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(54) **HEATING ASSEMBLIES FOR AEROSOL GENERATING SYSTEMS**

(57) A cartridge for an aerosol generating system, the cartridge being disposable and configured to connect to a base part comprising a heating element, the cartridge comprising: a liquid storage reservoir (24) configured for containing therein a liquid aerosol-forming substrate (20), and a thermal interface membrane comprising a heating surface (12), said thermal interface membrane

being configured to transfer heat from the heating element in the base part to said aerosol-forming substrate in the cartridge to generate an aerosol that may be inhaled by a user, wherein the heating surface is embossed to comprise a plurality of nucleation-enhancing micro- and/or nanostructures.

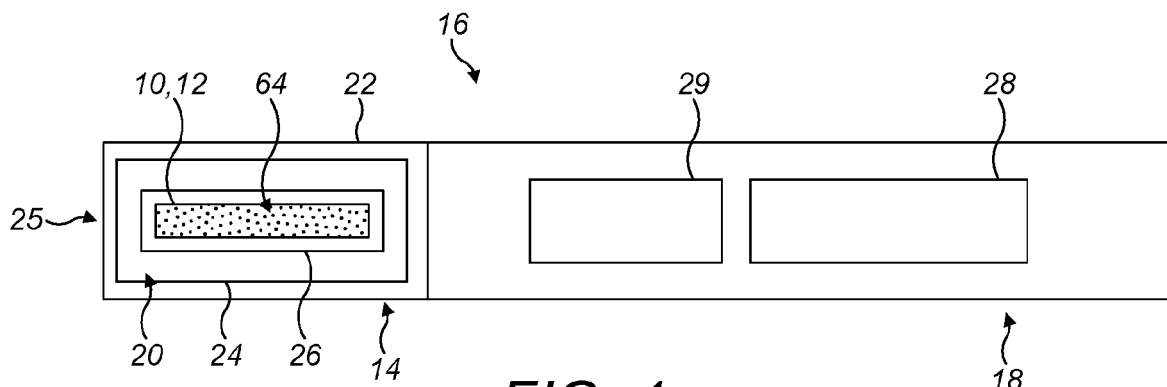


FIG. 1

Description

Technical Field

[0001] The present invention relates generally to a heating assembly for an aerosol generating system and particularly, but not exclusively, to a heating assembly for use in an aerosol generating system operable to generate an aerosol from a liquid aerosol generating substrate.

Technical Background

[0002] Electronic nicotine delivery systems, examples of which comprise electronic cigarettes and heat-not-burn aerosol-generating systems, are an alternative to conventional cigarettes. Instead of generating a combustion smoke, they comprise a heating assembly configured to heat an aerosol-forming substrate to generate an aerosol that may be inhaled by a user. The aerosol-forming substrate may comprise a liquid comprising an aerosol-forming substance, such as glycerine or propylene glycol, that creates the vapour when heated. Other common substances in the liquid are nicotine and various flavourings. In alternative arrangements, the aerosol forming substrate may be a tobacco-based substrate, which may be shaped, contained or wrapped in the form of a stick or a pod.

[0003] An electronic cigarette is a hand-held inhaler system, typically comprising a mouthpiece section, a liquid store and a power supply unit. Vaporization is achieved in a vaporization zone by a heating assembly which typically comprises a heating element and a fluid transfer element such as a wick. Vaporization occurs when the heating element heats the liquid in the wick until the liquid is transformed into vapour.

[0004] Various devices and systems are available which can use one of a number of different approaches to provide heat to the liquid aerosol generating substrate. One such approach is to provide an induction heating assembly. Such assemblies employ an electromagnetic field generator, such as an induction coil, to generate an alternating electromagnetic field that couples with, and inductively heats, a heating element in the form of a susceptor. Heat from the susceptor is transferred, for example by conduction, to the liquid aerosol generating substrate held in the wick, and an aerosol is generated as the substrate is heated for inhalation by a user of the device. A susceptor may be included within an aerosol generation device, for example as a wall of a heating chamber within the device. Alternatively, or additionally, a susceptor may be included in a consumable for use in an aerosol generation device.

[0005] Another approach for providing heat to an aerosol generating substrate is using a resistive heating assembly. In one example system, an electronic cigarette may comprise a disposable cartridge and a reusable base part. The cartridge has a simplified structure which

is achieved by keeping the main heating element in the re-usable base part, while the cartridge is provided with a heat transfer component. The heat transfer component typically comprises a thermal interface membrane (e.g. a thin thermally conductive sheet element) that is configured to transfer heat from the heating element to liquid in the cartridge at the thermal interface membrane to produce a vapour for inhalation by a user.

[0006] In both of the above-described systems, efficient heat transfer through a heating surface, such as a surface of a susceptor or of a heat transfer component, to the aerosol generating substrate is important in order to ensure efficient heating of the aerosol generating substrate.

[0007] The efficiency of heat transfer between a solid surface and a liquid may be determined by considering the heat transfer coefficient, critical heat flux, and/or superheat temperature of a given system. The heat transfer co-efficient HTC is a quantitative characteristic of heat transfer between a fluid and a surface, and is defined as:

$$HTC = \frac{q}{T_w - T_{fluid}}$$

where q is the heat flux through the heated surface, T_w is the temperature of the heated surface, and T_{fluid} is the local or bulk temperature of the fluid. Heat flux varies with temperature, and tends to increase up to a critical heat flux CHF. The CHF represents the maximum useful heat flux, as above this temperature boiling becomes unstable and difficult to control. The superheat temperature is defined as $\Delta T = T_w - T_{sat}$, where T_{sat} is the saturation temperature (i.e. the temperature at which, for a corresponding saturation pressure, a liquid boils). Typically, improved efficiency of heat transfer may be characterised by an increase the heat transfer coefficient (HTC) and/or critical heat flux, while usually minimizing the superheat temperature.

[0008] It is an object of the invention to improve thermal efficiency within an aerosol generating system.

Summary

[0009] According to a first aspect of the invention, we provide a cartridge for an aerosol generating system, the cartridge being disposable and configured to connect to a base part comprising a heating element, the cartridge comprising:

a liquid storage reservoir configured for containing therein a liquid aerosol-forming substrate, and a thermal interface membrane comprising a heating surface, said thermal interface membrane being configured to transfer heat from the heating element in the base part to said aerosol-forming substrate in the cartridge to generate an aerosol that may be inhaled by a user,

wherein the heating surface is embossed to comprise a plurality of nucleation-enhancing micro- and/or nanostructures.

[0010] Many factors affect the heat transfer coefficient (HTC) between a heating surface and a heated liquid in the boiling evaporation regime, including material properties, surface properties and heat flux through the interface. We have noted that increasing the amount of nucleation points on a heating surface can improve the heating performance in terms of the HTC, by increasing sites for vapour bubbles to form on the surface, which in turn can promote bubble detachment from the surface and increase the amount of heat flux through the interface. Such nucleation points may be formed on the surface by said plurality of nucleation-enhancing micro- and/or nanostructures.

[0011] Improving the HTC of a system improves heating efficiency within the system. This may allow a lower heater surface temperature to achieve a boiling efficiency which is comparable to a conventional heater surface (i.e. absent said nucleation-enhancing micro- and/or nanostructures) at a higher temperature, and/or may allow a given heater surface temperature to achieve a greater amount of vapour in the case of a heater surface including said nucleation-enhancing micro- and/or nanostructures. Furthermore, a vapour formed at a lower temperature may result in an improved user experience, by reducing the vapour temperature experienced by the user.

[0012] Embossing typically refers to a continuous process whereby a starting material is continuously fed between two rollers, which may be heated and/or pressurised, in order to produce deformations in the surface of the sheet material. Embossing can thus be used to quickly and cheaply produce a heating surface having a relatively complex surface geometry of physical micro- and/or nanostructures.

[0013] As used herein, a microstructure refers to a structure on a scale which is not visible to the naked eye, typically as revealed by an optical microscope above 25x magnification. A microstructure typically has a largest dimension of less than 200µm, for example between 0.1µm and 100µm. As used herein, a nanostructure refers to a structure on a smaller scale. A nanostructure typically has a largest dimension of less than 0.1µm, for example between 0.1 nm and 100nm.

