptor element may extend all the way to a downstream end of the rod of aerosol-forming substrate. The susceptor element may extend all the way to an upstream end of the rod of aerosol-forming substrate. The susceptor element may have substantially the same length as the rod of aerosol-forming substrate. The susceptor element may extend from the upstream end to the downstream end of the rod of aerosol-forming substrate.

The susceptor element may be in the form of a pin, rod, strip or blade.

The susceptor element may have a length of between 5 and 15, 6 and 12, or 8 and 10 millimetres. The susceptor element may have a width of between 1 and 5 millimetres. The susceptor element may have a thickness of between 0.01 and 2, 0.5 and 2, or 0.5 and 1 millimetres.

Alternatively, there may be no susceptor materials present in the aerosol-forming substrate or in the rod of aerosol-forming substrate. Or the layer of carbon-based thermally conductive material may comprise or consist of one or more susceptor materials and may be the only susceptor material(s) present in the aerosol-forming substrate or in the rod of aerosol-forming substrate. That is, there may be no susceptor elements present in the aerosol-forming substrate or in the rod of aerosol-forming substrate except for the layer of thermally conductive material.

Suitable susceptor materials, for example materials for the susceptor element, include, but are not limited to: carbon, carbon-based materials, graphene, graphite, expanded graphite, molybdenum, silicon carbide, stainless steels, niobium, aluminium, nickel, nickel-containing compounds, titanium, and composites of metallic materials. Suitable susceptor materials may comprise a ferromagnetic material, for example, ferritic iron, a ferromagnetic alloy, such as ferromagnetic steel or stainless steel, ferromagnetic particles, and ferrite. A suitable susceptor material may be, or comprise, aluminium. A susceptor material preferably comprises more than 5 percent, preferably more than 20 percent, more preferably more than 50 percent or more than 90 percent of ferromagnetic or paramagnetic materials. Preferred susceptor materials may comprise a metal, metal alloy or carbon.

Particularly preferred susceptor materials may be, or comprise, carbon, carbon-based materials, graphene, graphite, or expanded graphite. Advantageously, such materials have relatively high thermal conductivities, relatively low densities, and may be inductively heated. These materials may be preferred when the layer of carbon-based thermally conductive material acts as, or comprises a material that acts as, a susceptor.

As explained in more detail later with reference to an aerosol-generating system, in use, susceptor materials may convert electromagnetic energy into heat. This may heat the aerosol-forming material of the aerosol-forming substrate.

The aerosol-forming substrate may have a longitudinal direction and a transverse, or radial, direction perpendicular to the longitudinal direction. For example, the aerosol-forming substrate may be in the form of a plug. The plug may be right cylindrical in shape. The plug may have a length extending in the longitudinal direction and a radius extending in the transverse, or radial, direction. The longitudinal direction may refer to a direction extending from an upstream end to a downstream end of the substrate, or to a direction extending from an upstream end to a downstream end of an article of which the substrate is part. The aerosol-forming substrate may have a thermal conductivity of greater than 0. 0.05, 0.1, 0.15, 0.2, 0.3, 0.4, 0.5, 0.75, 1, 1.25, 1.5, 2, 5, 10, 20, 50, 100, 200, or 500 W/(mK) in at least one direction at 25 degrees Celsius.

Advantageously, increasing the thermal conductivity of the substrate may reduce temperature gradients in the substrate in use. It may be particularly advantageous to increase the thermal conductivity of the substrate in the transverse direction because, when used with a heating blade, large temperature gradients typically exist in the transverse direction in prior art substrates.

According to a third aspect of the present disclosure, there is provided an aerosol-generating article comprising an aerosol-forming substrate. Any features described above in relation to an aerosol-forming substrate may be applicable to the aerosol-forming substrate of the aerosol-generating article.

The aerosol-generating article may be for use with an electrical aerosol-generating device.

The aerosol-generating article may comprise a plurality of elements. The plurality of elements may be assembled in the form of a rod. The plurality of elements may be assembled within a wrapper or casing. The aerosol-generating article may have a length of between 30 mm and 120 mm, for example between 40 mm and 80 mm, for example about 45 mm. The aerosol generating article may have a diameter of between 3.5 mm and 10 mm, for example between 4 mm and 8.5 mm, for example between 4.5 mm and 7.5 mm.

The plurality of elements may include an upstream element. The plurality of elements may include the aerosol-forming substrate. The plurality of elements may include a support element. The plurality of elements may include an aerosol-cooling element. The plurality of elements may include a mouthpiece element.

The aerosol-generating article may comprise an intermediate hollow section. The intermediate hollow section may be located between the rod of aerosol-generating substrate and the mouthpiece element. The intermediate hollow section may comprise one or both of the support element and the aerosol-cooling element. The intermediate hollow section may consist of one or both of the support element and the aerosol-cooling element.

The upstream element may be located at an upstream end of the article. The aerosol-forming substrate may be located downstream, for example immediately downstream, of the upstream element. Alternatively, the aerosol-forming substrate may be located at an upstream end of the article, for example where no upstream element is present. The support element may be located downstream, for example immediately downstream, of the aerosol-forming substrate. The aerosol-cooling element may be located downstream, for example immediately downstream, of the support element. The mouthpiece element may be located downstream, for example immediately downstream, of the aerosol-cooling element. The mouthpiece element may be located at a downstream end, or mouth end, of the article.

The upstream element may advantageously prevent direct physical contact with an upstream end of the aerosol-forming substrate. The upstream element may also advantageously reduce the likelihood of material from the aerosol-forming substrate falling out of the article. The support element may advantageously provide support to the article and help to properly locate other components of the article. The aerosol-cooling element may advantageously allow an aerosol to cool so it is a more desirable temperature when it reaches a user. The mouthpiece element may advantageously act as a filter.

The plurality of elements of the aerosol-generating article may be assembled by means of a suitable wrapper, for example a cigarette paper. A cigarette paper may be any suitable material for wrapping components of an aerosol-generating article in the form of a rod. Suitable materials for the wrapper are well-known in the art. The cigarette paper may grip the component elements of the aerosol-generating article when the article is assembled. The cigarette paper may hold component elements in position within the rod.

The upstream element may be in the form of a plug, for example a porous plug. The upstream element may comprise one or more longitudinally extending cavities. The upstream element may comprise a slit or aperture. The slit or aperture may extend from the upstream end to the downstream end of the upstream element. The slit of aperture may be suitable for allowing a heating pin, rod or blade to pass therethrough in use. The upstream element may be made of a porous material. The upstream element may be made of the same material as used for one of the other components of the aerosol-generating article, such as the mouthpiece element, the aerosol-cooling element, or the support element. The upstream element may comprise, or be formed from, one or more of a filter material, ceramic, polymer material, cellulose acetate, cardboard, zeolite or aerosol-generating substrate. It may be preferable that the upstream element comprises, or is formed from, cellulose acetate, for example a plug of cellulose acetate.

Optionally, the front plug has a length of between 2 and 10, 3 and 8, or 4 and 6 mm, for example around 5 mm. Optionally, the aerosol-forming substrate within the article has a length of between 5 and 20, 8 and 15, or 10 and 15 mm, for example around 12 mm.

The upstream element may have a length of between 1 and 10, 3 and 8, or 4 and 6 millimetres. The upstream element may have a length of about 5 millimetres.

Advantageously, the upstream element may prevent a consumer from seeing the layer of thermally conductive material through an upstream end of the article.

The support element may comprise, or be, a hollow tube, for example a substantially cylindrical hollow tube. The hollow tube may define an internal cavity. The internal cavity may extend in the longitudinal direction. Airflow through the internal cavity may be substantially unrestricted. Thus, the hollow tube may not substantially contribute to a resistance to draw (RTD) of the article. A thickness of the wall of the hollow tube may be between 2 and 4 millimetres.

The support element may be formed from any suitable material or combination of materials. For example, the support element may be formed from one or more materials selected from the group consisting of: cellulose acetate; cardboard; crimped paper, such as crimped heat resistant paper or crimped parchment paper; and polymeric materials, such as low density polyethylene (LDPE). In a preferred embodiment, the support element is formed from cellulose acetate. Other suitable materials include polyhydroxyalkanoate (PHA) fibres.

It may be particularly preferred that the support element comprises or is formed from cellulose acetate.

The support element may have an external diameter that is approximately equal to the external diameter of the aerosol-generating article. The support element may have an external diameter of between 5 and 12, 5 and 10, or 5 and 8, 6 and 12, 6 and 10, or 6 and 8 millimetres. The support element may have an external diameter of approximately 7.2 millimetres.

A peripheral wall of the support element may have a thickness of at least 1, 1.5 or 2 millimetres, for example where the support element comprises or is a second hollow tube.

The support element may have a length of at least 5, 6, 7 or 8 millimetres. Alternatively or in addition, the support element may have a length of less than 15, 12 or 10 millimetres.

The aerosol-cooling element may comprise, or be, a second hollow tube, for example a substantially cylindrical second hollow tube. The second hollow tube may define a second internal cavity. The second internal cavity may extend in the longitudinal direction. Airflow through the second internal cavity may be substantially unrestricted. Thus, the second hollow tube may not substantially contribute to a resistance to draw (RTD) of the article. A thickness of the wall of the second hollow tube may be between 1 and 3 millimetres.

The aerosol-cooling element may comprise, or be formed from, any suitable material or combination of materials. For example, the aerosol-cooling element may comprise or be formed from one or more materials selected from the list consisting of: cellulose acetate; cardboard; crimped paper, such as crimped heat resistant paper or crimped parchment paper; and polymeric materials, such as low density polyethylene (LDPE). Other suitable materials include polyhydroxyalkanoate (PHA) fibres. It may be preferable that the aerosol-cooling element comprises or is formed from cellulose acetate.

The aerosol-cooling element may have an external diameter that is approximately equal to the external diameter of the aerosol-generating article. The aerosol-cooling element may have an external diameter of between 5 and 12, 5 and 10, or 5 and 8, 6 and 12, 6 and 10, or 6 and 8 millimetres. The aerosol-cooling element may have an external diameter of approximately 7.2 millimetres.

The aerosol-cooling element may have an internal diameter of at least about 2, 2.5, or 3 millimetres, for example where the aerosol-cooling element comprises or is a second hollow tube.

A peripheral wall of the aerosol-cooling element may have a thickness of less than about 2.5, 1.5, 1.25, 1, 0.9, or 0.8 millimetres, for example where the aerosol-cooling element comprises or is a second hollow tube.

The aerosol-cooling element may have a length of at least 5, 6, 7 or 8 millimetres. Alternatively or in addition, the aerosol-cooling element may have a length of less than 15, 12 or 10 millimetres.

The mouthpiece element may comprise a filtration material, for example a fibrous filtration material. The mouthpiece element may comprise, or be, a plug of cellulose acetate. The mouthpiece element may be translucent or opaque.

The mouthpiece element may have an external diameter that is approximately equal to the external diameter of the aerosol-generating article. The mouthpiece element may have an external diameter of between 5 and 12, 5 and 10, or 5 and 8, 6 and 12, 6 and 10, or 6 and 8 millimetres. The mouthpiece element may have an external diameter of approximately 7.2 millimetres.

The mouthpiece element may have a length of at least 5, 8 or 10 millimetres. Alternatively or in addition, the mouthpiece element may have a length of less than 25, 20 or 15 millimetres. The mouthpiece element may have a length of approximately 12 millimetres.

Advantageously, a longer mouthpiece element may be more resilient to deformation, or better adapted to recover its initial shape after deformation, and may provide for improved grip by the consumer to facilitate insertion of the aerosol-generating article into a heating device. In addition, a longer mouthpiece element may provide a higher level of filtration and removal of undesirable aerosol constituents so that a higher quality aerosol can be delivered. In addition, the use of a longer mouthpiece element enables a more complex mouthpiece to be provided since there is more space for the incorporation of mouthpiece components such as capsules, threads and restrictors.

The aerosol-generating article may have an overall length of between 38 and 70, 40 and 70, 42 and 70, 38 and 60, 40 and 60, or 42 and 60, 38 and 50, 40 and 50, or 42 and 50 millimetres. The aerosol-generating article may have an overall length of around 45 millimetres.

The aerosol-generating article may have an external diameter of at least about 5, 6, or 7 millimetres. The aerosol-generating article may have an external diameter of less than about 12, 10 or 8 millimetres. The aerosol-generating article may have an external diameter of about 7.25 millimetres.

