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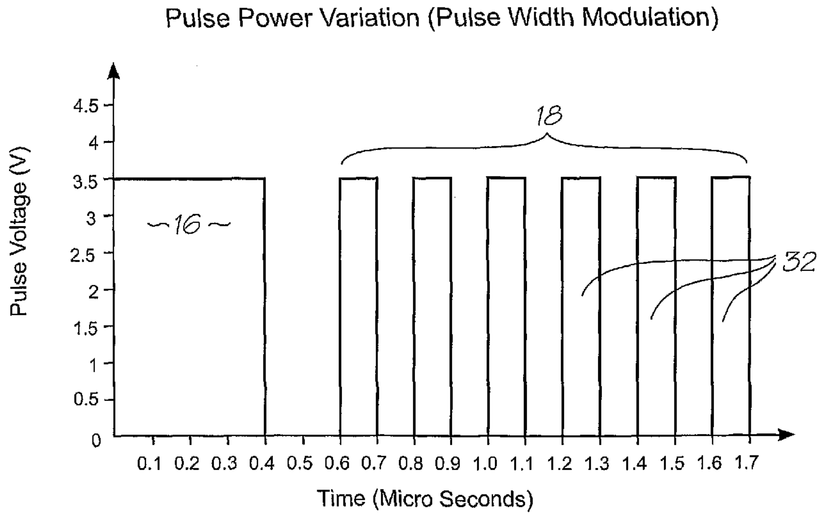
(54) **Title:** INKJET PRINTHEAD WITH ADJUSTABLE BUBBLE IMPULSE



(57) **Abstract:** An inkjet printhead with an array of nozzles (26) and corresponding heaters (10) configured for heating printing fluid (20) to nucleate a vapor bubble (12) that ejects a drop (24) of the printing fluid through the nozzle. Drive circuitry (22) generates an electrical drive pulse to energize the heaters (10) and is configured to adjust the drive pulse power to vary the vapor bubble nucleation time. By varying the power of the pulse used to generate the bubble, the printhead can operate with small, efficiently generated bubbles during normal printing, or it can briefly operate with large high energy bubbles if it needs to recover decapped nozzles.

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INKJET PRINTHEAD WITH ADJUSTABLE BUBBLE IMPULSE

FIELD OF THE INVENTION

The present invention relates to inkjet printers and in particular, inkjet printheads that generate vapor bubbles to eject droplets of ink.

CO-PENDING APPLICATIONS

The following applications have been filed by the Applicant simultaneously with the present application:

PUA001US	PUA002US	PUA003US	PUA004US	PUA005US
PUA006US	PUA007US	PUA008US	PUA009US	PUA010US
PUA011US	PUA012US	PUA013US	PUA014US	PUA015US
MTE001US				

The disclosures of these co-pending applications are incorporated herein by reference. The above applications have been identified by their filing docket number, which will be substituted with the corresponding application number, once assigned.

CROSS REFERENCES TO RELATED APPLICATIONS

Various methods, systems and apparatus relating to the present invention are disclosed in the following US Patents/ Patent Applications filed by the applicant or assignee of the present invention:

09/575197	7079712	09/575123	6825945	09/575165	6813039	6987506
7038797	6980318	6816274	7102772	09/575186	6681045	6728000
09/575145	7088459	09/575181	7068382	7062651	6789194	6789191
6644642	6502614	6622999	6669385	6549935	6987573	6727996
6591884	6439706	6760119	09/575198	6290349	6428155	6785016
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11/482988	11/482989	11/482982	11/482983	11/482984	11/495818	11/495819

An application has been listed by its docket number. This will be replaced when application number is known. The disclosures of these applications and patents are incorporated herein by reference.

BACKGROUND TO THE INVENTION

The present invention involves the ejection of ink drops by way of forming gas or vapor bubbles in a bubble forming liquid. This principle is generally described in US 3,747,120 to Stemme. These devices have heater elements in thermal contact with ink that is disposed adjacent the nozzles, for heating the ink thereby forming gas bubbles in the ink. The gas bubbles generate pressures in the ink causing ink drops to be ejected through the nozzles.

