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(54) **METHOD FOR REDUCING SECONDARY SATELLITES IN INK JET PRINTING**

(57) A method for driving a droplet jetting element comprising a piezo electric actuator in connection with a liquid chamber ending in a nozzle is disclosed. The piezo electric actuator is capable of shaping a volume of the liquid chamber upon application of an electric voltage to the electrodes of the actuator. The method comprises the steps of: filling the liquid chamber with a liquid that is capable of being ejected in droplets from the nozzle and

applying a driving waveform to the piezo electric actuator, wherein the driving waveform comprises a first part for discharging a droplet from the nozzle, shortly followed by a second part for preventing a primary satellite droplet, wherein the second part comprises a variable retention timing to reduce an amount of liquid in a secondary satellite droplet.

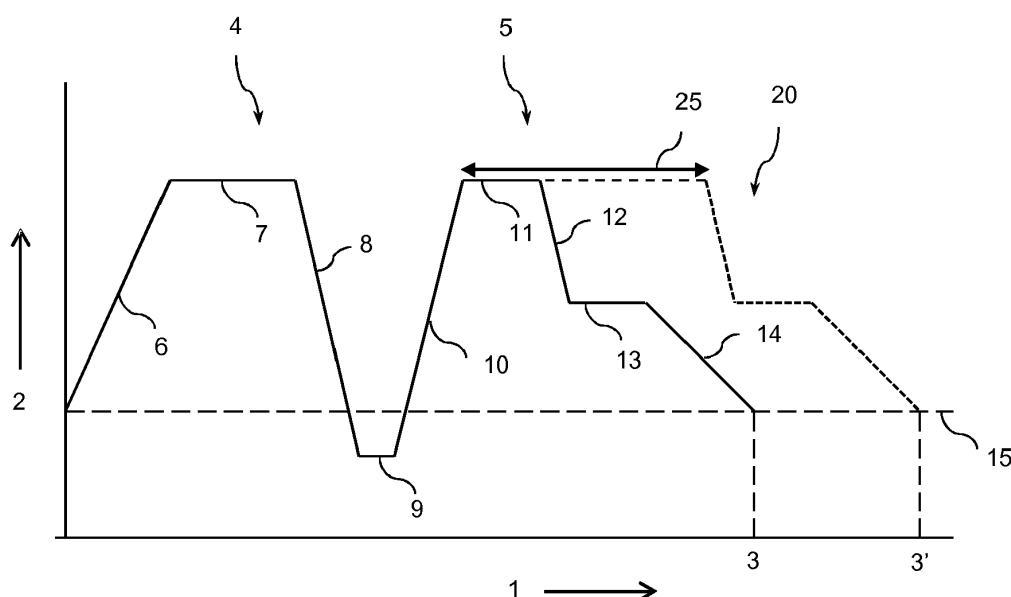


Fig. 1

Description

BACKGROUND OF THE INVENTION

1. Field of the invention

[0001] The invention relates to a method for driving a droplet jetting element comprising a piezo electric actuator in connection with a liquid chamber ending in a nozzle, the piezo electric actuator being capable of shaping a volume of the liquid chamber upon application of an electric voltage to the electrodes of the actuator, the method comprising the steps of: filling the liquid chamber with a liquid that is capable of being ejected in droplets from the nozzle and applying a driving waveform to the piezo electric actuator, wherein the driving waveform comprises a part for discharging a droplet from the nozzle, shortly followed by a part for preventing a primary satellite droplet.

2. Description of the Related Art

[0002] It is well known that a droplet of a liquid may be discharged from a nozzle of a liquid chamber by shaping the volume of the chamber on a timescale comparable to the Helmholtz resonance frequency of the liquid geometry. For example, the chamber is first expanded to draw liquid, such as ink, into the chamber. This expanded state is maintained for a short time and then the chamber is contracted for pushing the liquid out of the chamber in a fill-before-fire driving method. The mechanisms that play a role in the behaviour of the liquid and the formation of droplets are the subject of extensive academic and applied research. The viscosity of the liquid, which is strongly dependent on the liquid temperature, is an important parameter in this behaviour.