According to the present disclosure, there is provided an aerosol-generating system comprising an aerosol-generating article as described above and an aerosol-generating device.

The aerosol-generating device may be an electrical aerosol-generating device. The aerosol-generating device may be engageable with, and disengageable from, the aerosol-generating article. For example, the aerosol-generating device may be configured to receive at least a portion of the aerosol-generating article.

The aerosol-generating device may be configured to heat the aerosol-generating article. The aerosol-generating device may be configured to resistively heat the aerosol-generating article. The device may comprise a heating element. The heating element may be configured to contact, for example penetrate, the aerosol-forming substrate in use. The heating element may be configured to be resistively heated. The heating element may comprise an electrically resistive track. In use, a current may be passed through the track to resistively heat the track. The heating element may be in the form of a pin, rod or blade.

The aerosol-generating device may be configured to inductively heat the aerosol-generating article. The device may comprise an inductor, such as an inductor coil. The device may be configured to generate a fluctuating electromagnetic field. In use, this fluctuating electromagnetic field may induce eddy currents in a susceptor material, for example a susceptor material of the thermally conductive material, or a susceptor material of a heating element of the device, or both. Where the device comprises an inductively heatable heating element, such a heating element may be configured to contact, for example penetrate, the aerosol-forming substrate in use. The heating element may be in the form of a pin, rod or blade. The eddy currents may heat up the susceptor material and thereby heat up the aerosol-forming substrate in use.

In a fourth aspect of the disclosure there is provided a method of forming an aerosol-forming substrate.

The method may comprise combining a layer of aerosol-forming material with a layer of carbon-based thermally conductive material to form a co-laminated sheet.

The aerosol-forming substrate manufactured using this method may have the features described with respect to the first aspect.

The layer of aerosol-forming material may be a continuous sheet of aerosol-forming material. The layer of carbon-based thermally conductive material may be a continuous sheet of carbon-based thermally conductive material. In such cases, the method may comprise forming a continuous co-laminated sheet.

The method may further comprise gathering the co-laminated sheet transversely relative to its longitudinal axis. The method may further comprise circumscribing the gathered co-laminated sheet with a wrapper to form a rod.

When the method comprises forming a continuous co-laminated sheet, the gathered sheet circumscribed with a wrapper may form a continuous rod. In such cases, the method may additionally comprise severing the continuous rods into a plurality of discrete rods.

Such a rod may be used as the aerosol-forming substrate of a heated aerosol-generating article. Preferably, the aerosol-generating article is a smoking article that generates an aerosol that is directly inhalable into a user's lungs through the user's mouth. More, preferably, the aerosol-generating article is a smoking article that generates a nicotine-containing aerosol that is directly inhalable into a user's lungs through the user's mouth.

The step of combining the layers may comprise placing the layer of carbon-based thermally conductive material and the layer of aerosol-forming material layers in contact with one another, preferably in intimate contact. The method may further comprise crimping the layer of carbon-based thermally conductive and the layer of aerosol-forming material layers while these layers in contact with one another. This may comprise feeding the carbon-based thermally conductive and aerosol-forming material layers through crimping rollers. The crimping rollers may engage and crimp the layers together to form a continuous crimped co-laminated sheet. The crimped co-laminated sheet may have a plurality of spaced-apart ridges or corrugations substantially parallel to the longitudinal axis of the sheet

As used herein, the term 'crimped' is intended to be synonymous with the term 'creped' and denotes a sheet having a plurality of substantially parallel ridges or corrugations. Preferably, a crimped sheet of homogenised tobacco material has a plurality of ridges or corrugations substantially parallel to the cylindrical axis of the rod. This advantageously facilitates gathering of the crimped sheet of homogenised tobacco material to form the rod. However, it will be appreciated that crimped sheets of homogenised tobacco material for use in the invention may alternatively or in addition have a plurality of substantially parallel ridges or corrugations disposed at an acute or obtuse angle to the cylindrical axis of the rod.

The step of combining the layers may comprise overlaying the sheet of carbon-based thermally conductive material on top of the sheet of aerosol-forming material.

Alternatively, the step of combining the sheets may comprise overlaying the sheet of aerosol-forming material on top of the sheet of carbon-based thermally conductive material.

In either case, a continuous process may be advantageously be achieved by feeding one of a sheet of the carbon-based thermally conductive material or the aerosol-forming material from a first bobbin on to a conveyer. The other sheet of the carbon-based thermally conductive material or the aerosol-forming material may be fed from a second bobbin on top of the sheet from the first bobbin on the conveyor.

Optionally, the method further comprises the step of forming the layer of aerosol-forming material. The step of forming the layer of aerosol-forming material may comprise the steps of a paper making process or, preferably, a casting process.

The step of forming the layer of aerosol-forming material may comprise casting a slurry comprising an organic material. The organic material is preferably homogenised tobacco material.

The step of forming the sheet additionally comprises drying the slurry to form an aerosol-forming material.

The step or steps of forming the layer of aerosol-forming material may be performed prior to the step of combining the layers may comprise overlaying the sheet of carbon-based thermally conductive material on top of the sheet of aerosol-forming material.

Alternatively, the step or steps of forming the layer of aerosol-forming material may be performed simultaneously with the step of combining the layers may comprise overlaying the sheet of carbon-based thermally conductive material on top of the sheet of aerosol-forming material. In particular, the sheet of aerosol-forming material may be formed on top of the sheet of carbon-based thermally conductive material. Preferably, a slurry of aerosol-forming material may be cast on to, preferably directly, on to the carbon-based thermally conductive material. The slurry may be dried while on top of the carbon-based thermally conductive material. In this way, a co-laminated sheet may be formed at the same time as providing the layer of aerosol-forming material. This is particularly advantageous in a continuous process to improve the speed and ease of manufacture of the co-laminated sheet.

Furthermore, the process of casting an aerosol-forming material often requires the slurry to be cast on to a support structure. However, casting the layer of aerosol-forming material on to the carbon-based thermally conductive material may advantageously remove the need for an additional support structure.

Preferably, the slurry comprise an aerosol former, reinforcement fibres and a binder. These features are described in the first aspect as features of the aerosol-forming material.

Optionally, forming the slurry comprises adding the fibres.

Optionally, the method, for example the step of forming the slurry, comprises a first mixing the slurry. Optionally, the first mixing occurs under a first pressure of no more than 500, 400, 300, 250, or 200 mbar. Optionally, the first mixing occurs for between 1 and 10, 2 and 8, or 3 and 6 minutes, for example for around 4 minutes.

Optionally, the method, for example the step of forming the slurry, comprises, after the first mixing, a second mixing. Optionally, the second mixing occurs under a second pressure which is less than the first pressure. Optionally, the second pressure is no more than 500, 400, 300, 200, 150, or 100 mbar. Optionally, the second mixing occurs for between 5 and 120, 5 and 80, 5 and 40, or 10 and 30 seconds, for example around 20 seconds.

Casting the slurry may comprise casting the slurry onto a flat support, for example a steel flat support. Alternatively, as described above, the slurry may be cast directly on to a sheet or layer of carbon-based thermally conductive material.

Optionally, after casting the slurry and before drying the slurry, the method may comprise setting a thickness of the slurry, for example setting a thickness of the slurry to between 100 and 1200, 200 and 1000, 300 and 900, 500 and 700 microns, for example around 600 microns.

Optionally, drying the slurry comprises providing a flow of a gas such as air over or past the slurry. Optionally, the flow of gas is heated. Optionally, the flow of gas is heated to a temperature of between 100 and 160, or 120 and 140 degrees Celsius. Optionally, the flow of gas is provided for between 1 and 10 or 2 and 5 minutes. Optionally, drying the slurry comprises drying the slurry until the slurry has a moisture content of between 1 and 20, 2 and 15, 2 and 10, or 3 and 7 wt %.

Optionally, drying the slurry forms the precursor for forming into a sheet of aerosol-forming material.

Optionally, the method comprises cutting the sheet of aerosol-forming material to form discrete elements of the aerosol-forming material. In a continuous process, the step of cutting the sheet of aerosol-forming material may be the same step as severing a continuous rod to form discrete rods.

Alternatively or additionally, the method of the fourth aspect may comprise forming the layer of carbon-based thermally conductive material. This may comprise preparing, forming or manufacturing a reconstituted carbon-based material.

The step of manufacturing a reconstituted carbon-based material may comprise forming a slurry comprising thermally conductive particles. The step of manufacturing the reconstituted carbon-based material may additionally comprise casting and drying the slurry to form the reconstituted carbon-based material.

Preferably, the slurry may comprise fibres. Preferably, the slurry may comprise a binder. The presence of one or both of fibres and binder in the slurry may increase the tensile strength of the cast and dried slurry.

Optionally, the slurry may comprise an aerosol-former.

Optionally, the slurry comprises water. Optionally, the slurry comprises between 20 and 90, 30 and 90, 40 and 90, 40 and 85, 50 and 80, 60 and 80, or 60 and 75 wt % water.

Optionally, forming the slurry comprises forming a first mixture. The first mixture may comprise the fibres. The first mixture may comprise water. The first mixture may comprise the aerosol-former.

Forming the slurring may comprise forming a second mixture. The second mixture may comprise the thermally conductive particles. The second mixture may comprise the binder. Forming the slurry may comprise adding the second mixture to the first mixture to form a combined mixture.

Optionally, the method, for example the step of forming the slurry, comprises a first mixing of the combined mixture. Optionally, the first mixing occurs under a first pressure of no more than 500, 400, 300, 250, or 200 mbar. Optionally, the first mixing occurs for between 1 and 10, 2 and 8, or 3 and 6 minutes, for example for around 4 minutes.

Optionally, the method, for example the step of forming the slurry, comprises, after the first mixing, a second mixing. Optionally, the second mixing occurs under a second pressure which is less than the first pressure. Optionally, the second pressure is no more than 500, 400, 300, 200, 150, or 100 mbar. Optionally, the second mixing occurs for between 5 and 120, 5 and 80, 5 and 40, or 10 and 30 seconds, for example around 20 seconds.

Optionally, casting the slurry comprises casting the slurry onto a flat support, for example a steel flat support.

Optionally, after casting the slurry and before drying the slurry, the method comprises setting a thickness of the slurry, for example setting a thickness of the slurry to between 100 and 1200, 200 and 1000, 300 and 900, 500 and 700 microns, for example around 600 microns.

Optionally, drying the slurry comprises providing a flow of a gas such as air over or past the slurry. Optionally, the flow of gas is heated. Optionally, the flow of gas is heated to a temperature of between 100 and 160, or 120 and 140 degrees Celsius. Optionally, the flow of gas is provided for between 1 and 10 or 2 and 5 minutes. Optionally, drying the slurry comprises drying the slurry until the slurry has a moisture content of between 1 and 20, 2 and 15, 2 and 10, or 3 and 7 wt %.

In a fifth aspect of the present disclosure there is provided a method of forming a rod comprising an aerosol-forming substrate. The method comprising the steps of:

providing a co-laminated sheet comprising a layer of aerosol-forming material and a layer of carbon-based thermally conductive material;

gathering the co-laminated sheet transversely relative to its longitudinal axis; and

circumscribing the gathered co-laminated sheet with a wrapper to form a continuous rod.

The method of the fifth aspect may further comprise any of the steps of the method of the fourth aspect.

In a sixth aspect, there is provided a method of forming an aerosol-generating article comprising the method steps of the fifth aspect.

The method may comprise assembling the aerosol-generating article from a plurality of components, the plurality of components including the aerosol-forming substrate.

Such an article may be, for example, in the form of a rod comprising a plurality of components, including the aerosol-forming substrate, assembled within a wrapper or casing.

The aerosol-generating article may have a length of between 30 mm and 120 mm, for example between 40 mm and 80 mm, for example about 45 mm. The aerosol generating article may have a diameter of between 3.5 mm and 10 mm, for example between 4 mm and 8.5 mm, for example between 4.5 mm and 7.5 mm.

Optionally, the aerosol-generating article comprises a front plug. Optionally, the aerosol-generating article comprises a first hollow tube, for example a first hollow acetate tube. Optionally, the aerosol-generating article comprises a second hollow tube, for example a second hollow acetate tube. Optionally, the second hollow tube comprises one or more ventilation holes. Optionally, the aerosol-generating article comprises a mouth plug filter. Optionally, the aerosol-generating article comprises wrapper, for example a paper wrapper.

