AN ELECTRICALLY HEATED SMOKING SYSTEM HAVING A LIQUID STORAGE PORTION

The present invention relates to an electrically heated smoking system for receiving an aerosol-forming substrate. In particular, the present invention relates to an electrically heated smoking system for receiving an aerosol-forming substrate, in which the aerosol-forming substrate is a liquid.

A number of prior art documents, for example US-A-5 060 671, US-A-5 388 594, US-A-5 505 214, US-A-5 591 368, WO-A-2004/043175, EP-A-0 358 002 and WO-A-2007/131449, disclose electrically operated smoking systems, having a number of advantages. One advantage is that they significantly reduce sidestream smoke, while permitting the smoker to selectively suspend and reinitiate smoking.

Other prior art documents, such as EP-A-0 295 122, EP-A-1 618 803 and EP-A-1 736 065, disclose electrical smoking systems which use a liquid as the aerosol-forming substrate. The liquid may be contained in a cartridge which is receivable in a housing. A power supply, such as a battery, is provided, connected to a heater to heat the liquid substrate during a puff, to form the aerosol which is provided to the smoker.

The electrically heated smoking systems of the prior art, including those described above, do have a number of advantages, but there is still room for improvement. It is therefore an object of the invention to provide an improved electrically heated smoking system.

According to a first aspect of the invention, there is provided an electrically heated smoking system comprising a shell and a replaceable mouthpiece, the shell comprising an electric power supply and electric circuitry; the mouthpiece comprising a liquid storage portion, a capillary wick having a first end and a second end, the first end extending into the liquid storage portion for contact with liquid therein, at least one heating element for heating the second end of the capillary wick, an air outlet, and an aerosol forming chamber between the second end of the capillary wick and the air outlet; wherein, when the shell and mouthpiece are engaged, the at least one heating element is in electrical connection with the power supply via the circuitry, the circuitry is arranged to provide an electric current pulse to the at least one heating element when a user initiates a puff, and a flow route for air is defined from at least one air inlet to the air outlet via the aerosol forming chamber, the flow route channelling the air flow around the heating element and the second end of the capillary wick.

The at least one air inlet may be provided in the shell or in the mouthpiece. In use, liquid is transferred from the liquid storage portion towards the heating element by capillary action in the capillary wick. When the heating element is activated, the liquid at the second end of the capillary wick is vaporised by the heating element to form a supersaturated vapour. The supersaturated vapour is mixed and carried in the air flow from the at least one air inlet to the

aerosol forming chamber. In the aerosol forming chamber, the vapour condenses to form an aerosol, which is carried towards the air outlet into the mouth of a user.

The electrically heated smoking system according to the invention provides a number of advantages. Firstly, because the replaceable mouthpiece contains the at least one heating element, the liquid storage portion and the wick, all elements which are potentially in contact with the liquid are changed when the mouthpiece is replaced. There will be no cross-contamination in the shell between different mouthpieces, for example ones using different liquids. In addition, the liquid in the liquid storage portion is protected from oxygen (because oxygen cannot generally enter the liquid storage portion via the capillary wick) and, in some embodiments light, so that the risk of degradation of the liquid is significantly reduced. Therefore, a high level of hygiene can be maintained. Secondly, the mouthpiece structure means that there is a low risk of leakage from the liquid storage portion, which is not the case for many of the electrically heated smoking systems of the prior art. This prevents wastage of the liquid, but also makes it difficult for an unauthorised user to access the liquid by dismantling the mouthpiece. Also, if the mouthpiece is replaced at suitable intervals, there is little chance of the heating element becoming clogged with liquid. Thirdly, because the circuitry provides a current pulse when a user initiates a puff, and the air is channelled around the heating element and second end of the capillary wick, the aerosolization is optimized. Finally, using a capillary wick extending between the liquid and the heating element, allows the structure of the mouthpiece to be relatively simple. There is preferably only one capillary mechanism in the system.

The at least one heating element may comprise a single heating element. Alternatively, the at least one heating element may comprise more than one heating element, for example two, three, four, five, six or more heating elements. The heating element or heating elements may be arranged appropriately so as to most effectively vaporise liquid at the second end of the capillary wick.