[0003] An analysis of the liquid being pushed out of the nozzle of the liquid chamber shows that the liquid initially comes out as a string that breaks up while being separated from a meniscus in or outside the nozzle. At the head of the string a principal droplet materializes, followed by a tail, in which a primary tail, a secondary tail and sometimes even a tertiary tail can be discerned. This analysis involves stroboscopic laser-induced fluorescence microscopy to image the fluid tail dynamics at nanoseconds temporal resolution. The different tails break up into different droplets, called satellites. The primary satellites, stemming from the primary tail, are droplets that mainly follow the path of the principal droplet and may or may not merge with this droplet, depending on their relative speed. The secondary (and tertiary) satellites, stemming from the secondary (and tertiary) tail, are droplets that are usually so small that they quickly lose their speed and are carried away by residual airflow. Their behaviour is comparable to mist. Whereas the primary satellites may disturb the pattern created by the principal droplets, especially when the jetting device is moving relative to a substrate that receives the droplets, as is quite

commonly the case, the further satellites mainly cause pollution of the device wherein the droplet jetting element is operated.

[0004] In US patent application US2010/0182363 a waveform is described that generates a drop of high-viscosity liquid and reduces the generation of other droplets. In particular, the separation of a primary satellite is suppressed by re-expanding the liquid chamber shortly after a contraction to discharge a principal droplet and by re-contracting the liquid chamber in two steps with two different voltage rates. The re-expansion element of the waveform draws in the meniscus of the liquid, causing a pinch off of the principal droplet. The re-contraction element restores the liquid chamber in its initial position. It is noted that sometimes all other droplets than the principal droplet are called mist. However, it is preferred to use the word mist only for the smallest satellites.

[0005] As it turns out, the primary satellite is sufficiently suppressed by application of the above-mentioned waveform, but secondary satellites are still abundantly present. Thus, the device wherein the droplet jetting element is operated, is profusely polluted by the material that is supposed to be jetted in droplets towards a receiving surface. In view of the large number of parameters, it is not straightforward how to adjust the waveform in order to reduce the amount of material in the secondary droplets.

[0006] It is therefore an object of the invention to reduce the amount of material that is ejected from the liquid chamber as mist droplets.

SUMMARY OF THE INVENTION

[0007] In order to achieve this object, the method according to the invention comprises a waveform wherein the second part comprises a variable retention timing to reduce an amount of liquid in a secondary satellite droplet.

[0008] It has been found that the difference of the meniscus speed and the speed of the primary tail can be quite large. This speed difference causes the secondary tail to contain a large amount of material. In fact, it was found that this amount of material can be reduced by changing the moment the meniscus comes out of the nozzle, which is done by altering the moment the re-contraction is set in. Therefore, the re-expanded state of the liquid chamber is maintained with a variable timing so that it can be adjusted to the right moment for reducing the amount of liquid in the secondary satellite droplets.

[0009] Further details of the invention are given in the dependent claims. The present invention may also be embodied in a jetting device.

[0010] Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes

and modifications within the scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

Figure 1 shows a waveform as applicable for viscous liquids;

Figure 2 shows a state of a liquid string being ejected from a nozzle;

Figure 3 shows an amount of material in secondary satellites as a function of the retention timing in the second part of the waveform.

DETAILED DESCRIPTION OF EMBODIMENTS

[0012] The present invention will now be described with reference to the accompanying drawings, wherein the same or similar elements are identified with the same reference numeral.

[0013] The jetting element that is used has a piezo-electric actuator in connection with a liquid chamber ending in a cylindrical nozzle with a diameter of 14 μm and a length of 10 μm . Droplets with an approximate volume of 1 pico-liter (about 12 μm diameter) are produced at a velocity of 6.8 m/s as measured at a distance of 0.5 mm from the nozzle. The liquid jetted from the element is Iso Bornyl Acrylate, which is a single component liquid with a viscosity and surface tension similar to more complex inks that are used in commercial inkjet printing. Resistive heating elements and temperature sensors are incorporated to accurately control and monitor the liquid temperature.