Optionally, the front plug is arranged a most upstream end of the article. Optionally, the aerosol-forming substrate is arranged downstream of the front plug. Optionally, the first hollow tube is arranged downstream of the aerosol-forming substrate. Optionally, the second hollow tube is arranged downstream of the first hollow tube. Optionally, the mouth plug filter is arranged downstream of one or both of the first hollow tube and the second hollow tube. Optionally, the mouth plug filter is arranged at a most downstream end of the article. Optionally, the most downstream end of the article, which may be referred to as a mouth end of the article, may be configured for insertion into a mouth of a user. A user may be able to inhale on, for example directly on, the mouth end of the article.

Optionally, the front plug, the aerosol-forming substrate, one or both of the first hollow tube and the second hollow tube, and the mouth plug filter are circumscribed by a wrapper, for example a paper wrapper.

Optionally, the front plug has a length of between 2 and 10, 3 and 8, or 4 and 6 mm, for example around 5 mm. Optionally, the aerosol-forming substrate within the article has a length of between 5 and 20, 8 and 15, or 10 and 15 mm, for example around 12 mm. Optionally, the first hollow tube has a length of between 2 and 20, 5 and 15, or 5 and 10 mm, for example around 8 mm. Optionally, the second hollow tube has a length of between 2 and 20, 5 and 15, or 5 and 10 mm, for example around 8 mm. Optionally, the mouth plug filter has a length of between 5 and 20, 8 and 15, or 10 and 15 mm, for example around 12 mm. The lengths of one or more of the front plug, the aerosol-forming substrate, the first hollow tube, the second hollow tube, and the mouth plug filter may extend in a longitudinal direction. One or more of the front plug, the aerosol-forming substrate, the first hollow tube, the second hollow tube, and the mouth plug filter may be substantially cylindrical, for example right cylindrical, in shape.

As would be understood by the skilled person having read this disclosure, the features described herein in relation to one aspect may be applicable to any other aspect.

As used herein, the term “aerosol-forming substrate” may refer to a substrate capable of releasing an aerosol or volatile compounds that can form an aerosol. Such volatile compounds may be released by heating the aerosol-forming substrate. An aerosol-forming substrate may comprise an aerosol-forming material. An aerosol-forming substrate may be adsorbed, coated, impregnated or otherwise loaded onto a carrier or support. An aerosol-forming substrate may conveniently be part of an aerosol-generating article or smoking article.

As used herein, the term “expanded graphite” may refer to a graphite-based material, or a material having a graphite-like structure. Expanded graphite may have carbon layers (similar to graphite, for example) with spacing between the carbon layers greater than the spacing found between carbon layers in regular graphite. Expanded graphite may have carbon layers with elements or compounds intercalated into spaces between the carbon layers.

As used herein, where not otherwise specified, the term “density” may be used to refer to true density. The measurement of true density can be done using a number of standard methods, these methods often being based on Archimedes’ principle. The most widely used method, when used to measure the true density of a powder, entails the powder being placed inside a container (a pycnometer) of known volume, and weighed. The pycnometer is then filled with a fluid of known density, in which the powder is not soluble. The volume of the powder is determined by the difference between the volume as shown by the pycnometer, and the volume of liquid added (i.e. the volume of air displaced).

As used herein, the term “aerosol-generating article” may refer to an article able to generate, or release, an aerosol, for example when heated.

As used herein, the term “longitudinal” may refer to a direction extending between a downstream or proximal end and an upstream or distal end of a component such as an aerosol-forming substrate or aerosol-generating article.

As used herein, the term “transverse” may refer to a direction perpendicular to the longitudinal direction.

As used herein, the term “aerosol-generating device” may refer to a device for use with an aerosol-generating article to enable the generation, or release, of an aerosol.

As used herein, the term “sheet” may refer to a generally planar, laminar element having a width and a length which are substantially greater than, for example at least 2, 3, 5, 10, 20 or 50 times, its thickness.

As used herein, the term “aerosol former” may refer to any suitable known compound or mixture of compounds that, in use, facilitates formation of an aerosol. The aerosol may be a dense and stable aerosol. The aerosol may be substantially resistant to thermal degradation at the operating temperature of the aerosol-forming substrate or aerosol-generating article.

As used herein, the term “rod” may refer to a generally cylindrical, for example right cylindrical, element of substantially circular, oval or elliptical cross-section.

As used herein, the term “crimped” may refer to a sheet or discrete element having one or more ridges or corrugations. The ridges or corrugations may be substantially parallel. When present in a component of an aerosol-generating article, the ridges or corrugations may extend in a longitudinal direction with respect to the aerosol-generating article.

The invention is defined in the claims. However, below there is provided a non-exhaustive list of non-limiting examples. Any one or more of the features of these examples may be combined with any one or more features of another example, embodiment, or aspect described herein.

EX1. An aerosol-forming substrate for use in a heated aerosol-generating article, the aerosol-forming substrate comprising a co-laminated sheet comprising a layer of aerosol-forming material and a layer of carbon-based thermally conductive material.

EX2. An aerosol-forming substrate according to example EX1, wherein the layer of carbon-based thermally conductive material is a material comprising carbon, for example materials comprising or consisting of one or more of graphite, expanded graphite, graphene, carbon nanotubes, charcoal, and diamond.

EX3. An aerosol-forming substrate according to example EX1 or EX2, wherein the layer of carbon-based thermally conductive material comprises or consists of at least one of graphite and expanded graphite may.

EX4. An aerosol-forming substrate according to any one of examples EX1 to EX3, wherein the width of the co-laminated sheet is greater than 10 mm, preferably greater than 20, 30, 40, 50, 60, 70, 80, 90, 100 millimeter.

EX5. An aerosol-forming substrate according to any one of examples EX1 to EX4, wherein the width of the co-laminated sheet is less than 300, 250, 200, 150 millimeter.

EX6. An aerosol-forming substrate according to any one of examples EX1 to EX5, wherein the layer of aerosol-forming material of the co-laminated sheet is in intimate contact with the layer of thermally-conducting material.

EX7. An aerosol-forming substrate according to any one of examples EX1 to EX6, wherein the layer of carbon-based thermally conductive material has a length and a width that is similar or the same as the length and width of the layer of aerosol-forming material.

EX8. An aerosol-forming substrate according to any one of examples EX1 to EX7, wherein the layer of carbon-based thermally conductive material is in contact with the layer of aerosol-forming material across substantially the entirety of a surface of the layer of thermally conductive material.

EX9. An aerosol-forming substrate according to any one of examples EX1 to EX8, wherein the layers of the co-laminated sheet form a single sheet.

EX10. An aerosol-forming substrate according to any one of examples EX1 to EX9, wherein the co-laminated sheet comprises more than one layer of aerosol-forming material.

EX11. An aerosol-forming substrate according to any one of examples EX1 to EX10, wherein the co-laminated sheet comprises more than one layer of thermally-conducting material.

EX12. An aerosol-forming substrate according to examples EX10, wherein the or each layer of aerosol-forming material is sandwiched between layers of thermally conductive material.

EX13. An aerosol-forming substrate according to example EX11, wherein the or each layer of thermally conductive material is sandwiched between layers of aerosol-forming material.

EX14. An aerosol-forming substrate according to any one of examples EX1 to EX13, wherein the co-laminated sheet comprises one or more additional layers comprising a material other than the layer of carbon-based thermally conductive material and the aerosol-forming material.

EX15. An aerosol-forming substrate according to any one of examples EX1 to EX14, wherein the or each layer of thermally conductive material is in the form of a film or foil.

EX16. An aerosol-forming substrate according to any one of examples EX1 to EX15, wherein the or each layer of thermally conductive material is flexible.

EX17. An aerosol-forming substrate according to any one of examples EX1 to EX16, wherein the or each layer of aerosol-forming material is flexible.

EX18. An aerosol-forming substrate according to any one of examples EX1 to EX17, wherein the co-laminated sheet is flexible.

EX19. An aerosol-forming substrate according to any one of examples EX1 to EX18, wherein the or each layer of thermally conductive material has a thickness less than 10, 5, 3, 2, 1, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1, 0.09, 0.08, 0.07, 0.06, 0.05, 0.04, 0.03 or 0.02 millimeter.

EX20. An aerosol-forming substrate according to any one of examples EX1 to EX19, wherein the or each layer of thermally conductive material has a thickness of between 10 and 0.02, or 5 and 0.02, 3 and 0.02, 2 and 0.02, 1 and 0.02, 0.9 and 0.02, 0.8 and 0.02, 0.7 and 0.02, 0.6 and 0.02, 0.5 and 0.02, 0.4 and 0.02, 0.3 and 0.02, 0.2 and 0.02, 0.1 and 0.02, 0.09 and 0.02, 0.08 and 0.02, 0.07 and 0.02, 0.06 and 0.02, 0.05 and 0.02, 0.04 and 0.02 millimeter.

EX21. An aerosol-forming substrate according to any one of examples EX1 to EX20, wherein the layer of carbon-based thermally conductive material comprises or consists of carbon fibres, graphite or graphene.

EX22. An aerosol-forming substrate according to example EX21, wherein the layer of carbon-based thermally conductive material comprises or consists of expanded graphite.

EX23. An aerosol-forming substrate according to example EX21 or EX22, wherein the layer of carbon-based thermally conductive material comprises both graphite and expanded graphite.

EX24. An aerosol-forming substrate according to any one of examples EX21 to EX23, wherein the layer of carbon-based thermally conductive material consists of a flexible graphite or a flexible graphite and expanded graphite foil or film.

EX25. An aerosol-forming substrate according to any one of examples EX1 to EX24, wherein the layer of carbon-based thermally conductive material has a density lower than or equal to a density of the aerosol-forming material.

EX26. An aerosol-forming substrate according to any one of examples EX1 to EX25, wherein the layer of thermally conductive material has a density which is at least 1, 2, 5, 10, 15, 20, 25, or 30 % less than a density of the aerosol-forming material.

EX27. An aerosol-forming substrate according to any one of examples EX1 to EX26, wherein the aerosol-forming substrate has a density of less than 1050, 1000, 950, 900, 850, 800, 850, 800, 750, 700, or 650 kg/m3.

EX28. An aerosol-forming substrate according to any one of examples EX1 to EX27, wherein the aerosol-forming substrate has a density of between 500 and 900 kg/m^3, for example between 600 and 800 kg/m^3.

EX29. An aerosol-forming substrate according to any one of examples EX1 to EX28, wherein the layer of carbon-based thermally conductive material has a density less than 3, 2, 1.8, 1.5, 1.2, 1, 0.8, 0.5, 0.2, 0.1, 0.05, 0.02 grams per centimetre cubed (g / cm^3).

EX30. An aerosol-forming substrate according to any one of examples EX1 to EX29, wherein the layer of carbon-based thermally conductive material has a density greater than 0.01, 0.02, 0.05, 0.1, 0.2, 0.5, 0.8, 1, 1.2, 1.5 or 1.8 grams per centimetre cubed (g / cm^3).

EX31. An aerosol-forming substrate according to any one of examples EX1 to EX30, wherein the layer of carbon-based thermally conductive material has a density between 0.01 and 3, 0.01 and 2, 0.01 and 1.8, 0.01 and 1.5, 0.01 and 1.2, 0.01 and 1, 0.01 and 0.8, 0.01 and 0.5, 0.02 and 3, 0.02 and 2, 0.02 and 1.8, 0.02 and 1.5, 0.02 and 1.2, 0.02 and 1, 0.02 and 0.8, 0.02 and 0.5, 0.01 and 3, 0.05 and 2, 0.05 and 1.8, 0.05 and 1.5, 0.05 and 1.2, 0.05

and 1, 0.05 and 0.8, 0.05 and 0.5 g/cm3, 0.1 and 3, 0.1 and 2, 0.1 and 1.8, 0.1 and 1.5, 0.1 and 1.2, 0.1 and 1, 0.1 and 0.8, 0.1 and 0.5, 0.2 and 3, 0.2 and 2, 0.2 and 1.8, 0.2 and 1.5, 0.2 and 1.2, 0.2 and 1, 0.2 and 0.8, 0.2 and 0.5, 0.5 and 3, 0.5 and 2, 0.5 and 1.8, 0.5 and 1.5, 0.5 and 1.2, 0.5 and 1, 0.5 and 0.8, 0.8 and 3, 0.8 and 2, 0.8 and 1.8, 0.8 and 1.5, 0.8 and 1.2, 0.8 and 1 grams per centimetre cubed (g / cm3).