[0014] The heating surface may comprise one or more hydrophobic and/or oleophobic regions. The plurality of nucleation-enhancing micro- and/or nanostructures may be operable to reduce the wettability of the surface in the one or more hydrophobic and/or oleophobic regions. A hydrophobic and/or oleophobic region may have increased bubble nucleation as compared with a more wettable region, such as a plain surface (i.e. a surface absent any deliberate micro- and/or nanostructures).

[0015] The heating surface may comprise one or more hydrophilic and/or oleophilic regions. The plurality of nucleation-enhancing micro- and/or nanostructures may be

operable to increase the wettability of the surface in the one or more hydrophilic and/or oleophilic regions. A hydrophilic and/or oleophilic region may have reduced bubble nucleation as compared with a less wettable region, such as a plain surface, but may improve thermal efficiency by delaying the critical heat flux.

[0016] The heating surface may comprise both hydrophobic and/or oleophobic regions and hydrophilic and/or oleophilic regions so as to be biphilic. The plurality of nucleation-enhancing micro- and/or nanostructures may be operable to increase the wettability of the surface in the one or more hydrophilic and/or oleophilic regions, and to reduce the wettability of the surface in the one or more hydrophobic and/or oleophobic regions. A biphilic surface may thus improve thermal efficiency by combining increased nucleation with good surface wetting.

[0017] The heating surface preferably comprises a biphilic region and a hydrophobic and/or oleophobic region. Thus, the heating surface may comprise a region of hydrophobic and/or oleophobic micro- and/or nanostructures mixed with hydrophilic and/or oleophilic micro- and/or nanostructures as well as a purely hydrophobic region. Heat transfer may be increased in the biphilic region as compared with the hydrophobic/oleophobic region.

[0018] The hydrophobic and/or oleophobic region may surround the biphilic region. Since a hydrophobic region may be liquid-repellent, such an arrangement may reduce leakage by encouraging liquid towards a central biphilic region of the heating surface.

[0019] The cartridge may further comprise a fluid transfer element located in fluid communication with an interior of the reservoir and configured to draw liquid aerosol-forming substrate from the reservoir towards the heating surface. The fluid transfer element may comprise a footprint (being a projection of the plane of the fluid transfer element which is operable in use to contact the heating surface). The thermal interface membrane may comprise a biphilic region of nucleation-enhancing micro- and/or nanostructures surrounded by a hydrophobic region, where the biphilic region preferably has a footprint that is larger than, or substantially the same as, the footprint of the fluid transfer element. Such an arrangement may further reduce leakage.

[0020] The plurality of nucleation-enhancing micro- and/or nanostructures may comprise a microstructure pattern of pillars or undulations. The pattern may be periodic (i.e. repeating) or non-periodic (i.e. not intentionally repeating).

[0021] The pillars or undulations may have a height in the range 0.5µm-50µm. A distance between a pillar or undulation and an adjacent pillar or undulation may be in the range 1µm-100µm.

[0022] A ground region between the pillars or undulations may be hydrophilic and/or oleophilic, and a top region of at least one of the pillars or undulations may be hydrophobic and/or oleophobic. A top region of each of the pillars or undulations may be hydrophobic and/or ole-

ophobic. Such a heating surface thus constitutes a biphilic surface.

[0023] One or more nanostructures may be located on a microstructure of the microstructure pattern of pillars or undulations, and may be located on each microstructure of the microstructure pattern. The one or more nanostructures may be located on a top region of the or each microstructure of the microstructure pattern. Alternatively, or additionally, the one or more nanostructures may be located in a ground region between the microstructures of the microstructure pattern.

[0024] The thermal interface membrane may be formed of a thin thermally and/or electrically conductive material. "Thin" as used herein means the starting material has a thickness of less than 500 μ m and greater than 10 μ m. Materials that can be considered "soft" such as aluminium can have a thickness of below 500 μ m, below 200 μ m, or even below 100 μ m. Materials that can be considered "hard" such as stainless steel can have a thickness of below 200 μ m, below 100 μ m, or even below 50 μ m. Selecting a thin material can prevent wear and damage to the rollers.

[0025] Preferably, the heating surface is operable to contact the aerosol forming substance during heating. The cartridge may comprise a fluid transfer element operable to deliver liquid aerosol forming substrate to the heating surface, and the heating surface may be operable to contact the liquid aerosol forming substance during heating.

[0026] The heating surface may comprise a thermally and/or electrically conductive material. The thermal interface membrane may comprise one or more of, but not limited to, graphite, molybdenum, silicon carbide, niobium, aluminium, iron, nickel, nickel containing compounds, titanium, mild steel, stainless steel, low carbon steel and alloys thereof, e.g., nickel chromium or nickel copper, and composites of metallic materials. The heating surface may comprise a surface of a susceptor.

[0027] According to a second aspect of the invention, we provide an aerosol generating system comprising a cartridge according to the first aspect of the invention and a base part comprising the heating element.

[0028] The cartridge and base part may additionally include any component conventionally present in an aerosol generating system, such as those discussed in the background section above, or in the detailed description below.

[0029] According to a further aspect of the invention, we provide an aerosol generating system comprising:

- an aerosol generation device comprising a region arranged for receiving a consumable comprising an aerosol-forming substrate,
- a heating assembly comprising a heating surface, said heating assembly being configured to heat said aerosol-forming substrate in the consumable to generate an aerosol that may be inhaled by a user, wherein the heating surface comprises a biphilic sur-

face, or

wherein the heating surface comprises a plurality of nucleation enhancing microstructures.

[0030] As discussed above, a biphilic surface may improve thermal efficiency by combining increased nucleation with good surface wetting.

[0031] The biphilic surface may comprise one or more hydrophobic and/or oleophobic regions and one or more hydrophilic and/or oleophilic regions. The one or more hydrophobic and/or oleophobic regions and one or more hydrophilic and/or oleophilic regions may be provided in a regular pattern on a micro- or nanoscale. The pattern of hydrophilic/oleophilic regions and hydrophobic/oleophobic regions may be provided as spots (e.g. of circular, elliptical, rectangular, square, hexagonal, triangular, pentagonal, or any other shape), stripes or channels on the heating surface. The biphilic surface may comprise one or more hydrophobic and/or oleophobic regions of a regular shape, such as a circular, elliptical or a polygon, surrounded by a hydrophilic and/or oleophilic ground.

[0032] The biphilic surface may be provided using physical (e.g. embossed) nucleation-enhancing micro- and/or nanostructures as discussed above, where the nucleation-enhancing micro- and/or nanostructures may comprise a microstructure pattern of pillars or undulations. A top surface of the pillars/undulations may have a hydrophobic and/or oleophobic interaction and a ground between the pillars or undulations may be hydrophilic and/or oleophilic.

[0033] The biphilic surface may be provided by one or more chemical coatings.

[0034] The features set out above may be combined together in any combination, and also with features selected from the detailed description below.

Brief description of the drawings

[0035] There now follows a detailed description of the invention, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 schematically shows an aerosol generating system including an aerosol generation device and an aerosol generating substrate;

Figure 2 illustrates the differing wettability between a hydrophobic surface, a hydrophilic surface and a super-hydrophilic surface;

Figure 3 compares (a) a plain heating surface with a heating surface that comprises (b) a plurality of nucleation-enhancing nanostructures, (c) plurality of nucleation-enhancing microstructures, and (d) plurality of nucleation-enhancing micro- and/or nanostructures;

Figure 4 schematically shows an embossing system;

Figure 5 illustrates a method of manufacturing a heating surface;

Figure 6 schematically shows a first microstructure pattern;

Figure 7 schematically shows a second microstructure pattern;

Figure 8 schematically shows a third microstructure pattern;

Figure 9 illustrates a first heating surface including a plurality of nucleation-enhancing nanostructures at 500x magnification;

Figure 10 illustrates a portion of the first heating surface of Figure 9 at 1000x magnification;

Figure 11 illustrates a second heating surface including a plurality of nucleation-enhancing microstructures at 500x magnification;

Figure 12 illustrates a portion of the second heating surface of Figure 9 at 1000x magnification;

Figure 13 illustrates a third heating surface including a plurality of nucleation-enhancing microstructures at 500x magnification; and

Figure 14 illustrates a fourth heating surface including a plurality of nucleation-enhancing micro- and nanostructures at 500x magnification.

