VAPORIZATION DEVICE CONTROL SYSTEMS AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This patent application claims priority to U.S. Patent Application no. 15/053,927, filed on February 25, 2016, titled "VAPORIZATION DEVICE SYSTEMS AND METHODS." This patent application also claim priority to U.S. patent application no. 15/379,898, filed on December 15, 2016 and titled "VAPORIZATION DEVICE SYSTEMS AND METHODS."

INCORPORATION BY REFERENCE

[0002] All publications and patent applications mentioned in this specification are herein incorporated by reference in their entirety to the same extent as if each individual publication or patent application was specifically and individually indicated to be incorporated by reference.

BACKGROUND

[0003] Electronic inhalable aerosol devices (e.g., vaporization devices, electronic vaping devices, etc.) and particularly electronic aerosol devices, typically utilize a vaporizable material that is vaporized to create an aerosol vapor capable of delivering an active ingredient to a user. Control of the temperature of the resistive heater must be maintained (e.g., as part of a control loop), and this control may be based on the resistance of the resistive heating element.

SUMMARY OF THE DISCLOSURE

[0003a] According to a first aspect of the present invention, there is provided a device including: a microcontroller including circuitry; resistance measurement circuit connected to the microcontroller and configured to measure a resistance of a resistive heater when power is not being applied to the resistive heater, the resistive heater configured to thermally contact a vaporizable material held in a reservoir; and a power source, wherein the microcontroller is configured to: determining a baseline resistance of the resistive heater, the determining of the baseline resistance comprising determining that a change in a measured resistance of the resistive heater with time is below a stability threshold during a period of time when the vaporization device has not been heating the resistive heater, calculating a target resistance of the resistive heater correlating to a temperature of the resistive heater, the target resistance based on the determined baseline resistance and a target change in resistance of the resistive heater, applying power from the power source to heat the resistive heater and adjusting the applied power to the resistive heater based on a difference between the measured resistance of the resistive heater and the target resistance of the resistive heater.

[0003b] According to a second aspect of the present invention, there is provided a method including: determining a baseline resistance of a resistive heater configured to cause vaporization of a vaporizable material that is in thermal contact with the resistive heater, the determining of the baseline resistance comprising determining that a change in a measured resistance of the resistive heater with time is below a stability threshold during a period of time when the vaporization device has not been heating the resistive heater; calculating a target resistance of the resistive heater correlating to a target temperature of the resistive heater, the target resistance based on the determined baseline resistance and a target change in resistance of the resistive heater; applying power to the resistive heater to heat the vaporizable material in thermal contact with the resistive heater; suspending the application of the applied power to the resistive heater while measuring the resistance of the resistive heater; and adjusting the applied power to the resistive heater based on a difference between a measured resistance of the resistive heater and the target resistance of the resistive heater.

[0004] Described herein are vaporization devices and methods of operating them. In particular, described herein are methods for controlling the temperature of a resistive heater (e.g., resistive heating element) by controlling the power applied to a resistive heater of a vaporization device by measuring the resistance of the resistive heater at discrete intervals before (e.g., baseline or ambient temperature) and during vaporization (e.g., during heating to vaporize a material within the device). Changes in the resistance during heating may be linearly related to the temperature of the resistive heater over the operational range, and therefore may be used to control the power applied to heat the resistive heater during operation. Also described herein are vaporization devices that are configured to measure the resistance of the resistive heater during heating (e.g., during a pause in the application of power to heat the resistive heater) and to control the application of power to the resistive heater based on the resistance values.

[0005] In general, in any of the methods and apparatuses described herein, the control circuitry (which may include one or more circuits, a microcontroller, and/or control logic) may compare a resistance of the resistive heater during heating, e.g., following a sensor input indicating that a user wishes to withdraw vapor, to a target resistance of the heating element. The target resistance is typically the resistance of the resistive heater at a desired (and in some cases estimated) target vaporization

CLAIMS

1. A device comprising:

   a microcontroller including circuitry;

   a resistance measurement circuit connected to the microcontroller and configured to measure a resistance of a resistive heater when power is not being applied to the resistive heater, the resistive heater configured to thermally contact a vaporizable material held in a reservoir; and

   a power source,

   wherein the microcontroller is configured to:

   determining a baseline resistance of the resistive heater, the determining of the baseline resistance comprising determining that a change in a measured resistance of the resistive heater with time is below a stability threshold during a period of time when the vaporization device has not been heating the resistive heater,

   calculating a target resistance of the resistive heater correlating to a temperature of the resistive heater, the target resistance based on the determined baseline resistance and a target change in resistance of the resistive heater,

   applying power from the power source to heat the resistive heater and adjusting the applied power to the resistive heater based on a difference between the measured resistance of the resistive heater and the target resistance of the resistive heater.

2. The device of claim 1, further comprising a sensor including an output connected to the microcontroller, wherein the microcontroller is configured to determine, based on the sensor output, when to apply the power from the power source to the resistive heater to heat the resistive heater.