[0014] In Fig. 1 a characteristic shape of the waveform to be applied for a droplet jetting element. The waveform is given as a voltage 2 along the vertical axis as a function of time 1 along the horizontal axis. The total time of the waveform 3 is in the order of 8 to 12 μs . The waveform comprises two parts: a first part 4, comprising an expansion element 6, a retention element 7 and a contraction element 8, has the effect of drawing the liquid into the liquid chamber, waiting for the acoustic wave to propagate and pushing liquid out of the nozzle of the chamber to generate a principal droplet. A short retention time 9 later a second part 5 of the waveform tries to keep the liquid that is not part of the principal droplet inside the liquid chamber and to restore an initial condition. This second part 5 comprises an re-expansion element 10, a retention element 11, a first re-contraction element 12, a retention element 13 and a second re-contraction ele-

ment 14. The base line 15 indicates the voltage of the initial state of the liquid chamber.

[0015] The dashed curve 20 indicates a waveform that gives a different, lower amount of material in secondary satellites that usually end up as pollution around the device comprising the jetting element. The total time 3' of this waveform is substantially longer. However, depending on the conditions during the liquid jetting, the retention time 11 may need to be varied to obtain a minimum of secondary satellites. The length of this timing is indicated by the arrow 25.

[0016] Fig. 2 shows a part of the liquid string 50 coming out of the nozzle of the jetting element at a fixed time. On top the meniscus 51 coming out of the nozzle is visible. Out of the meniscus a secondary tail 52 can be discerned. A transition 53 marks the boundary between the primary tail 54 and the secondary tail 52. The waveform is designed to keep the various tails as short as possible. An amount of material can be estimated from images such as shown in this Fig. 2.

[0017] Fig. 3 shows an amount of material in the secondary tail along the vertical axis 61 in units of femtoliter, as a function of the variable timing 25 in units of micro-seconds along the horizontal axis 60. A first curve 62 is at a slightly higher temperature, meaning a slightly lower viscosity than a second curve 63. Both curves show that a minimum can be found by varying the timing 25 for starting the re-contraction of the liquid chamber.

[0018] The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

Claims

1. A method for driving a droplet jetting element comprising a piezo electric actuator in connection with a liquid chamber ending in a nozzle, the piezo electric actuator being capable of shaping a volume of the liquid chamber upon application of an electric voltage to the electrodes of the actuator, the method comprising the steps of: filling the liquid chamber with a liquid that is capable of being ejected in droplets from the nozzle and applying a driving waveform to the piezo electric actuator, wherein the driving waveform comprises a first part for discharging a droplet from the nozzle, shortly followed by a second part for preventing a primary satellite droplet, wherein the second part comprises a variable retention timing to reduce an amount of liquid in a secondary satellite droplet.
2. A jetting device comprising a droplet jetting element having a piezo electric actuator in connection with a liquid chamber ending in a nozzle, the piezo electric

actuator being capable of shaping a volume of the liquid chamber upon application of an electric voltage to the electrodes of the actuator and a voltage generator that is configured to perform the method according to claim 1.

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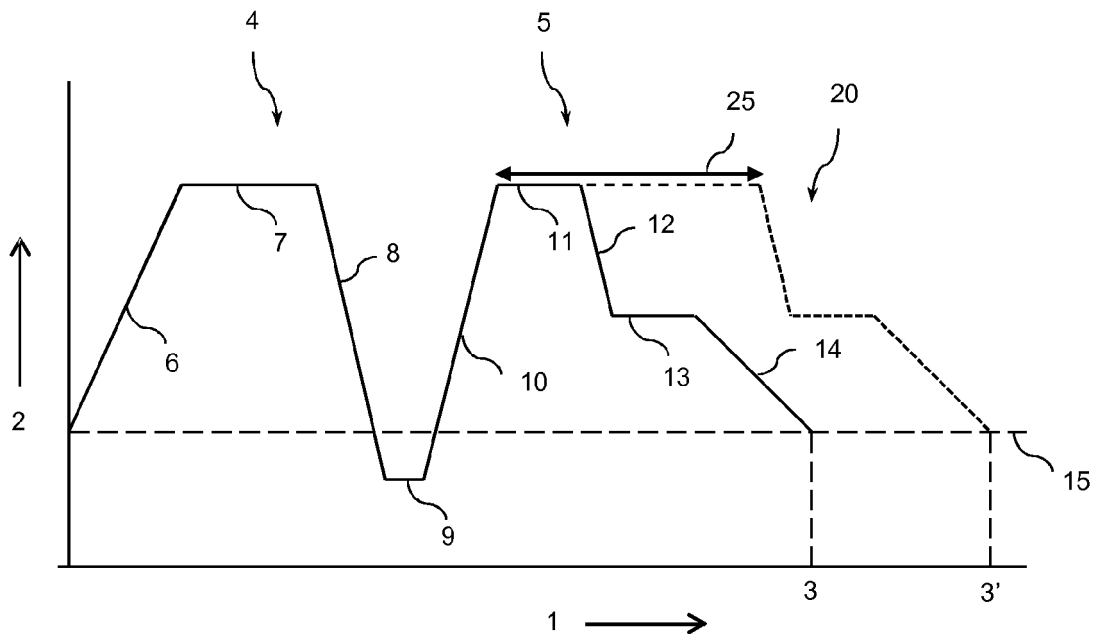