Detailed Description

[0036] As shown diagrammatically in Figure 1, an aerosol generating system 16 comprises an aerosol generation device 18 (also known as a vaporiser) having a region for receiving an aerosol generating substrate 20. An aerosol generation device 18 is a hand-held, portable device, by which it is meant that a user is able to hold and support the device 18 unaided, in a single hand.

[0037] The aerosol generating system includes a heating assembly 14, such as an induction heating assembly, having a heating surface 12. The heating surface 12 may comprise a surface of a susceptor 10, as in the example shown in Figure 1, or may comprise a surface of a heat transfer component or a resistive heating element.

[0038] The aerosol generating system 16 may further include a liquid storage reservoir 24 configured for containing therein aerosol generating substrate 20 in the form of a liquid to be vaporised. The liquid may comprise an aerosol-forming substance or precursor such as propylene glycol and/or glycerol and may contain other substances such as nicotine and acids. The liquid may also comprise flavourings such as e.g. tobacco, menthol or fruit flavour. A vapour transfer channel (not shown) extends from an air inlet to an outlet provided in a mouth-piece region 25 of the system.

[0039] A fluid transfer element 26, such as a wick, is located in fluid communication with the interior of the reservoir 24, and is configured to draw vaporisable liquid from the reservoir 24 towards the heating surface 12 at a vaporisation zone. The vaporisation zone is in fluid communication with the vapour transfer channel.

[0040] In use, an induction coil 22, i.e., an electromagnetic field generator, comprised in the induction heating assembly 14 is arranged to be energised by a power

source 28 to generate an alternating electromagnetic field that couples with, and inductively heats, the susceptor 10 due to eddy currents and magnetic hysteresis losses resulting in a conversion of energy from electromagnetic to heat. Heat from the susceptor 10 is transferred, for example by conduction, radiation and convection, to the aerosol generating substrate 20 at the vaporisation zone to heat the aerosol generating substrate 20 (without burning or combusting the aerosol generating substrate 20) thereby generating a vapour which cools and condenses to form an aerosol for inhalation by a user of the aerosol generation device 18.

[0041] In general terms, a vapour is a substance in the gas phase at a temperature lower than its critical temperature, which means that the vapour can be condensed to a liquid by increasing its pressure without reducing the temperature, whereas an aerosol is a suspension of fine solid particles or liquid droplets, in air or another gas. It should, however, be noted that the terms 'aerosol' and 'vapour' may be used interchangeably in this specification, particularly with regard to the form of the inhalable medium that is generated for inhalation by a user.

[0042] The induction coil 22 is energised by a power source 28 of the aerosol generation device 18, such as a battery. Aerosol generation devices 18 typically include a controller 29 and a user interface for controlling the operation of the aerosol generation device 18 via the controller 29.

[0043] The controller 29 is configured to detect the initiation of use of the aerosol generation device 18, for example, in response to a user input, such as a button press to activate the aerosol generation device 18, and/or in response to a detected airflow through the aerosol generation device 18. As will be understood by one of ordinary skill in the art, an airflow through the aerosol generation device 18 is indicative of a user inhalation or 'puff'. The aerosol generation device 18 may, for example, include a puff detector, such as an airflow sensor (not shown), to detect an airflow through the aerosol generation device 18.

[0044] The controller 29 includes electronic circuitry. The power source 28 and the electronic circuitry may be configured to operate at a high frequency. For example, the power source 28 and the electronic circuitry may be configured to operate at a frequency of between approximately 80 kHz and 500 kHz, possibly between approximately 150 kHz and 250 kHz, and possibly at approximately 200 kHz. The power source 28 and the electronic circuitry could be configured to operate at a higher frequency, for example in the MHz range, if required.

[0045] The induction coil 22 may have any shape, but typically is either an axial coil (i.e. a coil helically wound around a longitudinal axis into a generally cylindrical shape) or a flat coil (i.e. a spirally wound coil, typically lying in a single plane). The induction coil 22 may be arranged around the susceptor 10, for example to surround or fully surround the susceptor 10. The induction coil 22 may comprise a Litz wire or a Litz cable. It will,

however, be understood that other materials could be used, such as copper or silver tapes helically wound to form a coil about an appropriate support. The induction coil 22 may be arranged to operate in use with a fluctuating electromagnetic field having a magnetic flux density of between approximately 20mT and approximately 2.0T at the point of highest concentration.

[0046] Many susceptors used currently are relatively simple in geometry, being either a single strip of metal or multiple strips of metal. This leads to inefficiencies when heating a target material, (i.e. an aerosol generating substrate such as tobacco or e-liquid), due to a poor heat transfer coefficient (HTC) between the material of the susceptor and the target material.

[0047] The heat transfer coefficient in the boiling evaporation regime between a surface and a liquid in general depends on a number of parameters, including material properties, surface properties (such as wettability and surface roughness), and the heat flux through the interface.

[0048] As illustrated in Figure 2, wettability is a measure of a liquid's ability to interact with other fluids or surfaces. In particular, wettability measures the level of wetting when solid and liquid phases interact and is determined by measuring the contact angle θ between the surface and a liquid droplet on the surface. Low contact angles ($\theta < 90^\circ$) are classified as hydrophilic or oleophilic and high contact angles ($\theta > 90^\circ$) as hydrophobic or oleophobic, where "hydrophobic/hydrophilic" describes the contact angle of water-like liquids and "oleophobic/oleophilic" describes the contact angle of oil-like liquids. A surface can be both hydro and oleophobic/philic at the same time.

[0049] Figure 2 depicts a hydrophobic surface 200, where $\theta > 90^\circ$, and in particular is approximately 110° . Surfaces having a contact angle greater than or equal to 90° can be considered as having bad wetting. A surface that is extremely hydro-/oleophobic, e.g. where the contact angle exceeds 150° , may also be referred to as "super-hydro-/oleophobic". Figure 2 further depicts a hydrophilic surface 202, where $\theta < 90^\circ$, and in particular is approximately 70° . Surfaces having a contact angle less than 90° can be considered as having good wetting. Finally, Figure 2 shows a surface 204 having a contact angle of 0° , which can be referred to as complete or perfect wetting. Such a surface may be referred to as "super-hydrophilic" (or "super-oleophilic" in the case of an oil-like liquid).

[0050] The relationship between wettability and HTC is complex, and can vary with both material and temperature. Hydrophilic/oleophilic interaction ensures a large contact area between the surface and the liquid. However, once vapor bubbles appear they can be less prone to detach from the surface and this can affect the HTC in a negative way. Hydrophobic/oleophobic interaction, on the other hand, has a reduced contact area, but once produced a vapor can leave the interface more easily.

[0051] The performance in terms of the HTC is deter-

mined not only by wettability but also of the presence of nucleation sites which promote bubble detachment from the surface, and the amount of heat flux through the interface. The combination of all these parameters determines whether the nucleation of bubbles happens in a quasi-stable and controlled way, or whether the process becomes unstable and creates a vapor film between the liquid and the surface. To some extent, these parameters are dependent on the liquid which is being heated, in particular, the viscosity and surface tension of the liquid (both of which are temperature dependent). E-liquids of the type used as an aerosol forming substrate typically have a highly temperature dependent viscosity, making the effects of wettability difficult to predict for a given surface. We have found however, that increasing the presence of bubble nucleation sites on the surface of a material tends to have an overall positive effect on the HTC as compared with a plain surface absent such nucleation sites.

[0052] Nucleation sites refer to features of a surface structure of the substrate which promote bubble nucleation and detachment from the surface. Nucleation sites may be provided by physical surface structures formed on a microscopic and/or nanoscopic scale which are too small to admit liquid, allowing the ensuing vapour pocket to act as a site for bubble growth and release. Such physical surface structures may be provided by surface roughness, such as surface patterning or cavities formed on a microscopic and/or nanoscopic scale.

[0053] Referring again to Figure 1, the heating surface 12 of the heating assembly 14 comprises a plurality of nucleation-enhancing micro- and/or nanostructures, indicated generally at 64. Such nucleation-enhancing micro- and/or nanostructures are operable to provide nucleation sites on the heating surface, so improving the HTC of the heating surface as compared with a plain surface absent such features.