The at least one heating element preferably comprises an electrically resistive material. Suitable electrically resistive materials include but are not limited to: semiconductors such as doped ceramics, electrically "conductive" ceramics (such as, for example, molybdenum disilicide), carbon, graphite, metals, metal alloys and composite materials made of a ceramic material and a metallic material. Such composite materials may comprise doped or undoped ceramics. Examples of suitable doped ceramics include doped silicon carbides. Examples of suitable metals include titanium, zirconium, tantalum and metals from the platinum group. Examples of suitable metal alloys include stainless steel, nickel-, cobalt-, chromium-, aluminium-titanium- zirconium-, hafnium-, niobium-, molybdenum-, tantalum-, tungsten-, tin-, gallium-, manganese- and iron-containing alloys, and super-alloys based on nickel, iron, cobalt, stainless steel, Timetal and iron-manganese-aluminium based alloys. In composite materials, the

electrically resistive material may optionally be embedded in, encapsulated or coated with an insulating material or vice-versa, depending on the kinetics of energy transfer and the external physicochemical properties required. Examples of suitable composite heating elements are disclosed in US-A-5 498 855, WO-A-03/095688 and US-A-5 514 630.

The at least one heating element may take any suitable form. For example, the at least one heating element may take the form of a heating blade, such as those described in US-A-5 388 594, US-A-5 591 368 and US-A-5 505 214. Alternatively, the at least one heating element may take the form of a casing or substrate having different electro-conductive portions, as described in EP-A-1 128 741, or an electrically resistive metallic tube, as described in WO-A-2007/066374. Alternatively, the at least one heating element may be a disk (end) heater or a combination of a disk heater with heating needles or rods. Alternatively, the at least one heating element may take the form of a metallic etched foil insulated between two layers of an inert material. In that case, the inert material may comprise Kapton, all-polyimide or mica foil. Alternatively, the at least one heating element may take the form of a sheet of material, which may be rolled around the second end of the capillary wick. The sheet may be made from any suitable material, for example an iron-aluminium based alloy, an iron-manganese-aluminium base alloy or Timetal. The sheet may be rectangular in shape, or may have a patterned shape which may form a coil-like structure when rolled around the second end of the capillary wick. Other alternatives include a heating wire or filament, for example a Ni-Cr, platinum, tungsten or alloy wire, such as those described in EP-A-1 736 065, or a heating plate.

In a preferred embodiment, the at least one heating element comprises a coil of wire surrounding the second end of the capillary wick. In that embodiment, preferably the wire is a metal wire. Even more preferably, the wire is a metal alloy wire. The heating element may completely or partially encircle the second end of the capillary wick.

The at least one heating element may heat the liquid at the second end of the capillary wick by means of conduction. The heating element may be at least partially in contact with the second end of the wick. Alternatively, heat from the heating element may be conducted to the liquid by means of a heat conductive element. Alternatively, the at least one heating element may transfer heat to the incoming ambient air that is drawn through the electrically heated smoking system during use, which in turn heats the liquid by convection. The ambient air may be heated before passing through the system. Alternatively, the ambient air may be first drawn through the second end of the wick and then heated, as described in WO-A-2007/078273.

Preferably, the electric circuitry comprises a sensor to detect air flow indicative of a user taking a puff. The sensor may be an electro-mechanical device. Alternatively, the sensor may be any of: a mechanical device, an optical device, an opto-mechanical device and a micro electro mechanical systems (MEMS) based sensor. In that case, preferably, the electric circuitry is arranged to provide an electric current pulse to the at least one heating element when the

sensor senses a user taking a puff. Preferably, the time-period of the electric current pulse is pre-set, depending on the amount of liquid desired to be vaporised. The electric circuitry is preferably programmable for this purpose.

Alternatively, the electric circuitry may comprise a manually operable switch for a user to initiate a puff. The time-period of the electric current pulse is preferably pre-set depending on the amount of liquid desired to be vaporised. The electric circuitry is preferably programmable for this purpose.