The resistive heaters operate in an extremely harsh environment. They must heat and cool in rapid succession to form bubbles in the ejectable liquid, usually a water soluble ink. These conditions are highly conducive to the oxidation and corrosion of the heater material. Dissolved oxygen in the ink can attack the heater surface and oxidise the heater material. In extreme circumstances, the heaters 'burn out' whereby complete oxidation of parts of the heater breaks the heating circuit.

The heater can also be eroded by 'cavitation' caused by the severe hydraulic forces associated with the surface tension of a collapsing bubble.

To protect against the effects of oxidation, corrosion and cavitation on the heater material, inkjet manufacturers use stacked protective layers, typically made from Si_3N_4, SiC and Ta. Because of the severe operating conditions, the protective layers need to be relatively thick. US 6,786,575 to Anderson et al (assigned to Lexmark) is an example of this structure, and the heater material is ~0.1μm thick while the total thickness of the protective layers is at least 0.7μm.

To form a vapor bubble in the bubble forming liquid, the heater (i.e. the heater material and the protective coatings) must be heated to the superheat limit of the liquid (~300°C for water). This requires a large amount of energy to be supplied to the heater. However, only a portion of this energy is used to vaporize ink. Most of the 'excess' energy must be dissipated by the printhead and or a cooling system. The heat from the excess energy of successive droplet ejections can not raise the steady state temperature of the ink above its boiling point and thereby cause unintentional bubbles. This limits the density of the nozzles on the printhead, the nozzle firing rate and usually necessitates an active cooling system. This in turn has an impact on the print resolution, the printhead size, the print speed and the manufacturing costs.

Attempts to increase nozzle density and firing rate are hindered by limitations on thermal conduction out of the printhead integrated circuit (chip), which is currently the primary cooling mechanism of printheads on the market. Existing printheads on the market require a large heat sink to dissipate heat absorbed from the printhead IC.

Inkjet printheads can also suffer from a problem commonly referred to as 'decap'. This term is defined below. During periods of inactivity, evaporation of the volatile component of the bubble forming liquid will occur at the liquid-air interface in the nozzle. This will decrease the concentration of the volatile component in the liquid near the heater and increase the viscosity of the liquid in the chamber. The decrease in concentration of the volatile component will result in the production of less vapor in the bubble, so the bubble impulse (pressure integrated over area and time) will be reduced: this will decrease the momentum of ink forced through the nozzle and the likelihood of drop break-off. The increase in viscosity will also decrease the momentum of ink forced through the nozzle and increase the critical wavelength for the Rayleigh Taylor instability governing drop break-off, decreasing the likelihood of drop break-off. If the nozzle is left idle for too long, these phenomena will result in a "decapped nozzle" i.e. a nozzle that is unable to eject the liquid in the chamber. The "decap time" refers to the maximum time a nozzle can remain unfired before evaporation will decap the nozzle.

OBJECT OF THE INVENTION

The present invention aims to overcome or ameliorate some of the problems of the prior art, or at least provide a useful alternative.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides an inkjet printhead for printing a media substrate, the printhead comprising:

a plurality of nozzles;

a plurality of heaters corresponding to each of the nozzles respectively, each heater being configured for heating printing fluid to nucleate a vapor bubble that ejects a drop of the printing fluid through the corresponding nozzle; and,

drive circuitry for generating an electrical drive pulse to energize the heaters; wherein,

the drive circuitry is configured to adjust the drive pulse power to vary the vapor bubble nucleation time.

The power supplied to each heater determines the time scale for heating it to the 309°C ink superheat limit, where film boiling on the surface of the heater spontaneously nucleates a bubble. The time scale for reaching the superheat limit determines two things: the energy required to nucleate the bubble and the impulse delivered by the bubble (impulse being pressure integrated over area and time). By varying the power of the pulse used to generate the bubble, the printhead can operate with small, efficiently generated bubbles during normal printing, or it can briefly operate with large high energy bubbles if it needs to recover decapped nozzles.