[0054] Figure 3 illustrates bubble nucleation in different types of surface, and in particular shows how a surface 300 including one or more nanostructures 62a, a surface 302 including one or more microstructures 62b, and a surface 304 including one or more hierarchical structures 62c (having both microstructures and nanostructures) can improve nucleation as compared with a plain surface 306 absent nucleation-enhancing micro- and/or nanostructures, by providing surface regions 308 which are too small to admit liquid, allowing the ensuing vapour pocket to act as a site for bubble growth and release. It is noted that alterations to the surface structure may also have an effect on the wettability of the surface. This is also illustrated in Figure 3, which shows the surfaces 300, 302 and 306 as more hydrophobic than the unmodified plain surface 300.

[0055] Susceptor surface geometry is usually limited by the cost and complexity of the fabrication. Referring now to Figures 4 and 5, a method of manufacturing a heat transfer component having a heating surface including plurality of nucleation-enhancing micro- and/or na-

nostructures, is described below. The heat transfer component may be used in a heating assembly of an aerosol generating system, such as that described with reference to Figure 1. An example of such a heat transfer component is a susceptor of the type discussed above in connection with Figure 1, although it will be appreciated that the heat transfer component could equally be a resistive heating element or a thermal interface membrane.

[0056] The method illustrated in Figure 4 makes use of an embossing system 30. The embossing system 30 comprises a pair of opposed rollers, namely a first (in this case upper) roller 32 and a second (in this case lower) roller 34. Each of the rollers 32, 34 comprises a pressing surface 36. One or more, and in this case a plurality of, micro- and/or nanoscale shaping features 38 are provided on one or both of the pressing surfaces 36, such that when a starting material 40 is fed between the rollers 32, 34, the shaping features 38 are operable to make an impression into the starting material 40 to produce an embossed material 42 comprising a plurality of micro- and/or nanostructures 62, and in particular the nucleation-enhancing micro- and/or nanostructures 64 as discussed above in connection with Figure 3. It will be appreciated that the shaping features 38 and the micro- and/or nanostructures 62, 64 are not shown to scale in Figure 4.

[0057] Depending on whether one or both of the rollers 32, 34 comprises shaping features 38, the micro- and/or nanostructures may be located in a first (in this case upper) surface 46 of the embossed material 42 (produced by the first roller 32) or in a second (in this case lower) surface 48 of the embossed material (produced by the second roller 34), or in both the upper and lower surfaces 46, 48 (produced by both rollers, as shown in Figure 4).

[0058] Referring now to Figure 5, a method of manufacturing a heat transfer component, such as a susceptor, is shown. In block 50, the method begins by feeding the starting material 40 between a pair of opposing rollers, for example the rollers 32, 34 shown in Figure 4. At least one of the rollers has a shaped embossing surface, such as a surface 36 comprising micro- and/or nanoscale shaping features 38 as shown in Figure 4.

[0059] In block 52, the starting material 40 is embossed using the rollers to produce an embossed material 42 having a heating surface 12 having at least one, and preferably a plurality of, micro- and/or nanoscale nucleation-enhancing surface structures 64.

[0060] Following the embossing step, the embossed material 42 may be cut, for example using a cutter 70, to form a plurality of heat transfer components 60, such as susceptor 10. Each of the cut susceptors 10 comprises a heating surface 12 having a plurality of nucleation-enhancing micro- and/or nanostructures 64. In one example, the starting material is embossed in a sheet and later cut along the width and length direction to form the susceptors 10. Alternatively, the starting material can be pre-cut to a desired size in one direction (e.g. the width dimension) into a flat wire and then embossed, and then

cut along the length direction.

[0061] High resolution embossing processes are possible on metal surfaces, allowing nanometre scale features to be formed on one or both sides of a sheet with high spatial accuracy. Embossing processes can thus be used to achieve similar surface finishes to laser ablation and other surface treatment methods, such as chemical treatment, but at reduced complexity. Embossing allows for a specific pattern to be embedded into a heating surface and can contain a mixture of both nano and micro-scale features. Embossing can thus be used to produce a relatively complex surface geometry.

[0062] The starting material 40 for use in the methods described herein is typically a thin thermally and/or electrically conductive material. "Thin" as used herein means the starting material has a thickness of less than 500 μ m and greater than 10 μ m. Materials that can be considered "soft" such as aluminium can have a thickness of below 500 μ m, below 200 μ m, or even below 100 μ m. Materials that can be considered "hard" such as stainless steel can have a thickness of below 200 μ m, below 100 μ m, or even below 50 μ m. Selecting a thin material can prevent wear and damage to the rollers.

[0063] If the process is used to produce a susceptor, the starting material 40 is selected to be both electrically and thermally conducting. In such an example, the starting material (and thus the heat transfer component) may be graphite, molybdenum, silicon carbide, niobium, aluminium, iron, nickel, nickel containing compounds, titanium, mild steel, stainless steel, low carbon steel and alloys thereof, e.g., nickel chromium or nickel copper, and composites of metallic materials. In contrast, for a thermal interface membrane, the starting material need only be thermally conducting.

[0064] A heating surface 12 as described herein exhibits a microstructure pattern which increases the nucleation points on the surface and enhances the bubble departure from the surface. The microstructures ideally form a periodic or non-periodic pattern of structures such as pillars or sharp-like surface undulations (height in the range between 0.5 and 50 μ m) with distance between individual pillars in the range between 1 and 100 μ m. The micropillars may have a regular cross-section, such as a circular, elliptical or a polygon cross-section.

[0065] Figure 6 illustrates an example of a first microstructure pattern 400 comprised of a plurality of regularly repeating micropillars 402 each having a generally circular cross-section. The pillars are of approximately the same diameter as one another, and a minimum spacing 404 between the pillars 402 is of a comparable size to the diameter of the pillars.

[0066] Figure 7 illustrates an example of a second microstructure pattern 406 comprised of a plurality of regularly repeating micropillars 408 each having a generally hexagonal cross-section. The pillars 408 are of approximately the same size and dimensions as one another, and a minimum spacing 410 between the pillars 408 is approximately 50% larger than the largest cross-section-

al dimension of the pillars.

[0067] Figure 8 illustrates an example of a third microstructure pattern 412 comprised of a plurality of regularly repeating micropillars 414 each having a generally square cross-section. The pillars 412 are of approximately the same size and dimensions as one another, and a minimum spacing 414 between the pillars 412 is approximately the same size as the largest cross-sectional dimension of the pillars.

[0068] A preferred configuration includes a biphilic surface, where a top surface 418 of the pillars/undulations have a hydrophobic (and/or oleophobic) interaction and the rest of the surface, such as a ground 420 between the pillars, and optionally one or more side surfaces 422 of the pillars, is hydrophilic (and/or oleophilic). Thereby, the nucleation of bubbles and the departure of the bubbles from the surface is increased compared to sole hydro- and/or oleophobic/philic surfaces.

[0069] A similar effect can be achieved on surfaces absent any microstructures using biphilic chemical coatings, where the coating is provided in a pattern similar to that described above (i.e. hydrophobic and/or oleophobic regions of a regular shape, such as a circular, elliptical or a polygon, surrounded by a hydrophilic and/or oleophilic ground). The pattern of hydrophilic and/or oleophilic zones and hydrophobic and/or oleophobic zones can range from spots of circular, elliptical, rectangular, square, hexagonal, triangular, pentagonal, or any other shape, including strips or channels of the surface.

[0070] It will be appreciated that many other geometries may be produced in addition to those discussed above, which constitute merely examples. The micro- and/or nanoscale nucleation-enhancing surface structures 64 may be of any embossable or etchable or printable shape, and may be provided on one or both sides of the material. The surface features provided on the first surface of a heat transfer component may differ to those provided on the second surface of the component in shape and/or size.

[0071] Some further examples of micro- and/or nanoscale nucleation-enhancing surface structures 64 are shown in Figures 9-14. Each of the surfaces in Figures 9-14 was produced via the embossing process described above.