EX32. An aerosol-forming substrate according to any one of examples EX1 to EX31, wherein the layer of carbon-based thermally conductive material has a tensile strength greater than 1, 2, 3, 4, 5, 6, 7, 8 or 9 Megapascal (Mpa).

EX33. An aerosol-forming substrate according to any one of examples EX1 to EX32, wherein the layer of carbon-based thermally conductive material comprises or consists of a reconstituted carbon-based material.

EX34. An aerosol-forming substrate according to example EX33, wherein the layer of carbon-based thermally conductive material comprises or consists of reconstituted sheet of graphite.

EX35. An aerosol-forming substrate according to example EX33 or EX34, wherein the layer of carbon-based thermally conductive material comprises or consists of a reconstituted graphite film or foil.

EX36. An aerosol-forming substrate according to any one of examples EX33 to EX35, wherein the reconstituted carbon-based material comprises thermally conductive particles.

EX37. An aerosol-forming substrate according to example EX36, wherein each thermally conductive particle of the thermally conductive particles has a thermal conductivity of at least 1 Watt per metre Kelvin [W/(mK)] in at least one direction at 25 degrees Celsius.

EX38. An aerosol-forming substrate according to example EX36 or EX37, wherein some or all of the thermally conductive particles comprise carbon, for example at least 10, 30, 50, 70, 90, 95, 98, or 99 wt % carbon.

EX39. An aerosol-forming substrate according to any one of examples EX33 to EX38, wherein the reconstituted carbon-based material comprises an aerosol former.

EX40. An aerosol-forming substrate according to example EX39, wherein the reconstituted carbon-based material comprises the aerosol former on a dry weight basis of between 7 and 60 wt %.

EX41. An aerosol-forming substrate according to any one of examples EX33 to EX40, wherein the reconstituted carbon-based material comprise fibres.

EX42. An aerosol-forming substrate according to example EX41, wherein the layer of reconstituted carbon-based material comprises the fibres on a dry weight basis if between 2 and 20 wt %. Optionally, the fibres are cellulose fibres.

EX43. An aerosol-forming substrate according to any one of examples EX33 to EX42, wherein the reconstituted carbon-based material comprises a binder.

EX44. An aerosol-forming substate according to example EX43, wherein the reconstituted carbon-based material comprises the binder, on a dry weight basis, between 2 and 10 wt %.

EX45. An aerosol-forming substrate according to any one of examples EX33 to EX44, wherein the layer of carbon-based thermally conductive material does not comprise tobacco.

EX46. An aerosol-forming substrate according to examples EX45, wherein the layer of carbon-based thermally conductive material may not comprise nicotine.

EX47. An aerosol-forming substrate according to any one of examples EX33 to EX46, wherein the layer of carbon-based thermally conductive material may be formed by a casting process.

EX48. An aerosol-forming substrate according to any one of examples EX1 to EX47, wherein the co-laminated sheet comprises or has the form of a gathered sheet.

EX49. An aerosol-forming substrate according to any one of examples EX1 to EX48, wherein the layer of carbon-based thermally conductive material has a thermal conductivity of greater than 2, 5, 10, 20, 50, 100, 200, 500, 1000 or 1500 W/(mK).

EX50. An aerosol-forming substrate according to any one of examples EX1 to EX49, wherein the layer of carbon-based thermally conductive material lies in or defines a plane and wherein the layer of thermal conductivity of the carbon-based thermally conductive material in-plane is greater than 2, 5, 10, 20, 50, 100, 200, 500, 1000 or 1500 W/mK.

EX51. An aerosol-forming substrate according to any one of examples EX1 to EX50, wherein the layer of carbon-based thermally conductive material comprises more than 10, 30, 50, 70,80, 90, 95, 98, 99, 99.5, or 99.9% carbon by weight.

EX52. An aerosol-forming substrate according to any one of examples EX1 to EX51, wherein the layer of carbon-based thermally conductive material makes up less than or equal to 90, 80, 50, 20, 10, or 5 weight percent of the aerosol-forming substrate.

EX53. An aerosol-forming substrate according to any one of examples EX1 to EX52, wherein the layer of carbon-based thermally conductive material makes up more than or equal to 0.1, 0.2, 0.5, 1, 2, 3, 5, 10, 20, 30, 40, or 50 weight percent of the aerosol-forming substrate.

EX54. An aerosol-forming substrate according to any one of examples EX1 to EX53, wherein the layer of carbon-based thermally conductive material makes up between 20 and 90, 20 and 90, 30 and 90, 40 and 90, 20 and 80, 30 and 80, 40 and 80, 20 and 70, 30 and

70, 40 and 70, 20 and 60, 30 and 60, 40 and 60, 20 and 50, 30 and 50 weight percent of the aerosol-forming substrate.

EX55. A rod for an aerosol-generating article, comprising a gathered sheet of aerosol-forming substrate as defined in any one of examples EX1 to EX54, and a wrapper circumscribing the gathered sheet of aerosol-forming substrate.

EX56. A rod according to example EX55, further comprising a susceptor element located within the rod of aerosol-forming substrate.

EX57. A rod according to example EX56, wherein the susceptor element is an elongate susceptor element.

EX58. A rod according to example EX56 or EX57, wherein the susceptor element extends longitudinally within the rod of aerosol-forming substrate.

EX59. A rod according to any one of examples EX56 to EX58, wherein the rod is substantially cylindrical in shape.

EX60. A rod according to example EX59, wherein the susceptor element is positioned in a radially central position within the rod of aerosol-forming substrate and extends along a central, longitudinal axis of the rod of aerosol-forming substrate.

EX61. A rod according to any one of examples EX56 to EX60, wherein the susceptor element is in the form of a pin, rod, strip or blade.

EX62. A rod according to any one of examples EX56 to EX61, wherein the susceptor element has a length of between 5 and 15, 6 and 12, or 8 and 10 millimetres.

EX63. A rod according to example EX62, wherein the layer of carbon-based thermally conductive material comprises a susceptor material.

EX64. A rod according to example EX63, wherein there is no susceptor element present in the aerosol-forming substrate or in the rod of aerosol-forming substrate except for the layer of thermally conductive material.

EX65. An aerosol-generating article for use with an electrical aerosol-generating device, the article comprising an aerosol-forming substrate according to any one of examples EX1 to EX64.

EX66. An aerosol-generating article according to example EX65, comprising a plurality of elements assembled within a wrapper or casing in the form of a rod.

EX67. An aerosol-generating article according to example EX66, wherein the plurality of elements comprises an upstream element, the aerosol-forming substrate, a support element, an aerosol-cooling element and a mouthpiece element.

EX68. An aerosol-generating system comprising an aerosol-generating article as defined in any one of examples EX65 to EX67 and an electrical aerosol-generating device, wherein the aerosol-generating device is engageable with, and disengageable from, the aerosol-generating article.

EX69. An aerosol-generating system according to example EX68, wherein the aerosol-generating device is configured to resistively heat the aerosol-generating article.

EX70. An aerosol-generating system according to example EX69, wherein the device comprises a resistively heatable heating element.

EX71. An aerosol-generating system according to example EX70, wherein the heating element comprises an electrically resistive track.

EX72. An aerosol-generating system according to example EX71, wherein the aerosol-generating device is configured to inductively heat the aerosol-generating article.

EX73. An aerosol-generating system according to example EX72, wherein the device comprises an inductor, such as an inductor coil.

EX74. An aerosol-generating system according to example EX73 wherein the device is configured to generate a fluctuating electromagnetic field.

EX75. A method of forming an aerosol-forming substrate, the method comprising combining a layer of aerosol-forming material with a layer of carbon-based thermally conductive material to form a co-laminated sheet.

EX76. A method according to example EX75, wherein the layer of aerosol-forming material is a continuous sheet of aerosol-forming material.

EX77. A method according to example EX75 or EX76, wherein the layer of carbon-based thermally conductive material is a continuous sheet of carbon-based thermally conductive material.

EX78. A method according to any one of examples EX75 to EX77, wherein the method comprises forming a continuous co-laminated sheet.

EX79. A method according to any one of examples EX75 to EX78, further comprising gathering the co-laminated sheet transversely relative to its longitudinal axis.

EX80. A method according to any one of examples EX75 to EX79, wherein the method further comprises circumscribing the gathered co-laminated sheet with a wrapper to form a rod.

EX81. A method according to example EX80, wherein the method comprises forming a continuous co-laminated sheet, such that the gathered sheet circumscribed with a wrapper forms a continuous rod.

EX82. A method according to example EX81, further comprising severing the continuous rod into a plurality of discrete rods.

EX83. A method according to any one of examples EX75 to EX82, wherein the step of combining the layers comprises placing the carbon-based thermally conductive and aerosol-forming material layers in contact with one another, preferably in intimate contact.

EX84. A method according to example EX83, further comprising crimping the layer of carbon-based thermally conductive and aerosol-forming material layers while these layers are in contact with one another.

EX85. A method according to example EX84, wherein the crimping step comprises feeding the layer of carbon-based thermally conductive and aerosol-forming material layers through crimping rollers to form a continuous crimped co-laminated sheet.

EX86. A method according to example EX84, wherein the crimped co-laminated sheet has a plurality of spaced-apart ridges or corrugations substantially parallel to the longitudinal axis of the sheet.

EX87. A method according to any one of examples EX75 to EX86, wherein the step of combining the sheets comprises overlaying the sheet of aerosol-forming material on top of the sheet of carbon-based thermally conductive material.

EX88. A method according to any one of examples EX75 to EX87, wherein the step of combining the layers comprises overlaying the sheet of carbon-based thermally conductive material on top of the sheet of aerosol-forming material.

EX89. A method according to any one of examples EX75 to EX88, further comprising the step of forming the layer of aerosol-forming material.

EX90. A method according to example EX89, wherein the step of forming the layer of aerosol-forming material comprises the steps of a paper making process or, preferably, a casting process.

EX91. A method according to example EX90, wherein the step of forming the layer of aerosol-forming material comprises casting a slurry comprising an organic material.

EX92. A method according to example EX91, wherein the step of forming the sheet additionally comprises drying the slurry to form an aerosol-forming material.

EX93. A method according to any one of examples EX91 to EX93, wherein the step of combining the sheets comprises overlaying the sheet of aerosol-forming material on top of the sheet of carbon-based thermally conductive material; and wherein the step or steps of forming the layer of aerosol-forming material are performed prior to the step of combining the layers.

EX94. A method according to any one of examples EX91 to EX93, wherein the step or steps of forming the layer of aerosol-forming material may be performed simultaneously with the step of combining the layers.

EX95. A method according to example EX94, wherein the sheet of aerosol-forming material is formed on top of the sheet of carbon based thermally conductive material.

EX96. A method according to example EX95, wherein the step forming the sheet of aerosol-forming material comprises casting a slurry of aerosol-forming material on to, preferably directly on to, the layer of carbon-based thermally conductive material.

EX97. A method according to example EX96, further comprising the step of drying the slurry on top of the layer of carbon-based thermally conductive material.

EX98. A method according to any one of examples EX75 to EX97, further comprising forming the layer of carbon-based thermally conductive material.

EX99. A method according to example EX98, wherein the step of forming the layer of carbon-based thermally conductive material comprises preparing, forming or manufacturing a reconstituted carbon-based material.

EX100. A method according to example EX99, wherein the step of manufacturing a reconstituted carbon-based material comprises forming a slurry comprising thermally conductive particles.

EX101. A method according to example EX100, wherein the step of manufacturing the reconstituted carbon-based material additionally comprises casting and drying the slurry to form the reconstituted carbon-based material.

EX102. A method according to example EX99 or EX100, wherein slurry the comprises fibres.

EX103. A method according to any one of examples EX99 to EX102, wherein the slurry comprises a binder.

EX104. A method according to any one of examples EX99 to EX103, further wherein forming the slurry comprises forming a first mixture.

EX105. A method according to example EX104, wherein the first mixture comprises fibres.

EX106. A method according to example EX104 or EX105, wherein forming the slurring comprises forming a second mixture.

EX107. A method according to example EX106, wherein the second mixture comprises the thermally conductive particles.

EX108. A method of forming a rod comprising an aerosol-forming substrate, the method comprising the steps of:

providing a co-laminated sheet comprising a layer of aerosol-forming material and a layer of carbon-based thermally conductive material;

gathering the co-laminated sheet transversely relative to its longitudinal axis; and

circumscribing the gathered co-laminated sheet with a wrapper to form a continuous rod.

EX109. A method according to example EX108, the method comprising any of the steps of the method defined in any one of examples EX75 to EX108.