Fig. 1

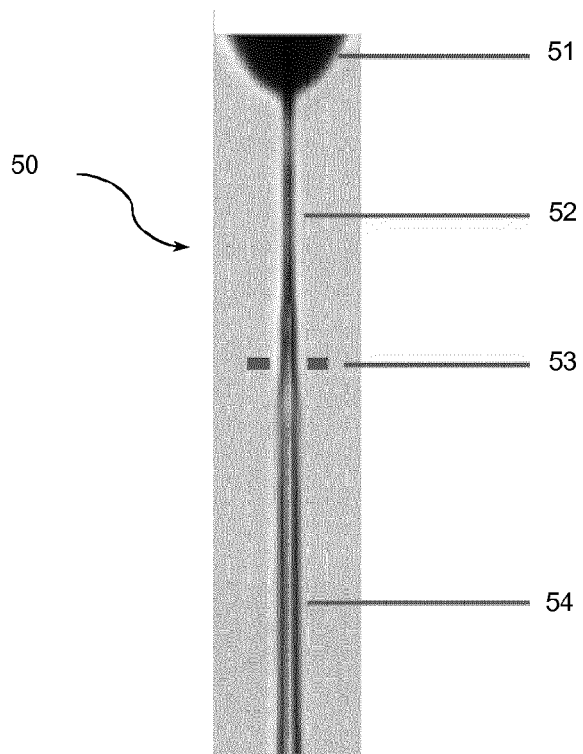


Fig. 2

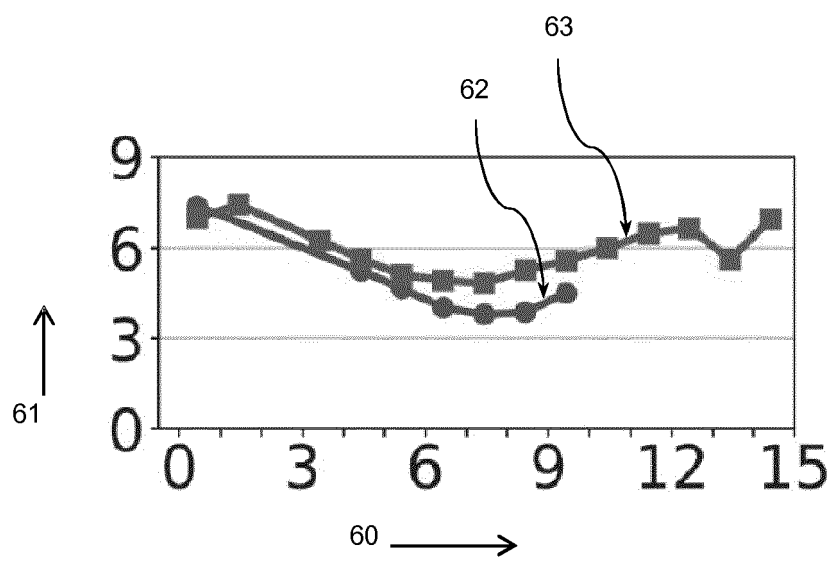


Fig. 3



EUROPEAN SEARCH REPORT

Application Number
EP 18 19 5808

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Place of search		Date of completion of the search	Examiner
The Hague		8 March 2019	Tzianetopoulou, T
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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