[0072] Figures 9 and 10 show a first heating surface 120 including a plurality of nucleation-enhancing nanostructures 62a. The nanostructures 62a are formed as a plurality of substantially parallel ridges 122 undulating so as to include a plurality of points 124 at periodically repeating intervals. The distance between two adjacent points is in the region of $10\mu\text{m}$. The distance between two adjacent ridges is in the region of $10\mu\text{m}$. The nanostructures 62a are provided in one or more nanostructured regions 126. In addition, the heating surface further includes one or more plain regions 128 comprising no intentional micro- and/or nanostructures.

[0073] Figures 11 and 12 show a second heating surface 220 including a plurality of nucleation-enhancing

microstructures 62b. The microstructures 62b are formed as a plurality of micropillars having a substantially rectangular cross section. The micropillars have a largest width dimension of approximately $80\mu\text{m}$ and a height in the region of $10\mu\text{m}$. A distance between adjacent micropillars is approximately $10\mu\text{m}$. The micropillars are formed in a regularly repeating pattern, and in particular are formed in a grid pattern. A top surface 222 of each micropillar and a ground surface 224 between adjacent micropillars are plain, i.e. substantially free of intentional micro- and/or nanostructures.

[0074] Figure 13 shows a third heating surface 320 including a plurality of nucleation-enhancing microstructures 62b. The microstructures 62b of surface 320 are provided in a similar pattern to those of Figures 11 and 12. However, rather than being micropillars they are instead microcavities having a substantially rectangular cross section. The microcavities have a largest width dimension of approximately $80\mu\text{m}$ and a height in the region of $10\mu\text{m}$. A distance between adjacent microcavities is approximately $10\mu\text{m}$. Again, a ground region 324 between adjacent cavities, as well as a base surface 322 of each microcavity are plain, i.e. substantially free of intentional micro- and/or nanostructures.

[0075] In contrast, Figure 14 shows a fourth heating surface 520 having a pattern of micropillars 62b that is substantially the same as that of Figures 11 and 12. In this case however, a ground region 524 between adjacent micropillars 62b is formed with nanostructures 62a in the form of sharp undulations, similar to those shown in Figures 9 and 10.

[0076] As discussed above, using micro- and/or nanostructures it is possible to modify the heat transfer properties of a surface, such as a heating surface of a thermal interface membrane of a liquid-based aerosol generating system.

[0077] Typically, a cartridge of a liquid-based aerosol generating system is provided with a fluid transfer element, such as a porous ceramic wick, in fluid communication with the interior of a reservoir chamber. The fluid transfer element is operable to absorb liquid aerosol generating substrate from the reservoir and deliver said liquid aerosol generating substrate to a vaporisation zone.

[0078] The cartridge is configured for connection in use to a base part comprising a heating element, a power source and control electronics. The heating element may, for example, be in the form of a rigid protruding heater that protrudes out of the base part for partial receipt within the cartridge.

[0079] A thermal interface membrane is provided in the cartridge, and is operable to transfer heat between the heating element in the base part and the fluid transfer element in the cartridge when the cartridge and base part are connected. The thermal interface membrane is a thin membrane such as a metal foil that is configured to ensure rapid and even heating of the vaporisation zone in an accurate and defined geometry, reducing the amount of lateral thermal spreading (i.e. thermal losses). The

thermal interface membrane is flexible, and so is able to deform, and so at least partially conform, to the shape of the heating element when a connection is made between the cartridge and the base part. Heat from the heating element in the base part is thus transferred to the fluid transfer element through the thermal interface membrane by conduction, convection and/or radiation (but primarily via conduction) when the cartridge is thermally connected to the base part in order to effect vaporisation of the aerosol generating liquid held in the fluid transfer medium.

[0080] A fluid transfer element may be considered to include a footprint, being a projection of the fluid transfer element in a plane which contacts the heating surface of the thermal interface membrane. It can be particularly desirable to optimise the heat transfer properties of the heating surface in the portion of the heating surface which contacts the fluid transfer element, being a portion of the heating surface which has substantially the same shape and size as the footprint of the fluid transfer element. Thus, a region of mixed oleophilic and oleophobic structures may be provided in the middle of the heating surface. The term "middle" refers here to a central portion of the heating surface rather than any internal portion of the heat transfer element. The central biphilic region preferably has a footprint having an area that is substantially the same as the footprint of the fluid transfer element, although it may be larger or smaller if required. The central biphilic region preferably has a footprint having a shape that is substantially the same as the footprint of the fluid transfer element.

[0081] In the portion of the heating surface which does not contact the fluid transfer element, it can be desirable to increase hydro- and/or oleophobicity, in order to encourage liquid towards the vaporisation zone. Thus, it can be useful to surround the central biphilic region with a hydrophobic region in order to reduce leakage.

[0082] Although exemplary embodiments have been described in the preceding paragraphs, it should be understood that various modifications may be made to those embodiments without departing from the scope of the appended claims. Thus, the breadth and scope of the claims should not be limited to the above-described exemplary embodiments.

[0083] Any combination of the above-described features in all possible variations thereof is encompassed by the present disclosure unless otherwise indicated herein or otherwise clearly contradicted by context.

Claims

1. A cartridge for an aerosol generating system, the cartridge being disposable and configured to connect to a base part comprising a heating element, the cartridge comprising:

a liquid storage reservoir (24) configured for con-

taining therein a liquid aerosol-forming substrate (20), and

a thermal interface membrane comprising a heating surface (12), said thermal interface membrane being configured to transfer heat from the heating element in the base part to said aerosol-forming substrate in the cartridge to generate an aerosol that may be inhaled by a user, wherein the heating surface is embossed to comprise a plurality of nucleation-enhancing micro- and/or nanostructures.

2. The cartridge of claim 1, wherein the heating surface comprises:
 - (i) one or more hydrophobic and/or oleophobic regions; and/or
 - (ii) one or more hydrophilic and/or oleophilic regions.
3. The cartridge of claim 1, wherein the heating surface comprises both hydrophobic and/or oleophobic regions and hydrophilic and/or oleophilic regions so as to be biphilic.
4. The cartridge of claim 1, wherein the heating surface comprises a biphilic region and a hydrophobic and/or oleophobic region.
5. The cartridge of claim 4, wherein the hydrophobic and/or oleophobic region surrounds the biphilic region.
6. The cartridge of any preceding claim, wherein the cartridge further comprises a fluid transfer element (26) located in fluid communication with an interior of the reservoir and configured to draw liquid aerosol-forming substrate from the reservoir towards the heating surface (12) at a vaporisation zone, the fluid transfer element comprising a footprint, wherein the thermal interface membrane comprises a biphilic region of nucleation-enhancing micro- and/or nanostructures surrounded by a hydrophobic region, the biphilic region having substantially the same footprint as the fluid transfer element.
7. The cartridge of any preceding claim, wherein the plurality of nucleation-enhancing micro- and/or nanostructures comprises a microstructure pattern of pillars or undulations.
8. The cartridge of claim 8, wherein the pillars or undulations have a height in the range 0.5 μ m-50 μ m, and/or, wherein a distance between a pillar or undulation and an adjacent pillar or undulation is in the range 1 μ m-100 μ m.