EX110. A method of forming an aerosol-generating article comprising the method steps of example EX108 or EX109.

Specific embodiments will be further described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 shows a schematic cross-sectional view of a first embodiment of an aerosol-generating article;

Figure 2 shows a schematic cross-section of a first apparatus for forming a rod according to a specific embodiment;

Figure 3 shows a schematic cross-section of a first apparatus for forming a rod according to a specific embodiment;

Figure 4 shows a schematic cross-sectional view of a first embodiment of an aerosol-generating system;

Figure 5 shows a schematic cross-sectional view of a second embodiment of an aerosol-generating system; and

Figure 6 shows a schematic cross-sectional view of a second embodiment of an aerosol-generating article.

Figure 1 shows a schematic cross-sectional view of a first embodiment of an aerosol-generating article 10. The aerosol-generating article 10 comprises a rod 12 of aerosol-forming substrate and a downstream section 14 at a location downstream of the rod 12 of aerosol-forming substrate. Further, the aerosol-generating article 10 comprises an upstream section 16 at a location upstream of the rod 12 of aerosol-forming substrate. Thus, the aerosol-generating article 10 extends from an upstream or distal end 18 to a downstream or proximal or mouth end 20.

The aerosol-generating article has an overall length of about 45 millimetres.

The downstream section 14 comprises a support element 22 located immediately downstream of the rod 12 of aerosol- forming substrate, the support element 22 being in longitudinal alignment with the rod 12. In the embodiment of Figure 1, the upstream end of the support element 22 abuts the downstream end of the rod 12 of aerosol-generating substrate. In addition, the downstream section 14 comprises an aerosol-cooling element 24 located immediately downstream of the support element 22, the aerosol-cooling element 24 being in longitudinal alignment with the rod 12 and the support element 22. In the embodiment of Figure 1, the upstream end of the aerosol-cooling element 24 abuts the downstream end of the support element 22.

As will become apparent from the following description, the support element 22 and the aerosol-cooling element 24 together define an intermediate hollow section 50 of the aerosol-generating article 10. As a whole, the intermediate hollow section 50 does not substantially contribute to the overall RTD of the aerosol-generating article. An RTD of the intermediate hollow section 26 as a whole is substantially 0 millimetres H_2O.

The support element 22 comprises a first hollow tubular segment 26. The first hollow tubular segment 26 is provided in the form of a hollow cylindrical tube made of cellulose acetate. The first hollow tubular segment 26 defines an internal cavity 28 that extends all the way from an upstream end 30 of the first hollow tubular segment to a downstream end 32 of the first hollow tubular segment 20. The internal cavity 28 is substantially empty, and so substantially unrestricted airflow is enabled along the internal cavity 28. The first hollow tubular segment 26 – and, as a consequence, the support element 22 – does not substantially contribute to the overall RTD of the aerosol-generating article 10. In more detail, the RTD of the first hollow tubular segment 26 (which is essentially the RTD of the support element 22) is substantially 0 millimetres H_2O.

The first hollow tubular segment 26 has a length of about 8 millimetres, an external diameter of about 7.25 millimetres, and an internal diameter (D_{FTS}) of about 1.9 millimetres. Thus, a thickness of a peripheral wall of the first hollow tubular segment 26 is about 2.67 millimetres.

The aerosol-cooling element 24 comprises a second hollow tubular segment 34. The second hollow tubular segment 34 is provided in the form of a hollow cylindrical tube made of cellulose acetate. The second hollow tubular segment 34 defines an internal cavity 36 that extends all the way from an upstream end 38 of the second hollow tubular segment to a downstream end 40 of the second hollow tubular segment 34. The internal cavity 36 is substantially empty, and so substantially unrestricted airflow is enabled along the internal cavity 36. The second hollow tubular segment 28 – and, as a consequence, the aerosol-cooling element 24 – does not substantially contribute to the overall RTD of the aerosol-generating article 10. In more detail, the RTD of the second hollow tubular segment 34 (which is essentially the RTD of the aerosol-cooling element 24) is substantially 0 millimetres H_2O.

The second hollow tubular segment 34 has a length of about 8 millimetres, an external diameter of about 7.25 millimetres, and an internal diameter (D_{STS}) of about 3.25 millimetres. Thus, a thickness of a peripheral wall of the second hollow tubular segment 34 is about 2 millimetres. Thus, a ratio between the internal diameter (D_{FTS}) of the first hollow tubular segment 26 and the internal diameter (D_{STS}) of the second hollow tubular segment 34 is about 0.75.

The aerosol-generating article 10 comprises a ventilation zone 60 provided at a location along the second hollow tubular segment 34. In more detail, the ventilation zone is provided at about 2 millimetres from the upstream end of the second hollow tubular segment 34. In this embodiment, the ventilation zone 60 comprises a circumferential row of perforations through a paper wrapper 70 and a ventilation level of the aerosol-generating article 10 is about 25 percent.

In the embodiment of Figure 1, the downstream section 14 further comprises a mouthpiece element 42 at a location downstream of the intermediate hollow section 50. In more detail, the mouthpiece element 42 is positioned immediately downstream of the aerosol-cooling element 24. As shown in the drawing of Figure 1, an upstream end of the mouthpiece element 42 abuts the downstream end 40 of the aerosol-cooling element 24.

The mouthpiece element 42 is provided in the form of a cylindrical plug of low-density cellulose acetate.

The mouthpiece element 42 has a length of about 12 millimetres and an external diameter of about 7.25 millimetres. The RTD of the mouthpiece element 42 is about 12 millimetres H_2O. The ratio of the length of the mouthpiece element 42 to the length of the intermediate hollow section 50 is approximately 0.6.

The rod 12 of aerosol-forming substrate has an external diameter of about 7.25 millimetres and a length of about 12 millimetres.

The upstream section 16 comprises an upstream element 46 located immediately upstream of the rod 12 of aerosol-forming substrate, the upstream element 46 being in longitudinal alignment with the rod 12. In the embodiment of Figure 1, the downstream end of the upstream element 46 abuts the upstream end of the rod 12 of aerosol-forming substrate. The upstream element 46 is provided in the form of a cylindrical plug of cellulose acetate. The upstream element 46 has a length of about 5 millimetres. The RTD of the upstream element 46 is about 30 millimetres H_2O.

The upstream element 46, rod 12 of aerosol-forming substrate, support element 22, aerosol-cooling element 24, and mouthpiece element 42 are circumscribed by the paper wrapper 70.

The rod 12 of aerosol-forming substrate comprises a gathered co-laminated sheet comprising a layer of aerosol-forming material 13 and a layer of carbon-based thermally conductive material 15. The layer of aerosol-forming material 13 is in intimate contact with the layer of carbon-based thermally conductive material with one layer being stacked on top of the other layer. As will be described below, the sheet is gathered so as to form a plurality of substantially parallel ridges or corrugations. As such, the cross-section of the sheet shown in Figure 1 appears to have a plurality of layers of aerosol-forming material 13 sandwiched between layers of carbon-based thermally conductive material 15 resulting from the corrugated co-laminated structure of the rod of aerosol-forming substrate 12.

The aerosol-forming material 13 comprises a reconstituted sheet comprising tobacco material and glycerine.

The layer of carbon-based thermally conductive material 15 is a foil made of graphite, expanded graphite or both graphite and expanded graphite.

The cardboard tube 34 has a length of 16 mm and provides a free space within the article 10 within which volatile components generated by heating of the aerosol-forming substrate can cool and form an aerosol.

The mouthpiece element 42 is provided in the form of a cylindrical plug of low-density cellulose acetate. The mouthpiece element 42 has a length of about 12 millimetres and an external diameter of about 7.2 mm. The RTD of the mouthpiece element 42 is about 12 millimetres $H2O$.

It should be clear that the configuration of the aerosol-generating article 10 of figure 1 is intended to serve as an example only. The thermally enhanced aerosol-forming substrate could, for example, be employed in an aerosol generating article that is longer, for example 80 mm long, and thinner, for example 4.5 mm in diameter.

Figure 2 shows an apparatus for forming the rod 12 of aerosol-forming substrate. The apparatus generally comprises: supply means for providing a continuous co-laminated sheet of homogenised tobacco and aluminium foil; crimping means for crimping the continuous co-laminated sheet; rod forming means for gathering the continuous crimped co-laminated sheet and circumscribing the gathered material with a wrapper to form a continuous rod; and cutting means for severing the continuous rod into a plurality of discrete rods. The apparatus also comprises transport means for transporting the continuous co-laminated sheet of material downstream through the apparatus from the supply means to the rod forming means via the crimping means.

As shown in Figure 2, the supply means for providing a continuous co-laminated sheet comprises a continuous co-laminated sheet comprising a layer of aerosol-forming material and a layer of thermally conductive material, the continuous co-laminated sheet being mounted on a bobbin 4. The crimping means comprises a pair of rotatable crimping rollers 6. In use, the continuous co-laminated sheet 2 is drawn from the first bobbin 4 and transported downstream to the pair of crimping rollers 6 by the transport means via a series of guide and tensioning rollers. As the continuous co-laminated sheet 2 is fed between the pair of crimping rollers 6, the crimping rollers engage and crimp the sheet 2 to form a continuous crimped co-laminated sheet 8 having a plurality of spaced-apart ridges or corrugations substantially parallel to the longitudinal axis of the sheet through the apparatus.

The continuous crimped sheet 8 is transported downstream from the pair of crimping rollers 6 towards the rod forming means and fed through a converging funnel or horn 31. The converging funnel 31 gathers the continuous co-laminated sheet 8 transversely relative to its longitudinal axes. The sheet of material 8 assumes a substantially cylindrical configuration as it passes through the converging funnel 31.

Upon exiting the converging funnel 31, the gathered co-laminated sheet is wrapped in a continuous sheet of wrapping material 37. The continuous sheet of wrapping material is fed from a bobbin 35 and enveloped around the gathered continuous crimped sheet of homogenised tobacco material by an endless belt conveyor or garniture. As shown in Figure 1, the rod forming means comprises an adhesive application means 17 that applies adhesive to one of the longitudinal edges of the continuous sheet of wrapping material, so that when the opposed longitudinal edges of the continuous sheet of wrapping material are brought into contact they adhere to one other to form a continuous rod.

The rod forming means further comprises a drying means 19 downstream of the adhesive application means 17, which in use dries the adhesive applied to the seam of the continuous rod as the continuous rod is transported downstream from the rod forming means to the cutting means.

The cutting means comprises a rotary cutter 21 that severs the continuous rod into a plurality of discrete rods of unit rod length or multiple unit rod length.

Figure 3 shows an alternative apparatus for forming the rod 12 of aerosol-forming substrate. The apparatus of Figure 3 is similar to the apparatus of Figure 2 and like features are numbered accordingly. The difference between the apparatus of Figure 2 and Figure 3 is that the apparatus of Figure 3 comprises separate bobbins for a continuous sheet of aerosol-forming material and a continuous sheet of thermally conductive material rather than a single bobbin 43 comprising a co-laminated sheet of aerosol-forming substrate.

In the apparatus of Figure 3, a continuous sheet of aerosol-forming material is mounted on a primary bobbin 23 and a continuous sheet of carbon-based thermally conductive material is mounted on a secondary bobbin 33. In use, the continuous sheet of aerosol-forming material is drawn from the primary bobbin 23 and transported downstream to the pair of crimping rollers 6 by the transport mechanism via a series of guide and tensioning rollers. The continuous sheet carbon-based thermally conductive material is similarly drawn from the secondary bobbin 33 and transported downstream to the pair of crimping rollers 6 by the transport mechanism. Prior to passing through the crimping rollers 6, the continuous sheet of carbon-based thermally conductive material is brought into intimate contact with the aerosol-forming material such that the carbon-based thermally conductive material overlies the aerosol-forming material. This forms a continuous co-laminated sheet comprising a layer of carbon-based thermally conductive material and a layer of aerosol-forming material which passes through the crimping rollers 6. The continuous co-laminated sheet then proceeds through the apparatus of Figure 3 in the same way as described in relation to Figure 2.

In other embodiments, the bobbin of aerosol-forming material may be swapped with the bobbin of carbon-based thermally conductive material such that the aerosol-forming material overlies the carbon-based thermally conductive material prior to passing through the crimping rollers.