In preferred embodiments, the power supplied to the heaters in printing mode is sufficient to cause nucleation in less than 1μs, and more preferably between 0.4μs and 0.5μs, and the power supplied to the heaters in maintenance mode results in nucleation times above 1μs.

In some forms, the energy in each printing pulse is less than the maximum amount of thermal energy that can be removed by the drop, being the energy required to heat a volume of the ejectable liquid equivalent to the drop volume from the temperature at which the liquid enters the printhead to the heterogeneous boiling point of the ejectable liquid. In this form, the printhead is "self cooling", a mode of operation in which the nozzle density and nozzle fire rate are unconstrained by conductive heatsinking, an advantage that facilitates integrating the printhead into a pagewidth printer.

In some forms, the power delivered to each heater may be adjusted by changing the voltage level of the pulse supplied to the heater. In other forms, the power is adjusted using pulse width modulation of the voltage pulse, to adjust the time averaged power of the pulse.

Optionally, the drive circuitry is configured to operate in a normal printing mode and a high impulse mode such that the drive pulses are less than 1 microsecond long in the normal printing mode and greater than 1 microsecond long in the high impulse mode.

Optionally, the high impulse mode is a maintenance mode used to recover nozzles affected by decap.

Optionally, the high impulse mode is used to increase the volume of the ejected drops of printing fluid.

Optionally, the high impulse mode is used to compensate for printing fluid with higher viscosity than other printing fluid ejected during the normal printing mode, to provide more consistent drop volumes.

Optionally, each of the drive pulses has less energy than the energy required to heat a volume of the printing fluid equivalent to the drop volume, from the temperature at which the printing fluid enters the printhead to the heterogeneous boiling point of the printing fluid.

Optionally, the drive pulse power is adjusted in response to temperature feedback from the array of nozzles.

Optionally, the drive pulse power is adjusted by changing its voltage.

Optionally, the drive pulse power is adjusted using pulse width modulation to change the time averaged power of the drive pulse.

Optionally, the maintenance mode operates before the printhead prints to a sheet of media substrate.

Optionally, the maintenance mode operates after the printhead prints a sheet of media substrate and before it prints a subsequent sheet of media substrate.

Accordingly in a second aspect the present invention provides a MEMS vapour bubble generator comprising:

a chamber for holding liquid;

a heater positioned in the chamber for thermal contact with the liquid; and,

drive circuitry for providing the heater with an electrical pulse such that the heater generates a vapour bubble in the liquid; wherein,

the pulse has a first portion with insufficient power to nucleate the vapour bubble and a second portion with power sufficient to nucleate the vapour bubble, subsequent to the first portion.

If the heating pulse is shaped to increase the heating rate prior to the end of the pulse, bubble stability can be greatly enhanced, allowing access to a regime where large, repeatable bubbles can be produced by small heaters.

Preferably the first portion of the pulse is a pre-heat section for heating the liquid but not nucleating the vapour bubble and the second portion is a trigger section for nucleating the vapour bubble. In a further preferred form, the pre-heat section has a longer duration than the trigger section. Preferably, the pre-heat section is at least two micro-seconds long. In a further preferred form, the trigger section is less than a micro-section long.

Preferably, the drive circuitry shapes the pulse using pulse width modulation. In this embodiment, the pre-heat section is a series of sub-nucleating pulses. Optionally, the drive circuitry shapes the pulse using voltage modulation.

In some embodiments, the time averaged power in the pre-heat section is constant and the time averaged power in the trigger section is constant. In particularly preferred embodiments, the MEMS vapour bubble generator is used in an inkjet printhead to eject printing fluid from nozzle in fluid communication with the chamber.