9. The cartridge of claim 7 or claim 8, wherein a ground region between the pillars or undulations is hydrophilic and/or oleophilic, and a top region of at least one of the pillars or undulations is hydrophobic and/or oleophobic. 5
10. The cartridge of any one of claims 7-9 wherein one or more nanostructures are located on a microstructure of the microstructure pattern of pillars or undulations. 10
11. The cartridge of any one of claims 1-10, wherein the pattern is a periodic pattern which repeats at regular intervals. 15
12. The cartridge of any preceding claim, wherein the heating surface is operable to contact the aerosol-forming substrate during heating.
13. The cartridge of any preceding claim, wherein the thermal interface membrane comprises a second surface opposite to the heating surface, wherein the second surface is also embossed to comprise a plurality of nucleation-enhancing micro- and/or nanostructures. 20
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14. The cartridge of any preceding claim, wherein the thermal interface membrane has a thickness of 500 μm or less. 30
15. An aerosol generating system comprising the cartridge of any preceding claim and a base part comprising the heating element. 35

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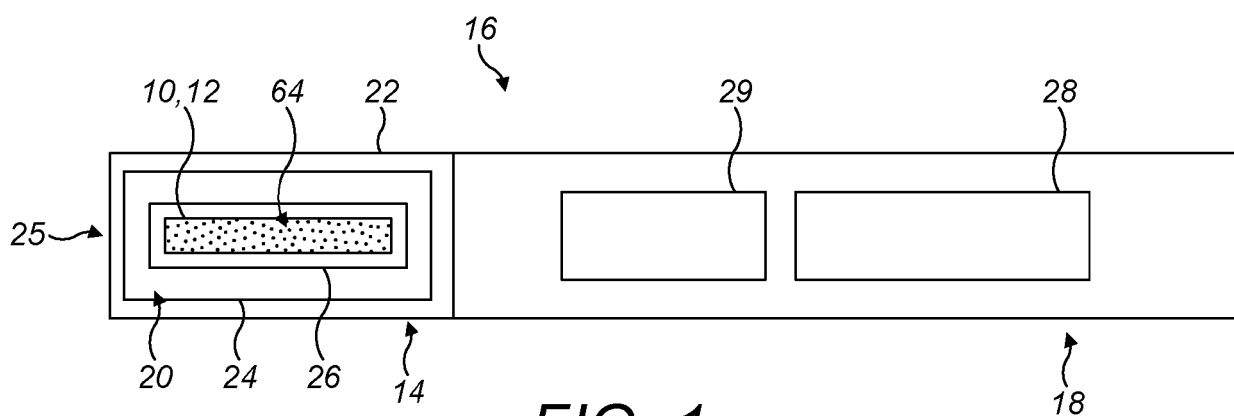