3. The device of claim 1, further comprising a pressure sensor including an output connected to the microcontroller, wherein the microcontroller is

configured to apply the power from the power source to the resistive heater in response to the pressure sensor detecting a change in pressure.

4. The device of claim 1, further comprising a target resistance circuit configured to calculate the target resistance.

5. The device of claim 1, wherein the resistance measurement circuit is configured to compare the resistance of the resistive heater to the target resistance, wherein the measurement circuit comprises a Wheatstone bridge, an amplified Wheatstone bridge, and/or an RC charge time circuit.

6. The device of claim 1, further comprising a memory configured to store the determined baseline resistance of the resistive heater.

7. The device of claim 1, further comprising a temperature input coupled to the microcontroller and configured to provide a device temperature.

8. The device of claim 1, wherein the microcontroller is configured to calculate the temperature of the resistive heater from the measured resistance of the resistive heater and a temperature coefficient of resistivity for the resistive heater and to display the calculated temperature on an output in communication with the microcontroller.

9. The device of claim 1, further comprising a wick in fluid communication with the reservoir and adjacent to the resistive heater.

10. The device of claim 1, wherein the resistive heater comprises a coil.

11. The device of claim 1, wherein the microcontroller is configured to apply the power from the power source to the resistive heater at an applied power duty cycle.

12. The device of claim 11, wherein the microcontroller is configured to apply power at the applied power duty cycle based on a difference between the resistance of the resistive heater and the target resistance of the resistive heater.

13. The device of claim 11, wherein the microcontroller is configured to limit the applied power duty cycle to a maximum duty cycle.

14. The device of claim 13, wherein the maximum duty cycle corresponds to a maximum average power in the resistive heater calculated using a battery voltage measurement and the measured resistance of the resistive heater.

15. The device of claim 11, wherein the period of time is more than 10 seconds.

16. A method comprising:

determining a baseline resistance of a resistive heater configured to cause vaporization of a vaporizable material that is in thermal contact with the resistive heater, the determining of the baseline resistance comprising determining that a change in a measured resistance of the resistive heater with time is below a stability threshold during a period of time when the vaporization device has not been heating the resistive heater;

calculating a target resistance of the resistive heater correlating to a target temperature of the resistive heater, the target resistance based on the determined baseline resistance and a target change in resistance of the resistive heater;

applying power to the resistive heater to heat the vaporizable material in thermal contact with the resistive heater;

suspending the application of the applied power to the resistive heater while measuring the resistance of the resistive heater; and

adjusting the applied power to the resistive heater based on a difference between a measured resistance of the resistive heater and the target resistance of the resistive heater.

17. The method of claim 16, wherein the measured resistance of the resistive heater is measured when the resistive heater has been unpowered for more than 10 seconds and when a change in the resistance of the resistive heater is below the stability threshold of 1% per millisecond.

18. The method of claim 16, wherein the measured resistance of the resistive heater is measured when the resistive heater has been unpowered for more than 20 seconds.

19. The method of claim 16, wherein the measured resistance of the resistive heater is measured when the resistive heater has been unpowered for more than 20 seconds and when a change in the resistance of the resistive heater is below the stability threshold of 5% per millisecond.

20. The method of claim 16, wherein the target resistance is based on the baseline resistance of the resistive heater at an ambient temperature and the target change in temperature of the resistive heater.

21. The method of claim 16, wherein adjusting the power applied to the resistive heater includes using a Wheatstone bridge to compare the resistance of the resistive heater to a reference resistance.

22. The method of claim 16, wherein adjusting the power applied to the resistive heater includes measuring the resistance using a voltage divider, Wheatstone bridge, amplified Wheatstone bridge, or RC charge time circuit.

23. The method of claim 16, further comprising calculating a temperature of the resistive heater from the measured resistance of the resistive heater and a temperature coefficient of resistivity for the heater.

24. The method of claim 16, wherein applying power to the resistive heater to heat the vaporizable material comprises detecting a change in pressure from a pressure sensor indicating that a user is drawing from the vaporization device.

25. The method of claim 16, further comprising placing the vaporizable material in thermal contact with the resistive heater, the placing including wicking the vaporizable material into a wicking material adjacent to the resistive heater.

26. The method of claim 16, wherein applying the power to the resistive heater to heat the vaporizable material comprises applying the power at an applied power duty cycle.

27. The method of claim 26, wherein adjusting the power applied to the resistive heater includes setting the applied power duty cycle based on the difference between the measured resistance of the resistive heater and the target resistance of the resistive heater.

28. The method of claim 26, further comprising limiting the applied power duty cycle to a maximum duty cycle.

29. The method of claim 26, further comprising limiting the applied power duty cycle to a maximum duty cycle that corresponds to a maximum average power in the resistive heater calculated using a battery voltage measurement and the resistance of the resistive heater.

30. The method of claim 16, wherein the period of time is more than 10 seconds.