Using a low power over a long time scale (typically >> 1μs) to store a large amount of thermal energy in the liquid surrounding the heater without crossing over the nucleation temperature, then switching to a high power to cross over the nucleation temperature in a short time scale (typically < 1μs), triggers nucleation and releasing the stored energy.

Optionally, the first portion of the pulse is a pre-heat section for heating the liquid but not nucleating the vapour bubble and the second portion is a trigger section for superheating some of the liquid to nucleate the vapour bubble.

Optionally, the pre-heat section has a longer duration than the trigger section.

Optionally, the pre-heat section is at least two micro-seconds long.

Optionally, the trigger section is less than one micro-section long.

Optionally, the drive circuitry shapes the pulse using pulse width modulation.

Optionally, the pre-heat section is a series of sub-nucleating pulses.

Optionally, the drive circuitry shapes the pulse using voltage modulation.

Optionally, the time averaged power in the pre-heat section is constant and the time averaged power in the trigger section is constant.

In another aspect the present invention provides a MEMS vapour bubble generator used in an inkjet printhead to eject printing fluid from a nozzle in fluid communication with the chamber.

Optionally, the heater is suspended in the chamber for immersion in a printing fluid.

Optionally, the pulse is generated for recovering a nozzle clogged with dried or overly viscous printing fluid.

TERMINOLOGY

"Power" in the context of this specification is defined as the energy required to nucleate a bubble, divided by the nucleation time of the bubble.

Throughout the specification, references to 'self cooled' or 'self cooling' nozzles will be understood to be nozzles in which the energy required to eject a drop of the ejectable liquid is less than the maximum amount of thermal energy that can be removed by the drop, being the energy required to heat a volume of the ejectable fluid equivalent to the drop volume from the temperature at which the fluid enters the printhead to the heterogeneous boiling point of the ejectable fluid.

The term "decap" is a reference to the phenomenon whereby evaporation from idle nozzles reduces the concentration of water in the vicinity of the heater (reducing bubble impulse) and increases the viscosity of the ink (increasing flow resistance). The term "decap time" is well known and often used in this field. Throughout this specification, "the decap time" is the maximum interval that a nozzle can remain unfired before evaporation of the volatile component of the bubble forming liquid will render the nozzle incapable of ejecting the bubble forming liquid.

The printhead according to the invention comprises a plurality of nozzles, as well as a chamber and one or more heater elements corresponding to each nozzle. Each portion of the printhead pertaining to a single nozzle, its chamber and its one or more elements, is referred to herein as a "unit cell".

In this specification, where reference is made to parts being in thermal contact with each other, this means that they are positioned relative to each other such that, when one of the parts is heated, it is capable of heating the other part, even though the parts, themselves, might not be in physical contact with each other.

Also, the term "printing fluid" is used to signify any ejectable liquid, and is not limited to conventional inks containing colored dyes. Examples of non-colored inks include fixatives, infra-red absorbant inks, functionalized chemicals, adhesives, biological fluids, water and other solvents, and so on. The ink or ejectable liquid also need not necessarily be a strictly a liquid, and may contain a suspension of solid particles or be solid at room temperature and liquid at the ejection temperature.

Brief Description of the Drawings

Preferred embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a sketch of a single unit cell from a thermal inkjet printhead;

Figure 2 shows the bubble formed by a heater energised by a 'printing mode' pulse;

Figure 3 shows the bubble formed by a heater energised by a 'maintenance mode' pulse;

Figure 4 is a voltage versus time plot of the variation of the pulse power using amplitude modulation; and,

Figure 5 is a voltage versus time plot of the variation of the pulse power using pulse width modulation.

Detailed Description of the Preferred Embodiments

Figure 1 shows the MEMS bubble generator of the present invention applied to an inkjet printhead. A detailed description of the fabrication and operation of some of the Applicant's thermal printhead IC's is provided in USSN 11/097,308 and USSN 11/246,687. In the interests of brevity, the contents of these documents are incorporated herein by reference.