FIG. 1

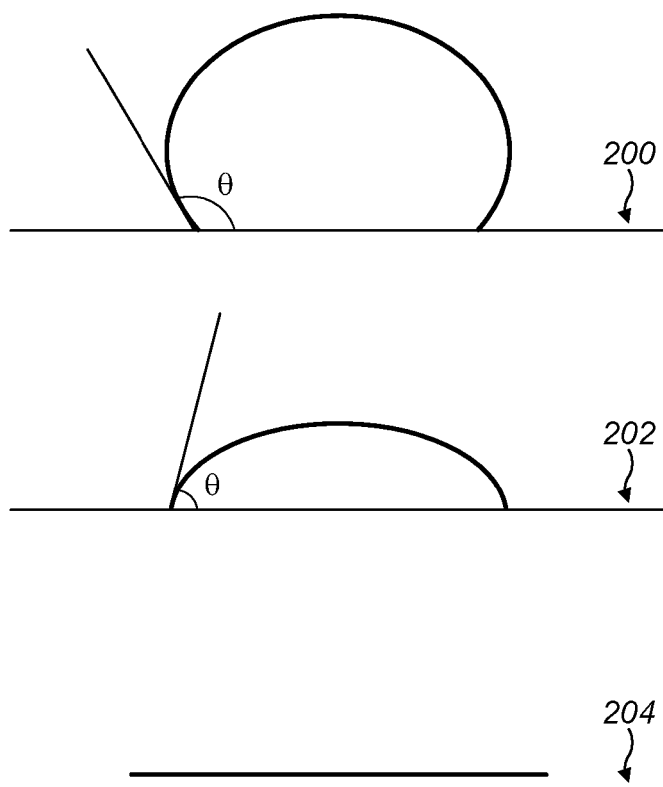


FIG. 2

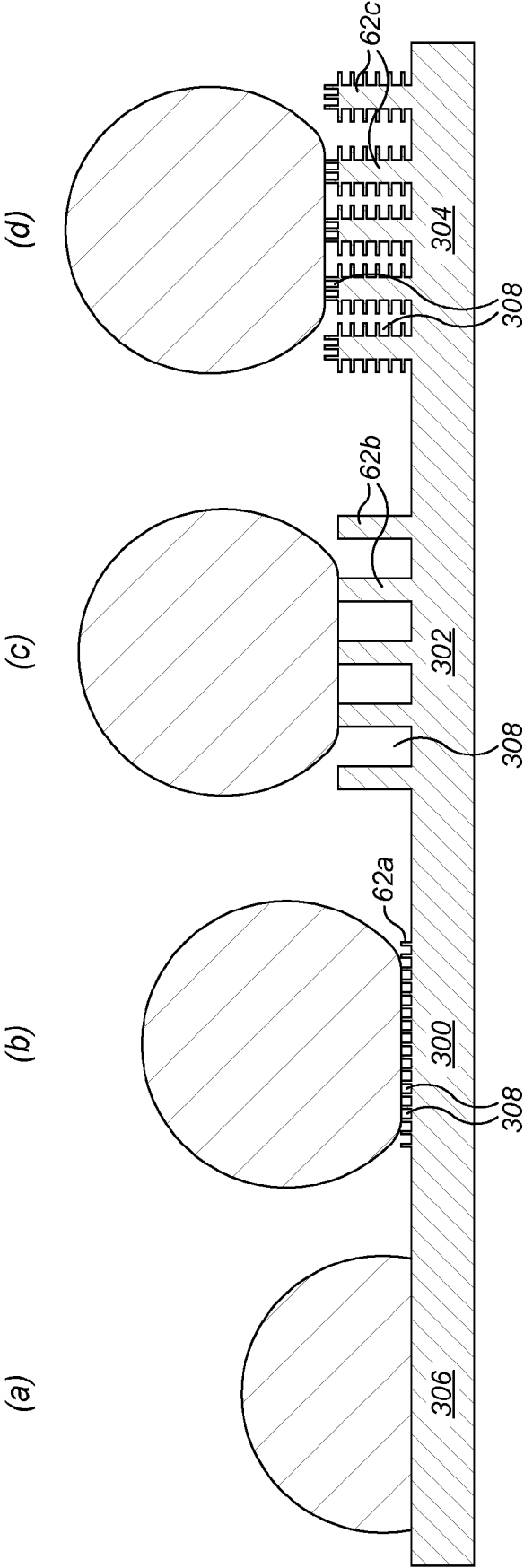


FIG. 3

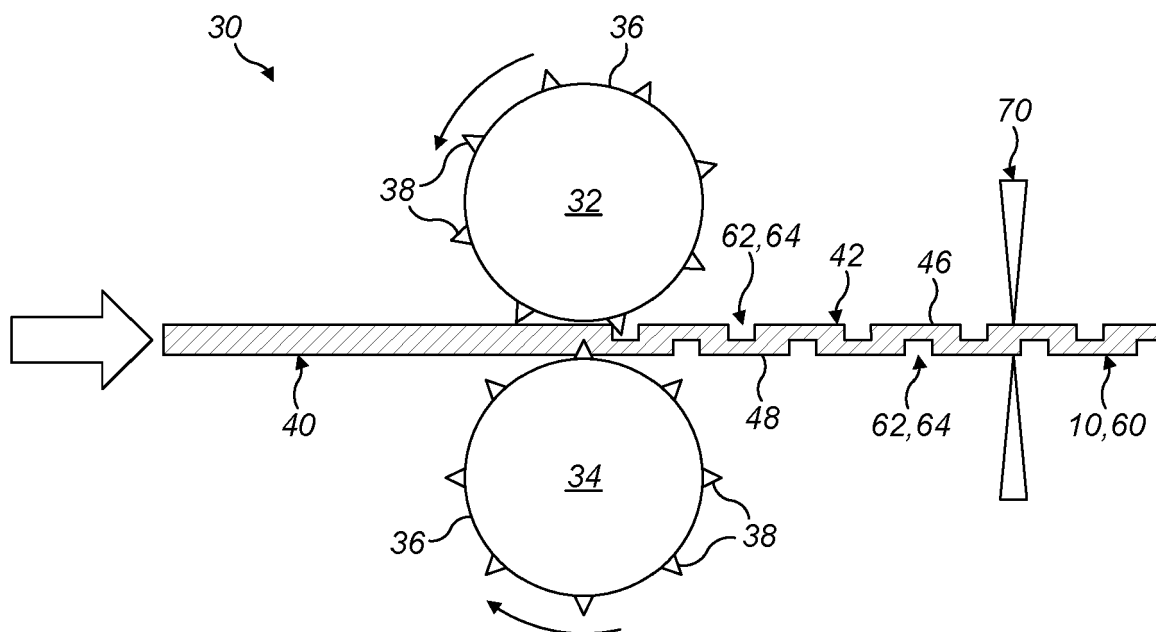


FIG. 4

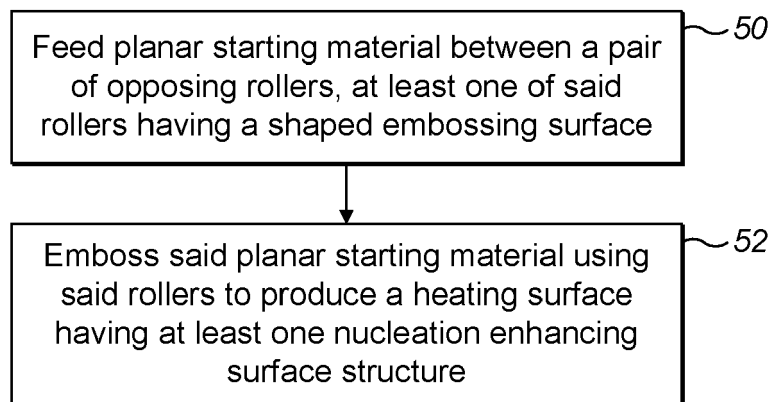


FIG. 5

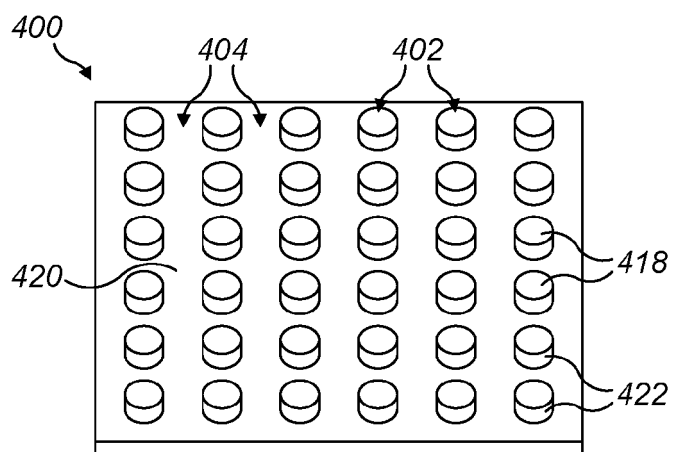


FIG. 6

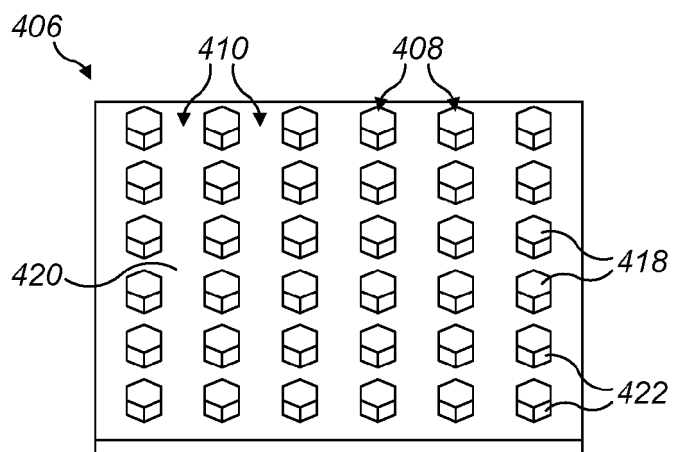


FIG. 7

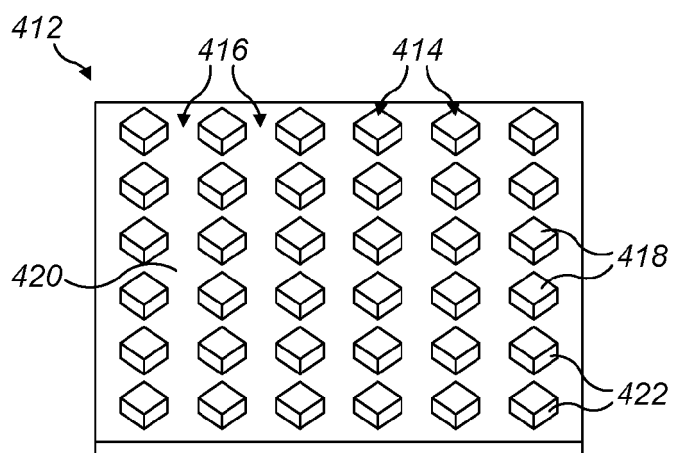


FIG. 8