In one embodiment, the aerosol-forming material described above is formed by a casting process comprising the following steps:

- pre-mixing finely shredded tobacco material, a binder, guar gum, with an aerosol-former, glycerine, to form a pre-mixture;
- mixing the pre-mixture with water to form a slurry;
- homogenising the slurry using a high-shear mixer;
- casting the slurry onto a conveyor belt; and
- controlling a thickness of the slurry and drying the slurry to form a large sheet of aerosol-forming material.

The above process may be used to produce a continuous sheet of aerosol-forming material for the bobbin 23 of the apparatus of Figure 3.

In another embodiment, the aerosol-forming material described above is formed by a casting process comprising the following steps:

- pre-mixing finely shredded tobacco material, a binder, guar gum, with an aerosol-former, glycerine, to form a pre-mixture;
- mixing the pre-mixture with water to form a slurry;
- homogenising the slurry using a high-shear mixer;
- casting the slurry onto a continuous sheet of carbon-based thermally conductive material; and
- controlling a thickness of the slurry and drying the slurry to form a large sheet of aerosol-forming material.

The above process may be used to produce a continuous co-laminated sheet comprising a layer of aerosol-forming material. The above process may be used to produce a continuous sheet of aerosol-forming material for the bobbin 4 of the apparatus of Figure 2.

In one embodiment, the carbon-based thermally conductive material is a commercially available foil or film.

Suitable carbon-based thermally conductive materials are available from NeoGraf solutions LLC, 11709 Madison Avenue, Lakewood, Ohio, United States 44107. In particular, the range of eGraf SpreaderShield (registered trademark) Heat Spreaders are suitable carbon-based thermally conductive materials. NeoGraf solutions provide low density Heat Spreaders in the form of a film or foil and having an in-plane conductivity of between 300 and 1600 W/(mK), a thickness as low as 17 micrometres and a tensile strength of greater than 7 Megapascals.

Another example of suitable carbon-based thermally conductive materials are the range of EYGS182307 PGS graphite sheets of Panasonic Industry available from RS Components (https://uk.rs-online.com/web/).

In another embodiment, the carbon-based thermally conductive material is a reconstituted carbon-based material.

In one embodiment, the method comprises forming the reconstituted carbon-based material. A slurry is formed using a lab disperser capable of mixing viscous liquids, dispersing powders through liquids, and removing gas from a mixture (for example by applying a vacuum or other suitably low pressure). In this embodiment, a commercially available lab disperser from PC Laborsystem was used.

To form the slurry, a first mixture is formed by adding to the lap disperser around 7.11 grams of the aerosol former, then around 157.5 grams of water, then around 1.57 grams of the fibres. Then, these first ingredients are mixed at 25 degrees Celsius for 5 minutes at 600-700 rpm to ensure a homogeneous mixture and to hydrate the fibers. Then, a second mixture is formed by manually mixing around 32.95 grams of the thermally conductive particles and around 0.92 grams of the binder. This mixing of the second mixture avoids the formation of lumps in the lab dispersion. Then, the second mixture is added to the first mixture to form a combined mixture. Then, the combined mixture is mixed at 5000 rpm for 4 minutes at 25 degrees Celsius and a first reduced pressure of around 200 mbar. The reduced pressure may help to ensure that the thermally conductive particles are homogeneously dispersed in the mixture and that there is little trapped air and few lumps in the combined mixture. Then, the combined mixture is mixed at 5000 rpm for 20 second minutes at 25 degrees Celsius and a second reduced pressure of around 100 mbar. This second reduced pressure may help to remove any remaining air bubbles. This forms a slurry for casting.

The slurry is then casted and dried using a suitable apparatus. In this embodiment, a commercially available Labcoater Mathis apparatus is used. This apparatus includes a stainless steel, flat support, and a coma blade for adjusting a thickness of slurry cast onto the flat support.

The slurry is cast onto the flat support and a gap between the coma blade and the flat support is set at 0.6 millimetres. This ensures that a thickness of the slurry is no more than 0.6 millimetres at any given point.

The slurry is then dried with hot air between 120 and 140 degrees Celsius for between 2 and 5 minutes. After this drying, a sheet of the aerosol-forming substrate is formed. This sheet has a thickness of around 159 microns, a grammage of around 125.7 grams per metre squared, and a density of around 0.79 kilograms per metre cubed.

Figure 4 shows a schematic cross-sectional view of a first embodiment of an aerosol-generating system 100. The system 100 comprises an aerosol-generating device 102 and the aerosol-generating article 10 of Figure 1.

The aerosol-generating device 102 comprises a battery 104, a controller 106, a heating blade 108 coupled to the battery, and a puff-detection mechanism (not shown). The controller 106 is coupled to the battery 104, the heating blade 108 and the puff-detection mechanism.

The aerosol-generating device 102 further comprises a housing 110 defining a substantially cylindrical cavity for receiving a portion of the article 10. The heating blade 108 is positioned centrally within the cavity and extends longitudinally from a base of the cavity.

In this embodiment, the heating blade 108 comprises a substrate and an electrically resistive track located on the substrate. The battery 104 is coupled to the heating blade 108 so as to be able to pass a current through the electrically resistive track and heat the electrically resistive track and heating blade 108 to an operational temperature.

In use, a user inserts the article 10 into the cavity, causing the heating blade 108 to penetrate the upstream element 46 and rod 12 of aerosol-forming substrate of the article 10. Figure 4 shows the article 10 inserted into the cavity of the device 102.

Then, the user puffs on the downstream end of the article 10. This causes air to flow through an air inlet (not shown) of the device 102, then through the article 10, from the upstream end 18 to the downstream end 20, and into the mouth of the user.

The user puffing on the article 10 causes air to flow through the air inlet of the device. The puff-detection mechanism detects that the air flow rate through the air inlet has increased to greater than a non-zero threshold flow rate. The puff-detection mechanism sends a signal to the controller 106 accordingly. The controller 106 then controls the battery 104 so as to pass a current through the electrically resistive track and heat up the heating blade 108. This heats up the rod 12 of aerosol-forming substrate, which is in contact with the heating blade 108.

The layer of thermally conductive material has a significantly higher thermal conductivity than the surrounding aerosol-forming material. As such, the layer of thermally conductive material may conduct heat energy throughout the bulk of the aerosol-forming material. This may result in a greater proportion of the aerosol-forming substrate reaching a sufficiently high temperature to release volatile compounds, and thus a higher usage efficiency of the aerosol-forming substrate.

Heating of the aerosol-forming substrate causes the aerosol-forming substrate to release volatile compounds. These compounds are entrained by the air flowing from the upstream end 18 of the article 10 towards the downstream end 20 of the article 10. The compounds cool and condense to form an aerosol as they pass through the internal cavities 28, 36 of the support element 22 and the aerosol-cooling element 24. The aerosol then passes through the mouthpiece element 42, which may filter out unwanted particles entrained in the air flow, and into the mouth of the user.

When the user stops inhaling on the article 10, the air flow rate through the air inlet of the device decreases to less than the non-zero threshold flow rate. This is detected by the puff-detection mechanism. The puff-detection mechanism sends a signal to the controller 106 accordingly. The controller 106 then controls the battery 104 so as to reduce the current being passed through the electrically resistive track to zero.

After a number of puffs on the article 10, the user may choose to replace the article 10 with a fresh article.

Figure 5 shows a schematic cross-sectional view of a second embodiment of an aerosol-generating system 200. The system 200 comprises an aerosol-generating device 202 and the aerosol-generating article 11 of Figure 1.

The aerosol-generating device 202 comprises a battery 204, a controller 206, an inductor coil 208, and a puff-detection mechanism (not shown). The controller 206 is coupled to the battery 204, the inductor coil 208 and the puff-detection mechanism.

The aerosol-generating device 202 further comprises a housing 210 defining a substantially cylindrical cavity for receiving a portion of the article 11. The inductor coil 208 spirals around the cavity.

The battery 204 is coupled to the inductor coil 208 so as to be able to pass an alternating current through the inductor coil 208.

In use, a user inserts the article 11 into the cavity. Figure 5 shows the article 11 inserted into the cavity of the device 202.

Then, the user puffs on the downstream end of the article 11. This causes air to flow through an air inlet (not shown) of the device 202, then through the article 11, from the upstream end 18 to the downstream end 20, and into the mouth of the user.

The user puffing on the article 11 causes air to flow through the air inlet of the device. The puff-detection mechanism detects that the air flow rate through the air inlet has increased to greater than a non-zero threshold flow rate. The puff-detection mechanism sends a signal to the controller 206 accordingly. The controller 206 then controls the battery 204 so as to pass an alternating current through the inductor coil 208. This causes the inductor coil 208 to generate a fluctuating electromagnetic field. The rod 13 of combined aerosol-forming substrate is located within this fluctuating electromagnetic field. The materials of the thermally conductive material 15, graphite and expanded graphite, are susceptor materials. Thus, the fluctuating electromagnetic field causes eddy currents in the thermally conductive material 15 (which is also electrically conductive). This causes the thermally conductive material 15 to heat up, thereby also heating nearby aerosol-forming material.

Heating of the aerosol-forming material cause the aerosol-forming material to release volatile compounds. These compounds are entrained by the air flowing from the upstream end 18 of the article 11 towards the downstream end 20 of the article 11. The compounds cool and condense to form an aerosol as they pass through the internal cavities 28, 36 of the support element and the aerosol-cooling element. The aerosol then passes through the mouthpiece element 42, which may filter out unwanted particles entrained in the air flow, and into the mouth of the user.

When the user stops inhaling on the article 11, the air flow rate through the air inlet of the device decreases to less than the non-zero threshold flow rate. This is detected by the puff-detection mechanism. The puff-detection mechanism sends a signal to the controller 206 accordingly. The controller 206 then controls the battery 204 so as to reduce the current being passed through the electrically resistive track to zero.

After a number of puffs on the article 11, the user may choose to replace the article 11 with a fresh article.

Figure 6 shows a schematic cross-sectional view of a second embodiment of an aerosol-generating article 510. This second embodiment is identical to the first embodiment of Figure 1 except that the rod 12 of aerosol-forming substrate has been replaced by an alternative rod 512 of aerosol-forming substrate. Identical reference numerals have been used for identical components in the embodiments of Figures 1 and 6.

The rod 512 of aerosol-forming substrate of the second embodiment of Figure 6 is identical to the rod 12 of aerosol-forming substrate of the first embodiment of Figure 1 except that the rod 512 of aerosol-forming substrate of the second embodiment of Figure 6 additionally includes an elongate susceptor element 580.

The susceptor element 580 is arranged substantially longitudinally within the rod 512 of aerosol-forming substrate so as to be approximately parallel with a longitudinal axis of the rod 512 of aerosol-forming substrate. As shown in the drawing of Figure 6, the susceptor element 580 is positioned in a radially central position within the rod and extends along the longitudinal axis of the rod 12.

The susceptor element 580 extends all the way from an upstream end to a downstream end of the rod 512 of aerosol-forming substrate. As such, the susceptor element 580 has substantially the same length as the rod 512 of aerosol-forming substrate.

In the embodiment of Figure 6, the susceptor element 580 is provided in the form of a strip of a ferromagnetic steel and has a length of about 12 millimetres, a thickness of about 60 micrometres, and a width of about 4 millimetres.

The aerosol-generating article 510 of Figure 6 may be used with the aerosol-generating device 202 of Figure 4 in the same way as the aerosol-generating article 11 of Figure 2. Notably, the inclusion of the susceptor element 580 means that the article 510 may be inductively heated regardless of whether the thermally conductive material comprise a suitable susceptor material for inductive heating.

For the purpose of the present description and of the appended claims, except where otherwise indicated, all numbers expressing amounts, quantities, percentages, and so forth, are to be understood as being modified in all instances by the term "about". Also, all ranges include the maximum and minimum points disclosed and include any intermediate ranges therein, which may or may not be specifically enumerated herein. In this context, therefore, a number A is understood as A ± 10% of A. Within this context, a number A may be considered to include numerical values that are within general standard error for the measurement of the property that the number A modifies. The number A, in some instances as used in the appended claims, may deviate by the percentages enumerated above provided that the amount by which A deviates does not materially affect the basic and novel characteristic(s) of the claimed invention. Also, all ranges include the maximum and minimum points disclosed and include any intermediate ranges therein, which may or may not be specifically enumerated herein.

Claims

1. An aerosol-forming substrate for use in a heated aerosol-generating article, the aerosol-forming substrate comprising a co-laminated sheet comprising a layer of aerosol-forming material and a layer of carbon-based thermally conductive material.

2. An aerosol-forming substrate according to claim 1, wherein the layer of carbon-based thermally conductive material is in the form of a film or foil.