A single unit cell 30 is shown in Figure 1. It will be appreciated that many unit cells are fabricated in a close-packed array on a supporting wafer substrate 28 using lithographic etching and deposition techniques common within in the field semi-conductor/MEMS fabrication. The chamber 20 holds a quantity of ink. The heater 10 is suspended in the chamber 20 such that it is in electrical contact with the CMOS drive circuitry 22. Drive pulses generated by the drive circuitry 22 energize the heater 10 to generate a vapour bubble 12 that forces a droplet of ink 24 through the nozzle 26.

The heat that diffuses into the ink and the underlying wafer prior to nucleation has an effect on the volume of fluid that vaporizes once nucleation has occurred and consequently the impulse of the vapor explosion (impulse = force integrated over time). Heaters driven with shorter, higher voltage heater pulses have shorter ink decap times. This is explained by the reduced impulse of the vapor explosion, which is less able to push ink made viscous by evaporation through the nozzle.

Using the drive circuitry 22 to shape the pulse in accordance with the present invention gives the designer a broader range of bubble impulses from a single heater and drive voltage.

Figure 2 is a line drawing of a stroboscopic photograph of a bubble 12 formed on a heater 10 during open pool testing (the heater is immersed in water and pulsed). The heater 10 is 30 microns by 4 microns by 0.5 microns and formed from TiAl mounted on a silicon wafer substrate. The pulse was 3.45 V for 0.4 microseconds making the energy consumed 127 nJ. The strobe captures the bubble at it's maximum extent, prior to condensing and collapsing to a collapse point. It should be noted that the dual lobed appearance is due to reflection of the bubble image from the wafer surface.

The time taken for the bubble to nucleate is the key parameter. Higher power (voltages) imply higher heating rates, so the heater reaches the bubble nucleation temperature more quickly, giving less time for heat to conduct into the heater's surrounds, resulting in a reduction in thermal energy stored in the ink at nucleation. This in turn reduces the amount of water vapor produced and therefore the bubble impulse. However, less energy is required to form the bubble because less heat is lost from the heater prior to nucleation. This is, therefore, how the printer should operate during normal printing in order to be as efficient as possible.

Figure 3 shows the bubble 12 from the same heater 10 when the pulse is 2.20 V for 1.5 microseconds. This has an energy requirement of 190 nJ but the bubble generated is much larger. The bubble has a greater bubble impulse and so can be used for a maintenance pulse or to eject bigger than normal drops. This permits the printhead to have multiple modes of operation which are discussed in more detail below.

Figure 4 shows the variation of the drive pulse using amplitude modulation. The normal printing mode pulse 16 has a higher power and therefore shorter duration as nucleation is reached quickly. The large bubble mode pulse 18 has lower power and a longer duration to match the increased nucleation time.

Figure 5 shows the variation of the drive pulse using pulse width modulation. The normal printing pulse 16 is again 3.45 V for 0.4 microseconds. However, the large bubble pulse 18 is a series of short pulses 32, all at the same voltage (3.45 V) but only 0.1 microseconds long with 0.1 microsecond breaks between. The power during one of the short pulses 32 is the same as that of the normal printing pulse 16, but the time averaged power of the entire large bubble pulse is lower.

Lower power will increase the time scale for reaching the superheat limit. The energy required to nucleate a bubble will be higher, because there is more time for heat to leak out of the heater prior to nucleation (additional energy that must be supplied by the heater). Some of this additional energy is stored in the ink and causes more vapor to be produced by nucleation. The increased vapor provides a bigger bubble and therefore greater bubble impulse. Lower power thus results in increased bubble impulse, at the cost of increased energy.

This permits the printhead to operate in multiple modes, for example:

a normal printing mode with high power delivered to each heater (low bubble impulse, low energy requirement);

a maintenance mode with low power delivered to each heater to recover decapped nozzles (high bubble impulse, high energy requirement);

a start up mode with lower power drive pulses when the ink is at a low temperature and therefore more viscous;

a draft mode that prints only half the dots (for greater print speeds) with lower power drive pulses for bigger bubbles to increase the volume of the ejected drops thereby improving the look of the draft image; or,

a dead nozzle compensation mode where larger drops are ejected from some nozzles to compensate for dead nozzles within the array.