Preferably, the at least one air inlet is in the shell. Alternatively, the at least one air inlet may be in the mouthpiece. In one embodiment, the at least one air inlet comprises two air inlets. Alternatively, there may be three, four, five or more air inlets. Preferably, if there is more than one air inlet, the air inlets are spaced around the shell or around the mouthpiece. In a preferred embodiment, the electric circuitry comprises a sensor to detect air flow indicative of a user taking a puff, and the at least one inlet is in the shell, upstream of the sensor. The air inlets are located appropriately such that the flow route for air channels the air flow around the heating element and the second end of the capillary wick, so as to optimize aerosolization.

Preferably, the electric power supply comprises a cell contained in the shell. The electric power supply may be a Lithium-ion battery or one of its variants, for example a Lithium-ion polymer battery. Alternatively, the power supply may be a Nickel-metal hydride battery or a Nickel cadmium battery or a fuel cell. In that case, preferably, the electrically heated smoking system is usable by a smoker until the energy in the power cell is used up.

Alternatively, the electric power supply may comprise circuitry chargeable by an external charging portion. In that case, preferably the circuitry, when charged, provides power for a pre-determined number of puffs, after which the circuitry must be re-connected to the external charging portion. An example of suitable circuitry is one or more capacitors or rechargeable batteries.

Preferably, the shell further comprises a puff indicator for indicating when the heating element is activated. In the embodiment in which the electric circuitry comprises a sensor to detect air flow indicative of a user taking a puff, the indicator may be activated when the sensor senses air flow indicative of the user taking a puff. In the embodiment in which the electric circuitry comprises a manually operable switch, the indicator may be activated by the switch.

Preferably, the shell and mouthpiece are arranged to releasably lock together when engaged.

Preferably, the liquid storage portion is not refillable. Thus, when the liquid in the liquid storage portion has been used up, the entire mouthpiece is replaced. Alternatively, the liquid storage portion may be refillable. In that case, the mouthpiece may be replaced after a certain number of refills of the liquid storage portion. Preferably, the liquid storage portion is arranged to hold liquid for a pre-determined number of puffs.

The liquid has physical properties, including viscosity, which allow the liquid to be transported through the capillary wick by capillary action. The liquid has a boiling point suitable for use in the electrically heated smoking system: if the boiling point is too high, the heating element will not be able to vaporise liquid at the second end of the capillary wick, but, if the boiling point is too low, the liquid may vaporise even without the heating element being activated. The liquid preferably comprises a tobacco-containing material comprising volatile tobacco flavour compounds which are released from the liquid upon heating. Alternatively, or in addition, the liquid may comprise a non-tobacco material. The liquid may include water, solvents, ethanol, plant extracts and natural or artificial flavours. Preferably, the liquid further comprises an aerosol former. Examples of suitable aerosol formers are glycerine and propylene glycol. Additional examples of potentially suitable aerosol formers are described in EP-A-0 277 519 and US-A-5 396 911.

The liquid storage portion is preferably a container. For example, the container may be a container such as that described in EP-A-0 893 071. Preferably, the liquid storage portion does not include any porous materials, so that there is only a single capillary mechanism (the capillary wick) in the electrically heated smoking system. This keeps the structure of the mouthpiece simple and the entire system low-maintenance. Preferably, the container is opaque, thereby limiting degradation of the liquid by light.

The electrically heated smoking system may further comprise an atomiser including the at least one heating element. In addition to the heating element, the atomiser may include one or more electromechanical elements such as piezoelectric elements. Additionally or alternatively, the atomiser may also include elements that use electrostatic, electromagnetic or pneumatic effects.

The capillary wick may have a fibrous or spongy structure. For example, the capillary wick may comprise a plurality of fibres or threads, generally aligned in the longitudinal direction of the smoking system, or sponge-like material formed into a rod shape along the longitudinal direction of the smoking system. The structure of the wick forms a plurality of small bores or tubes, through which the liquid can be transported from the liquid storage portion to the heating element, by capillary action. The capillary wick may comprise any suitable material or combination of materials. Examples of suitable materials are ceramic- or graphite-based materials in the form of fibres or sintered powders. The capillary wick may have any suitable capillarity and porosity so as to be used with different liquid physical properties such as density, viscosity, surface tension and vapour pressure.

The shell may comprise any suitable material or combination of materials. Examples of suitable materials include metals, alloys, plastics or composite materials containing one or more of those materials. Preferably, the material is light and non-brittle.