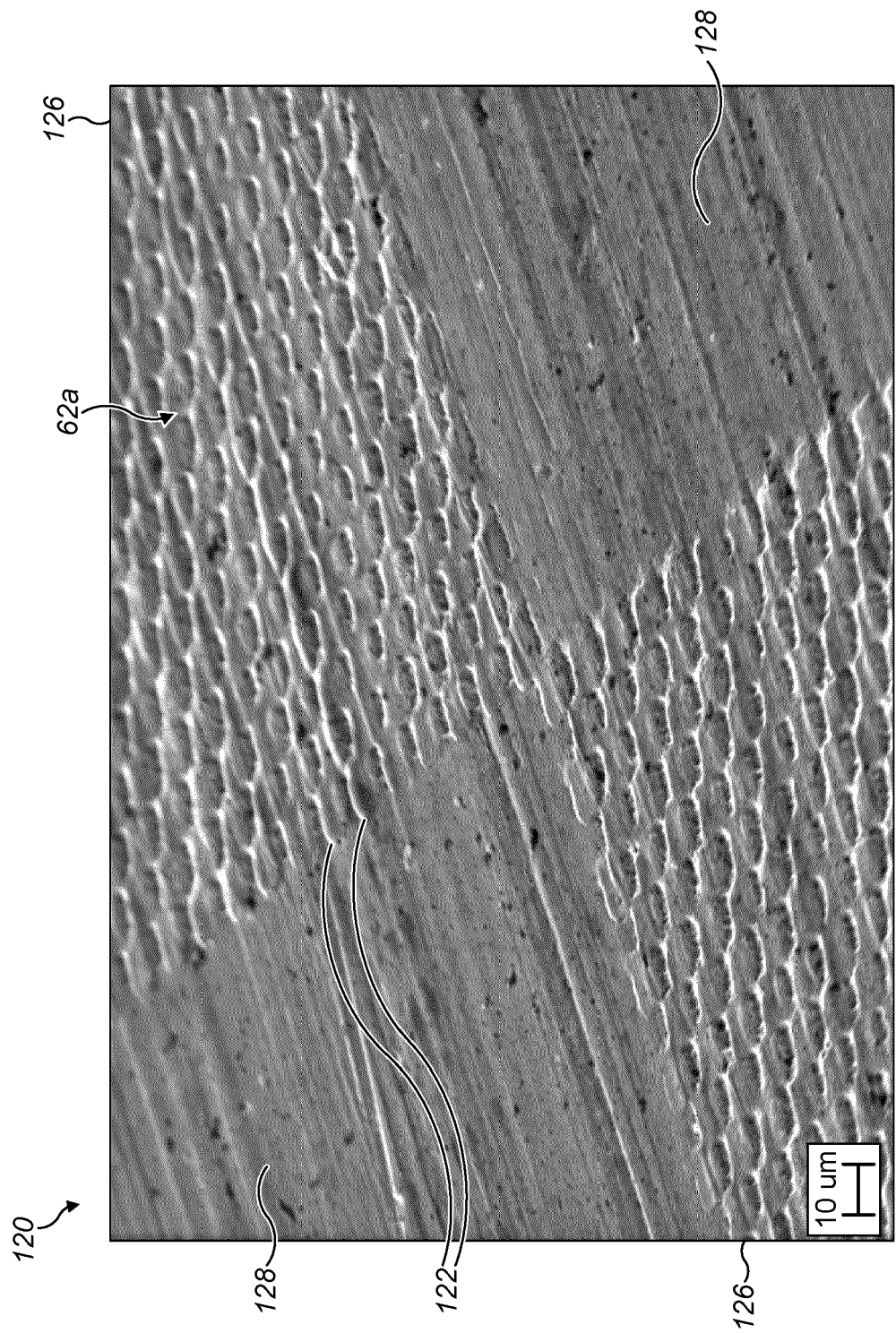


FIG. 9

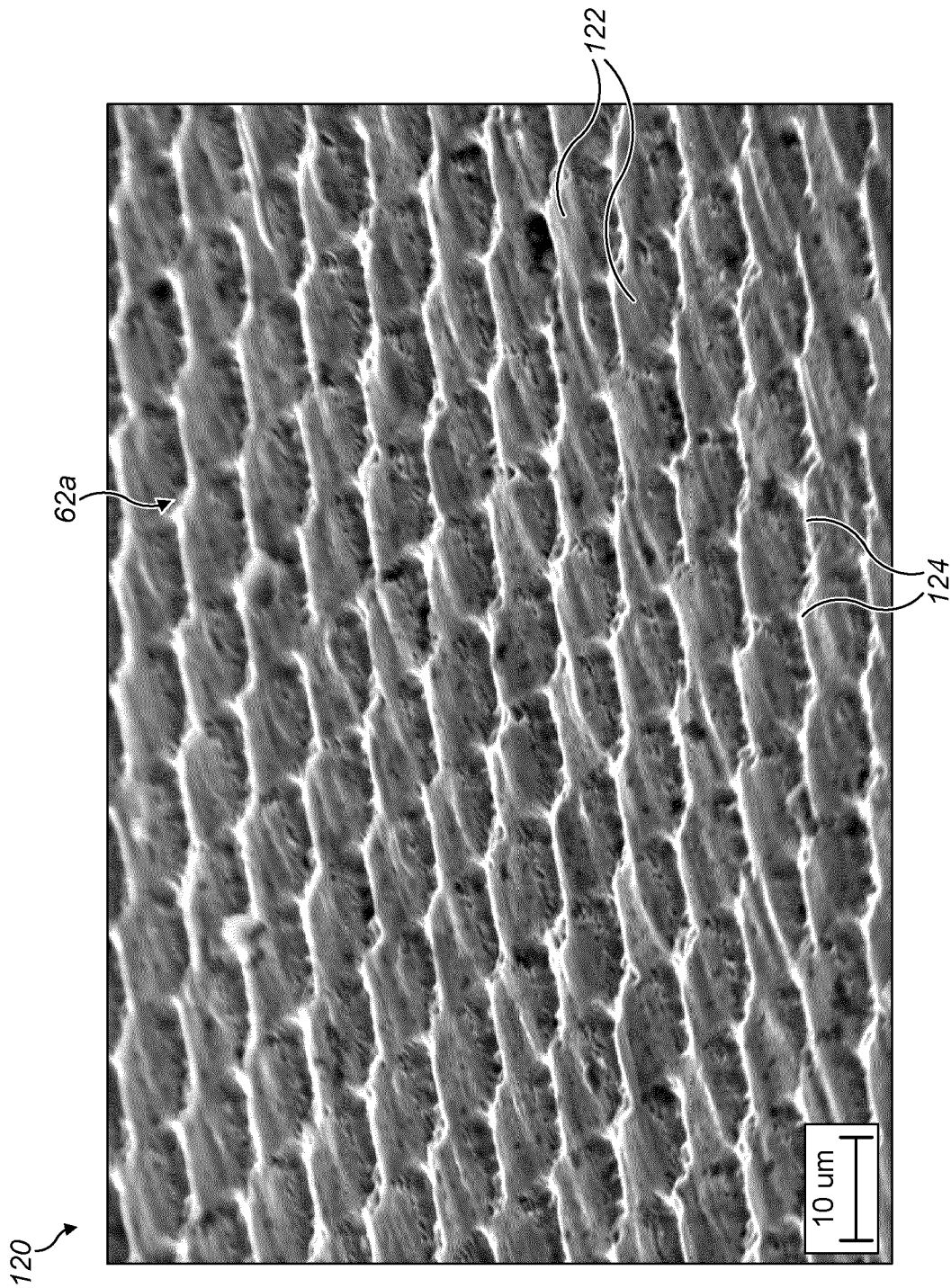


FIG. 10



FIG. 11



FIG. 12



FIG. 13

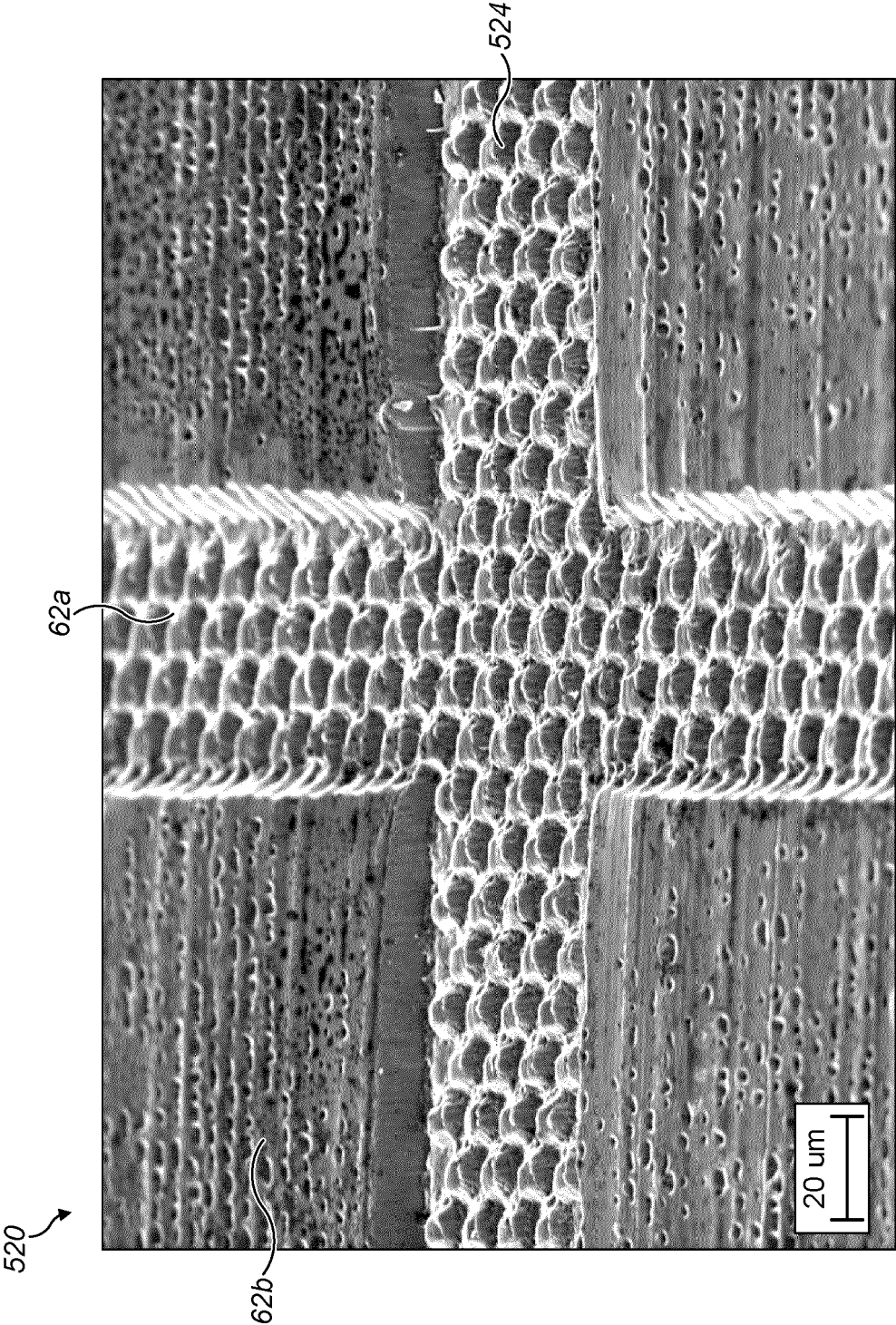


FIG. 14



EUROPEAN SEARCH REPORT

Application Number

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 16 April 2024	Examiner Koob, Michael
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