3. An aerosol-forming substrate according to claim 1 or 2, wherein the layer of carbon-based thermally conductive material comprises or consists of carbon fibres, graphite or graphene.

4. An aerosol-forming substate according to any one of the preceding claims, wherein the layer of thermally conductive material comprises a material having a thermal conductivity of greater than 1 W/mK.

5. An aerosol-forming substrate according to any one of the preceding claims, wherein the co-laminated sheet comprises or is in the form of a gathered sheet.

6. An aerosol-forming substrate according to any one of the preceding claims, wherein the layer of thermally conductive material comprises a reconstituted carbon-based material comprising thermally conductive particles..

7. An aerosol-forming substrate according to any one of the preceding claims, wherein the layer of thermally conductive material has a tensile strength greater than 1 Megapascal (MPa).

8. A rod for an aerosol-generating article, the rod comprising an aerosol-forming substrate as defined in any one of claims 1 to 7.

9. A heated aerosol-generating article comprising a rod according to claim 8.

10. An aerosol-generating system comprising an aerosol-generating article according claim 9 and an electrically operated aerosol-generating device.

11. A method of forming an aerosol-forming substrate comprising:
combining a layer of aerosol-forming material with a layer of carbon-based thermally conductive material to form a co-laminated sheet.

12. A method of forming an aerosol-forming substrate according to claim 11, wherein the method further comprises the step of forming the sheet of aerosol-forming material.

13. A method of forming an aerosol-forming substrate according to claim 12, wherein the step of combining the sheets comprises casting the sheet of aerosol-forming material on top of the sheet of carbon-based thermally conductive material.

14. A method of forming a rod comprising an aerosol-forming substrate; the method comprising the steps of:

providing a co-laminated sheet comprising an aerosol-forming material and a carbon-based thermally conductive material;

gathering the co-laminated sheet transversely relative to its longitudinal axis;

circumscribing the gathered co-laminated sheet with a wrapper to form a continuous rod; and

severing the continuous rod into a plurality of discrete rods.

15. A method of forming an aerosol-generating article comprising assembling the aerosol-generating article from a plurality of components, the plurality of components including an aerosol-forming substrate according to any one of claims 1 to 7.