The mouthpiece may comprise any suitable material or combination of materials.

Examples of suitable materials include thermoplastics that are suitable for food or pharmaceutical applications, for example polypropylene, polyetheretherketone (PEEK) and polyethylene.

Preferably, the electrically heated smoking system is portable. The electrically heated smoking system may have a size comparable to a conventional cigar or cigarette.

According to a second aspect of the invention, there is provided a mouthpiece for engaging with a shell to form an electrically heated smoking system, the shell having an electric power supply and electric circuitry, the mouthpiece comprising: a liquid storage portion; a capillary wick having a first end and a second end, the first end extending into the liquid storage portion for contact with liquid therein; at least one heating element for heating the second end of the capillary wick; an air outlet; and an aerosol forming chamber between the second end of the capillary wick and the air outlet, wherein, when the shell and mouthpiece are engaged, the at least one heating element is in electrical connection with the power supply via the circuitry, the circuitry is arranged to provide an electric current pulse to the at least one heating element when a user initiates a puff, and a flow route for air is defined from at least one air inlet to the air outlet via the aerosol forming chamber, the flow route channelling the air flow around the heating element and the second end of the capillary wick.

In a preferred embodiment, the at least one heating element comprises a coil of wire surrounding the second end of the capillary wick. In that embodiment, preferably the wire is a metal alloy wire.

According to the invention, there is also provided a shell arranged to engage with the mouthpiece of the second aspect of the invention.

According to a third aspect of the invention, there is provided a shell for engaging with a mouthpiece to form an electrically heated smoking system, the mouthpiece having a liquid storage portion, a capillary wick having a first end and a second end, the first end extending into the liquid storage portion for contact with liquid therein, at least one heating element for heating the second end of the capillary wick, an air outlet, and an aerosol forming chamber between the second end of the capillary wick and the air outlet, the shell comprising: an electric power supply; and electric circuitry, wherein, when the shell and mouthpiece are engaged, the at least one heating element is in electrical connection with the power supply via the circuitry, the circuitry is arranged to provide an electric current pulse to the at least one heating element when a user initiates a puff, and a flow route for air is defined from at least one air inlet to the air outlet via the aerosol forming chamber, the flow route channelling the air flow around the heating element and the second end of the capillary wick.

Preferably, the electric circuitry comprises a sensor to detect air flow indicative of a user taking a puff.

Preferably, the shell further comprises the at least one air inlet.

According to the invention, there is also provided a mouthpiece arranged to engage with the shell of the third aspect of the invention.

Features described in relation to one aspect of the invention may also be applicable to another aspect of the invention.

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

Figure 1 shows a shell of an electrically heated smoking system according to an embodiment of the invention;

Figure 2 shows a mouthpiece of an electrically heated smoking system according to an embodiment of the invention; and

Figure 3 shows a constructed electrically heated smoking system, comprising the shell of Figure 1 and the mouthpiece of Figure 2.

Figure 1 shows a shell of an electrically heated smoking system according to one embodiment of the invention. The shell 101 comprises an electric power supply in the form of battery 103, electric circuitry in the form of circuitry 105 and puff detection system 107, a puff indicator 109, electrical connections 111, electrical contacts 113, air inlets 115 and a lock mechanism 117. The shell 101 is designed to engage with the mouthpiece 201 of Figure 2.

Figure 2 shows a mouthpiece of an electrically heated smoking system according to one embodiment of the invention. The mouthpiece 201 comprises a liquid storage portion in the form of cartridge 203 containing liquid 205, a capillary wick 207, a heating element in the form of heating coil 209, an air outlet 211 and an aerosol forming chamber 213. The first end 207a of the capillary wick 207 extends into the cartridge 203 and the second end 207b of the capillary wick 207 is surrounded by the heating coil 209. The mouthpiece also includes a cap 215 to protect the second end 207b of the capillary wick 207 and an insulation ring 217. The mouthpiece 201 is designed to engage with the shell 101 of Figure 1.

Figure 3 shows the shell 101 of Figure 1 engaged with the mouthpiece 201 of Figure 2 to form an electrically heated smoking system 301 arranged to supply aerosol to a user on demand. The shell 101 and mouthpiece 201 are releasably locked together by lock mechanism 117. Ends of the heating coil 209 are in contact with the electrical contacts 113 on the shell. Operation of the system 301 is as follows.

Liquid 205 is transferred from the cartridge 203 from the first end 207a of the wick 207 to the second end 207b of the wick by capillary action. When the user draws on the device at the air outlet 211, ambient air is drawn through air inlets 115. In this embodiment, the puff detection system 107 senses the puff and activates the heating coil 209 and switches on the puff indicator 109. The battery 103 supplies a pulse of energy to the heating coil 209 to heat the second end 207b of the wick 207. The liquid in the second end 207b of the wick 207 is vaporised by the heating coil 209 to create a supersaturated vapour. At the same time, the liquid being vaporised

is replaced by further liquid moving towards the second end 207b of wick by capillary action. (This is sometimes referred to as "pumping action".) The supersaturated vapour created is mixed with and carried in the air flow from the air inlets 115 towards the aerosol forming chamber 213. Because of the relative positions of the air inlets 115 and the mouthpiece 211, the air flow is directed around the second end 207b of the wick so as to optimize formation of the aerosol in the aerosol forming chamber 213. In the aerosol forming chamber 213, the vapour condenses to form an inhalable aerosol, which is carried towards the outlet 211 and into the mouth of a user.

In this embodiment, the circuitry 105 and the puff detection system 107 are programmable. The circuitry 105 and puff detection system 107 can be used to manage the device operation. In this embodiment, when the puff detection system 107 senses the user taking a puff, the battery supplies a current pulse of a pre-determined time to the heating coil 209. The pre-determined time for the current pulse will depend on the amount of liquid required for a single puff, and the time taken for that amount of liquid to be vaporised. That will, in turn, depend on the properties of the liquid, the heating coil and the capillary wick. The pre-determined time may be between 0.5 and 3 seconds.

In this embodiment, the cartridge 203 in the mouthpiece is sized so as to contain sufficient liquid for a pre-determined number of puffs. After that pre-determined number of puffs, the cartridge could be refilled, but preferably the entire mouthpiece is replaced. The pre-determined number of puffs is ideally between 200 and 2000 puffs and this will depend on the desired size of the cartridge, mouthpiece and entire device, and the properties of the liquid being used. The cartridge 203 can be made from any suitable material. Examples include glass and plastic polymers such as PET or others used in the pharmaceutical or food industries. The material should be chosen so as to avoid leakage, breakage or abuse, as far as possible.

In the embodiment shown in Figures 1 to 3, when the shell and mouthpiece are engaged, the cartridge 203 is positioned upstream of the second end 207b of the wick and the heating coil 209. Thus, ambient air is drawn through air inlets 115 and passes around the cartridge 203 before reaching the second end 207b of the wick and the heating coil 209. However, in an alternative embodiment, the mouthpiece may be structured such that, when the shell and mouthpiece are engaged, the cartridge is positioned downstream of the second end of the wick and the heating coil. In that embodiment, the ambient air will be drawn through the air inlets, then the vapour or aerosol will pass around the cartridge on the way to the air outlet.

The capillary wick can be made from a variety of porous or capillary materials and preferably has a known, pre-defined capillarity. Examples include ceramic- or graphite-based materials in the form of fibres or sintered powders. Wicks of different porosities can be used to accommodate different liquid physical properties such as density, viscosity, surface tension and vapour pressure. The wick must be suitable so that the required amount of liquid can be

delivered to the heating coil.

The mouthpiece and shell are sized and shaped so as to engage with one another, so as to produce a suitably sized electrically heated smoking system which can be used by a smoker. The components of the mouthpiece and shell, including the power supply, circuitry, liquid storage portion, wick, heating element and aerosol forming chamber are appropriately sized and shaped for the system design. The system is preferably portable and may have a size similar to that of a conventional cigar or cigarette.

The system of the invention allows the control of particle concentration (mg/l or mg/puff volume) in the aerosol, the average particle size in the aerosol and the distribution (range) of particle sizes in the aerosol. These may be controlled by varying one or more of: the aerosol former formulation in the liquid, the energy transfer (thermal power per unit of surface area) at the heating element, the design of the aerosol forming chamber and the operating temperature. The energy transfer will depend on a number of factors including the materials used for the heating element and the wick, the diameter of the wick, the design of the heating element including, if the heating element is a coil, the length, diameter and pitch (distance between spirals) of the coil, and the power applied to the heating element.