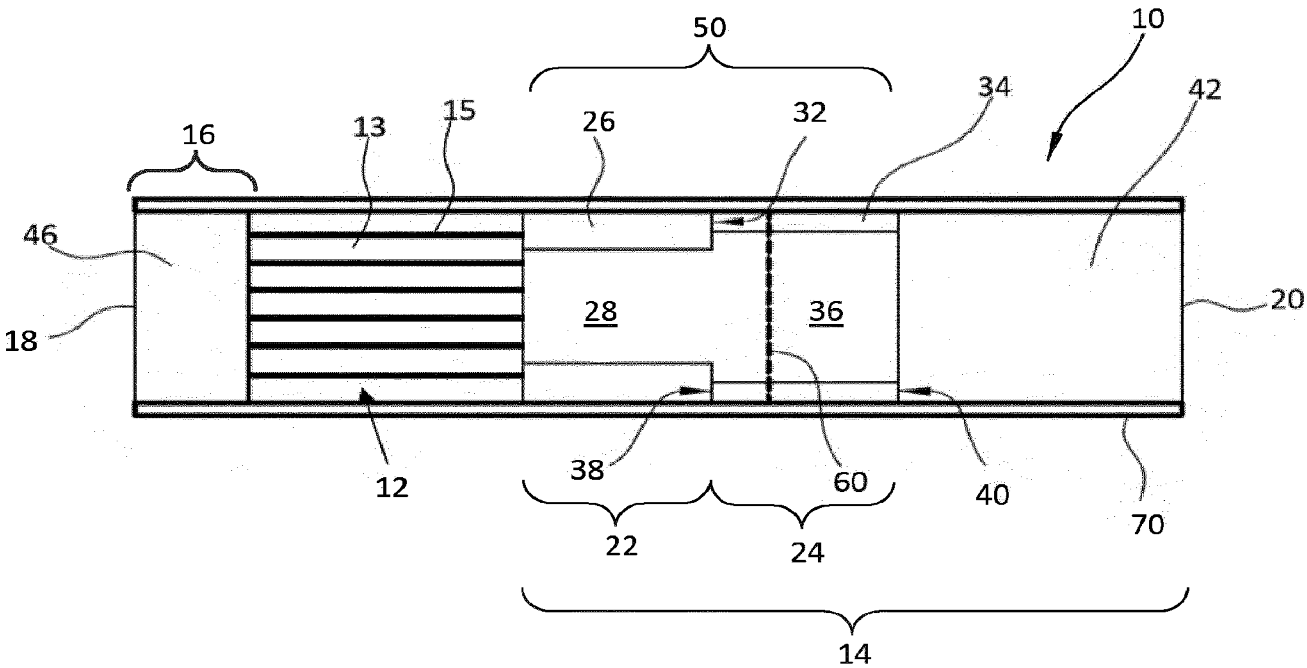

Figure 1

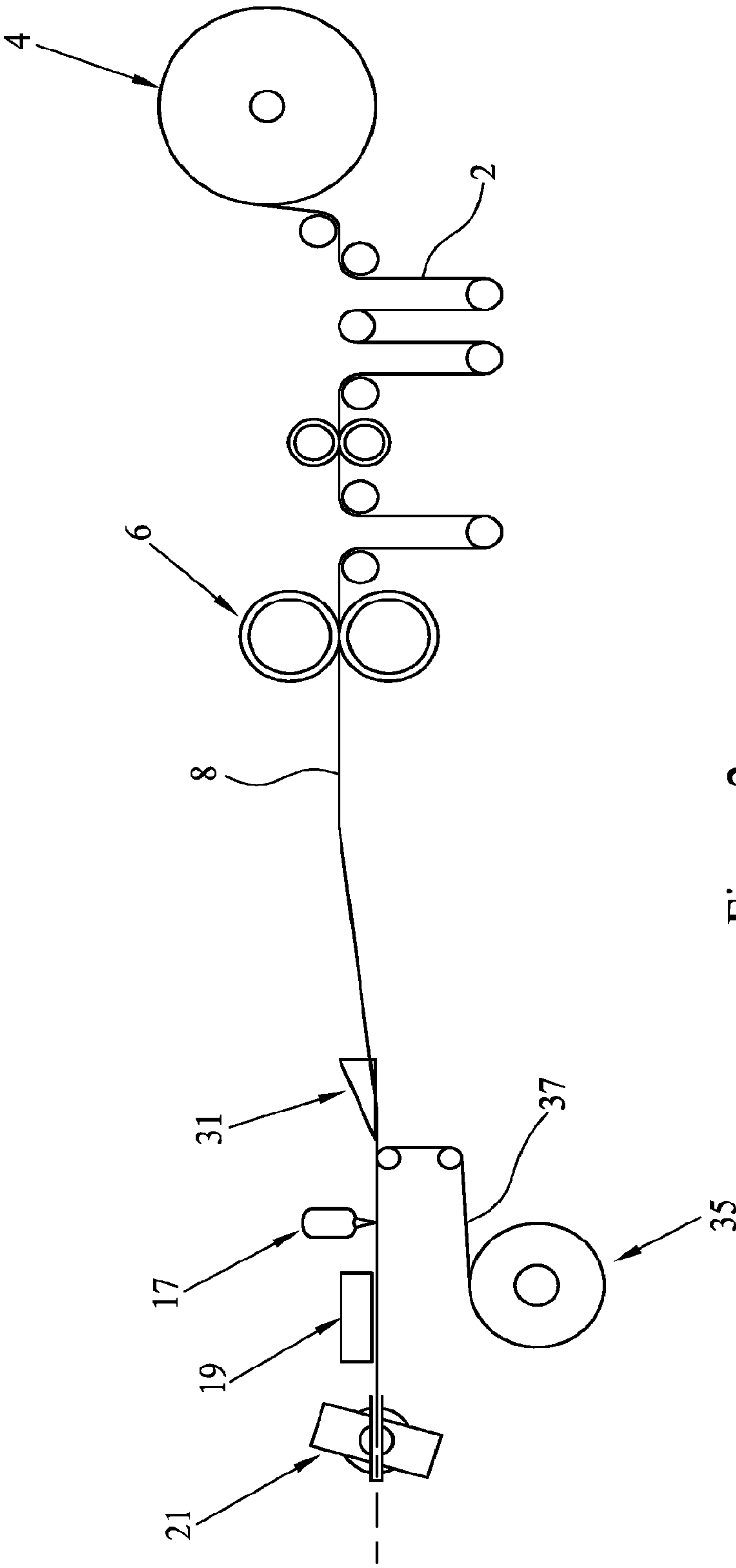

Figure 2

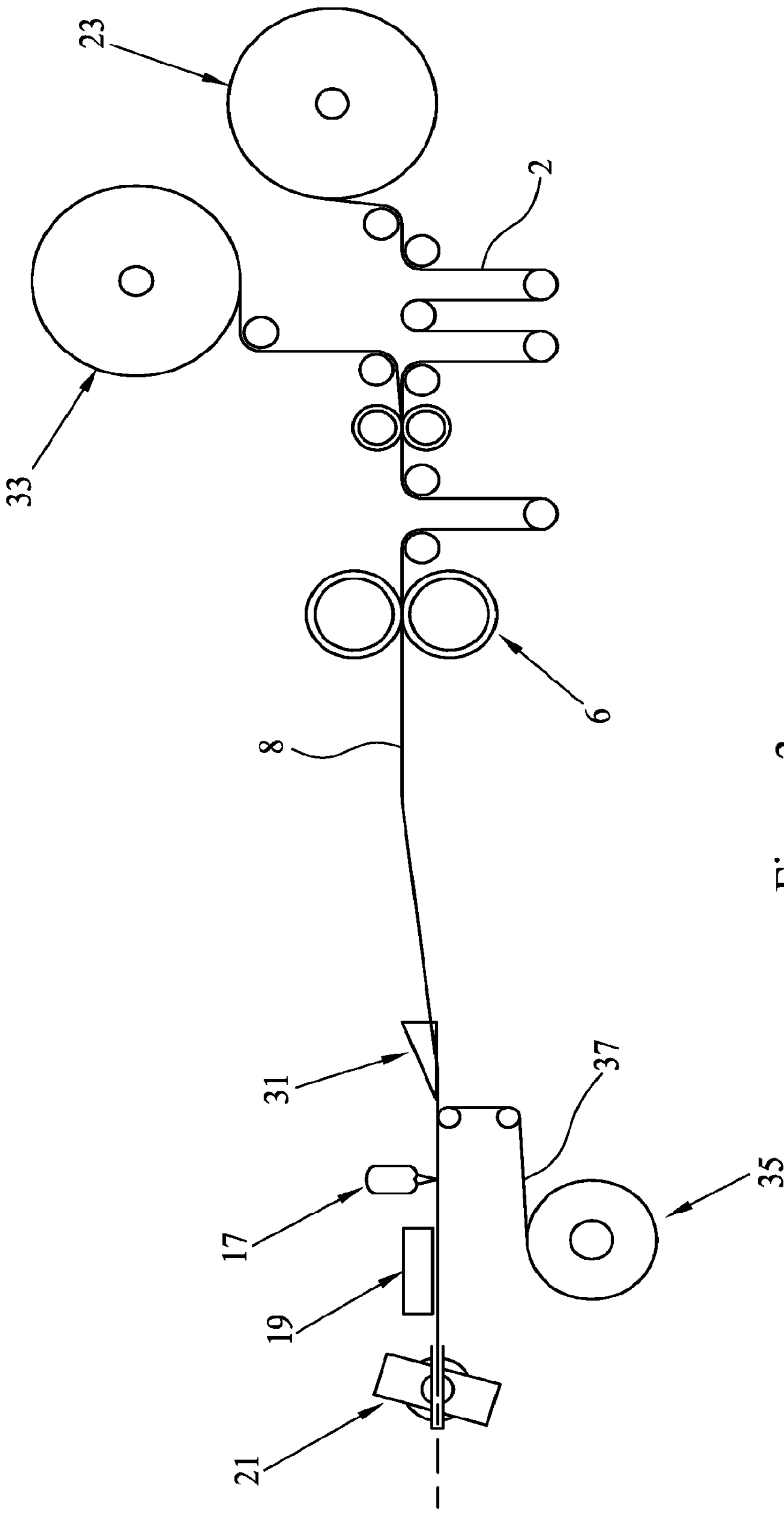

Figure 3

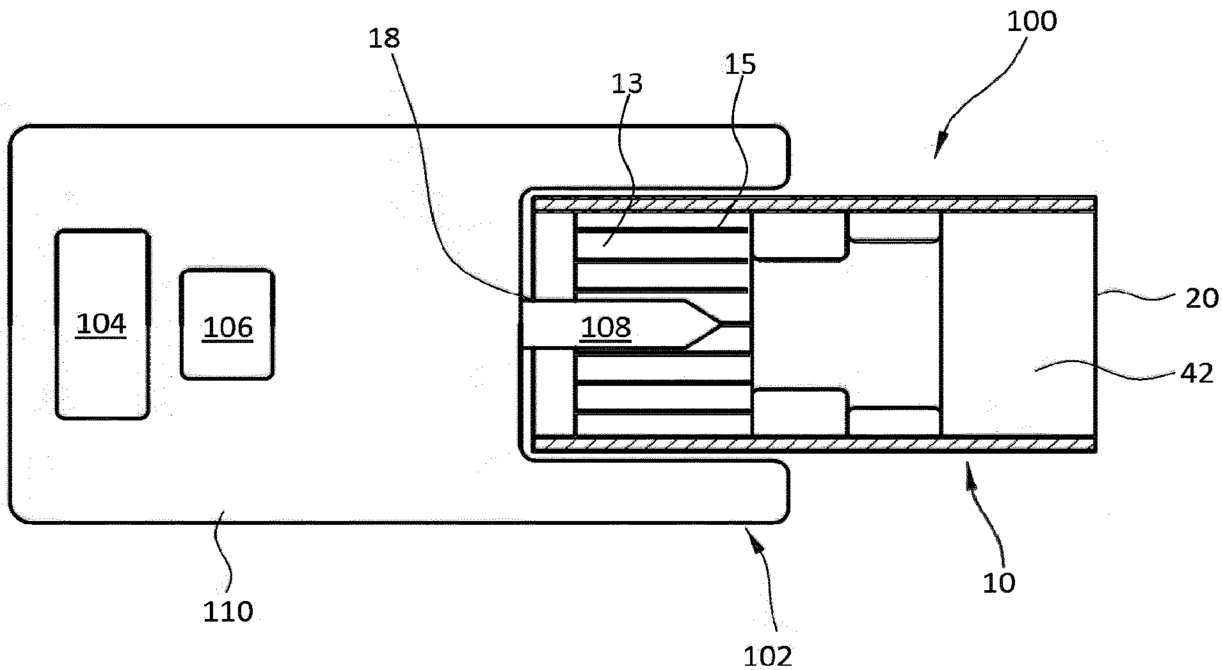

Figure 4

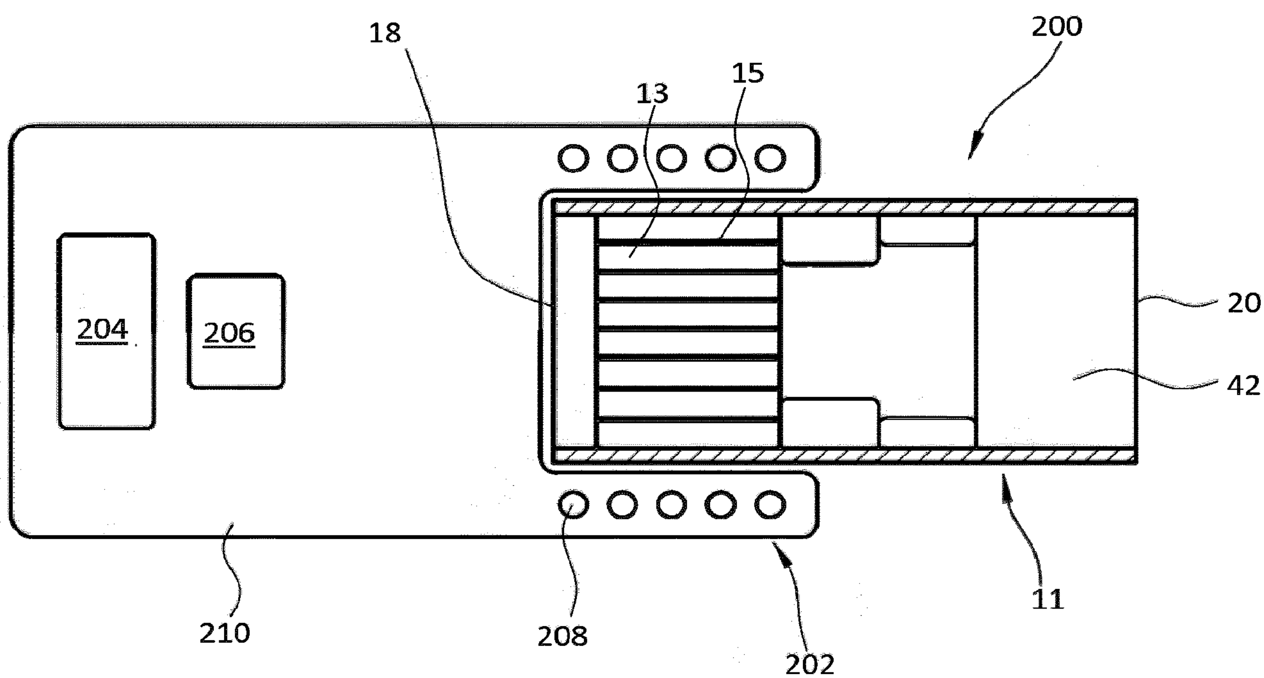

Figure 5

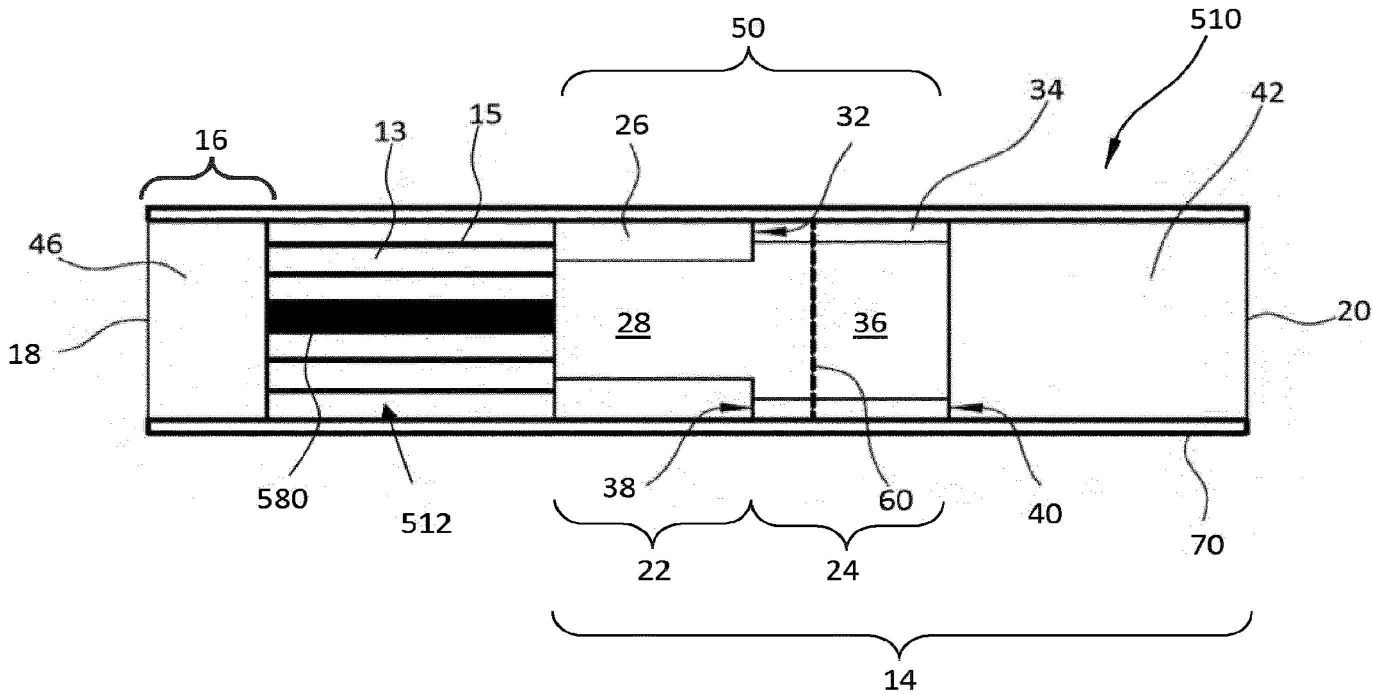

Figure 6

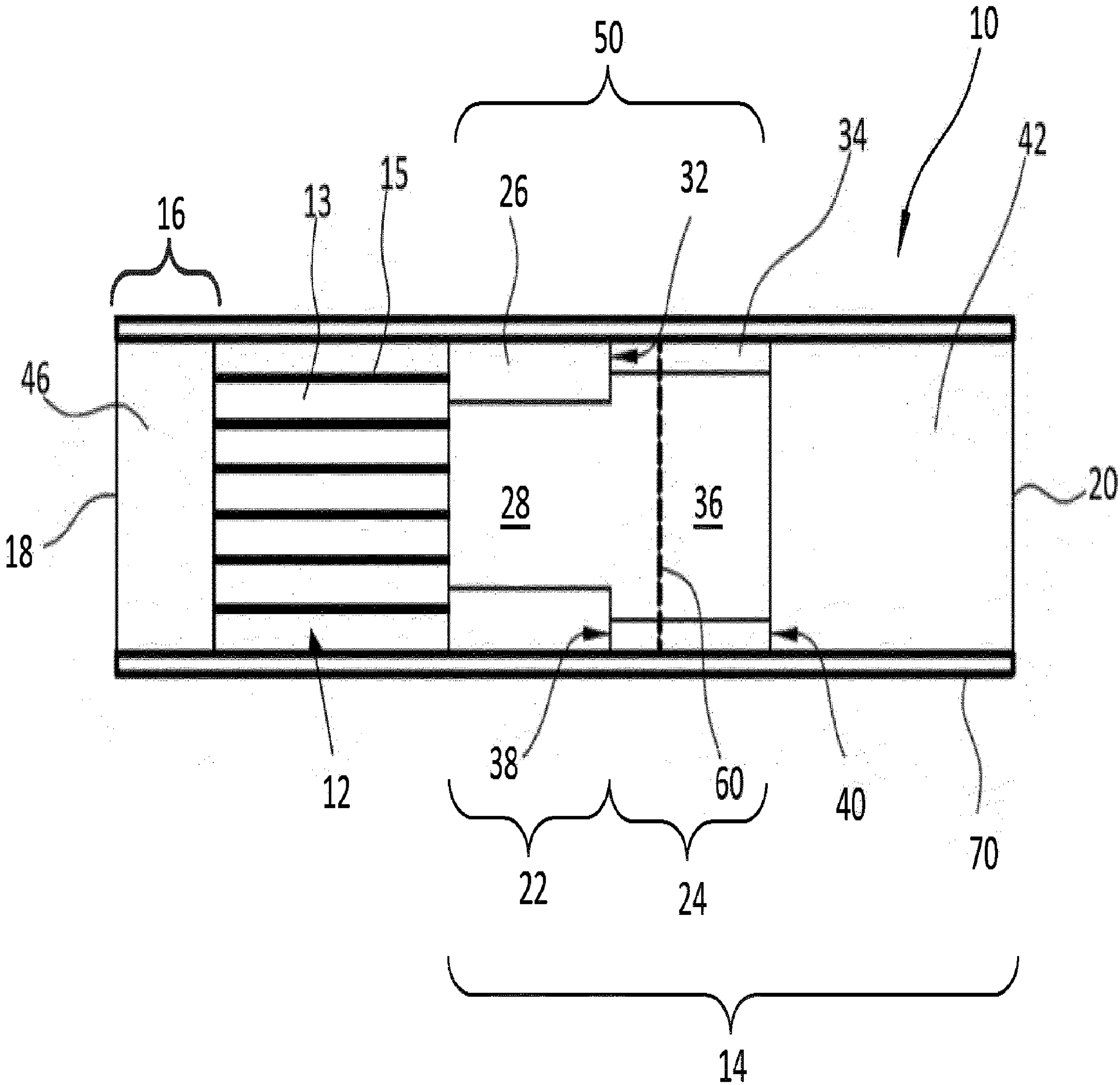

Figure 1