The operating temperature should be controlled to ensure that, as far as possible, no undesirable degradations of the aerosol former or formers and the flavouring material occur. This can be achieved, for example, by controlling the temperature of the heater if the heater is made from a suitable metal or alloy, using the variation in conductivity, or by controlling the amount of energy delivered to the heater. A preferred operating temperature at the heating element is in the range of 100 to 300 °Celsius. The arrangement shown in the Figures can operate within this temperature range, and may also provide a rapid response time (time between the user puffing on the system and the aerosol entering the user's mouth from the air outlet – this may be referred to as "time to puff") of between 10 and 500 ms.

CLAIMS

1. An electrically heated smoking system comprising a shell and a replaceable mouthpiece, the shell comprising an electric power supply and electric circuitry;

the mouthpiece comprising a liquid storage portion, a capillary wick having a first end and a second end, the first end extending into the liquid storage portion for contact with liquid therein, at least one heating element for heating the second end of the capillary wick, an air outlet, and an aerosol forming chamber between the second end of the capillary wick and the air outlet;

wherein, when the shell and mouthpiece are engaged,

the at least one heating element is in electrical connection with the power supply via the circuitry,

the circuitry is arranged to provide an electric current pulse to the at least one heating element when a user initiates a puff, and

a flow route for air is defined from at least one air inlet to the air outlet via the aerosol forming chamber, the flow route channelling the air flow around the heating element and the second end of the capillary wick.

2. An electrically heated smoking system according to claim 1, wherein the at least one heating element comprises a coil of wire surrounding the second end of the capillary wick.

3. An electrically heated smoking system according to claim 1 or claim 2, wherein the electric circuitry comprises a sensor to detect air flow indicative of a user taking a puff.

4. An electrically heated smoking system according to any preceding claim wherein the at least one air inlet is in the shell.

5. A mouthpiece for engaging with a shell to form an electrically heated smoking system, the shell having an electric power supply and electric circuitry, the mouthpiece comprising:

a liquid storage portion;

a capillary wick having a first end and a second end, the first end extending into the liquid storage portion for contact with liquid therein;

at least one heating element for heating the second end of the capillary wick;

an air outlet; and

an aerosol forming chamber between the second end of the capillary wick and the air outlet,

wherein, when the shell and mouthpiece are engaged, the at least one heating element is in

electrical connection with the power supply via the circuitry, the circuitry is arranged to provide an electric current pulse to the at least one heating element when a user initiates a puff, and a flow route for air is defined from at least one air inlet to the air outlet via the aerosol forming chamber, the flow route channelling the air flow around the heating element and the second end of the capillary wick.

6. A mouthpiece according to claim 5, wherein the at least one heating element comprises a coil of wire surrounding the second end of the capillary wick.

7. A shell arranged to engage with the mouthpiece of claim 5 or claim 6.

8. A shell for engaging with a mouthpiece to form an electrically heated smoking system, the mouthpiece having a liquid storage portion, a capillary wick having a first end and a second end, the first end extending into the liquid storage portion for contact with liquid therein, at least one heating element for heating the second end of the capillary wick, an air outlet, and an aerosol forming chamber between the second end of the capillary wick and the air outlet, the shell comprising:

an electric power supply; and

electric circuitry,

wherein, when the shell and mouthpiece are engaged, the at least one heating element is in electrical connection with the power supply via the circuitry, the circuitry is arranged to provide an electric current pulse to the at least one heating element when a user initiates a puff, and a flow route for air is defined from at least one air inlet to the air outlet via the aerosol forming chamber, the flow route channelling the air flow around the heating element and the second end of the capillary wick.

9. A shell according to claim 8, wherein the electric circuitry comprises a sensor to detect air flow indicative of a user taking a puff.

10. A shell according to claim 8 or claim 9, further comprising the at least one air inlet.

11. A mouthpiece arranged to engage with the shell of any of claims 8 to 10.