A primary objective for the printhead designer is low energy ejection, particularly if the nozzle density and nozzle fire rate (print speed) are high. The Applicant's MTC001US referenced above provides a detailed discussion of the benefits of low energy ejection as well as a comprehensive analysis of energy consumption during the ejection process. The energy of ejection affects the steady state temperature of the printhead, which must be kept within a reasonable range to control the ink viscosity and prevent the ink from boiling in the steady state. However, there is a drawback in designing the printhead for low energy printing: the low bubble impulse resulting from low energy operation makes the nozzles particularly sensitive to decap. Depending on the nozzle idle time and extent of decap, it may not be possible to eject from decapped nozzles with a normal printing pulse, because the bubble impulse may be too low. It is desirable, therefore, to switch to a maintenance mode with higher bubble impulse if and when nozzles must be cleared to recover from or prevent decap e.g. at the start of a print job or between pages. In this mode the printhead temperature is not as sensitive to the energy required for each pulse, as the total number of pulses required for maintenance is lower than for printing and the time scale over which the pulses can be delivered is longer.

Similarly, temperature feedback from the printhead can be used as an indication of the ink temperature and therefore, the ink viscosity. Modulating the drive pulses can be used to ensure consistent drop volumes. The printhead IC disclosed in the co-pending PUA001US to PUA015US (cross referenced above) describe how 'on chip' temperature sensors can be incorporated into the nozzle array and drive circuitry.

The invention has been described herein by way of example only. Ordinary workers in this field will readily recognize many variations and modifications which do not depart from the spirit and scope of the broad inventive concept.

CLAIMS

1. An inkjet printhead for printing a media substrate, the printhead comprising:

a plurality of nozzles;

a plurality of heaters corresponding to each of the nozzles respectively, each heater being configured for heating printing fluid to nucleate a vapor bubble that ejects a drop of the printing fluid through the corresponding nozzle;

drive circuitry for generating an electrical drive pulse to energize the heaters; wherein,

the drive circuitry is configured to adjust the drive pulse power to vary the vapor bubble nucleation time.

2. An inkjet printhead according to claim 1 wherein the drive circuitry is configured to operate in a normal printing mode and a high impulse mode such that the drive pulses are less than 1 microsecond long in the normal printing mode and greater than 1 microsecond long in the high impulse mode.

3. An inkjet printhead according to claim 2 wherein the high impulse mode is a maintenance mode used to recover nozzles affected by decap.

4. An inkjet printhead according to claim 2 wherein the high impulse mode is used to increase the volume of the ejected drops of printing fluid.

5. An inkjet printhead according to claim 2 wherein the high impulse mode is used to compensate for printing fluid with higher viscosity than other printing fluid ejected during the normal printing mode, to provide more consistent drop volumes.

6. An inkjet printhead according to claim 1 wherein each of the drive pulses has less energy than the energy required to heat a volume of the printing fluid equivalent to the drop volume, from the temperature at which the printing fluid enters the printhead to the heterogeneous boiling point of the printing fluid.

7. An inkjet printhead according to claim 1 wherein the drive pulse power is adjusted in response to temperature feedback from the array of nozzles.

8. An inkjet printhead according to claim 1 wherein the drive pulse power is adjusted by changing its voltage.

9. An inkjet printhead according to claim 1 wherein the drive pulse power is adjusted using pulse width modulation to change the time averaged power of the drive pulse.

10. An inkjet printhead according to claim 3 wherein the maintenance mode operates before the printhead prints to a sheet of media substrate.

11. An inkjet printhead according to claim 1 wherein the maintenance mode operates after the printhead prints a sheet of media substrate and before it prints a subsequent sheet of media substrate.

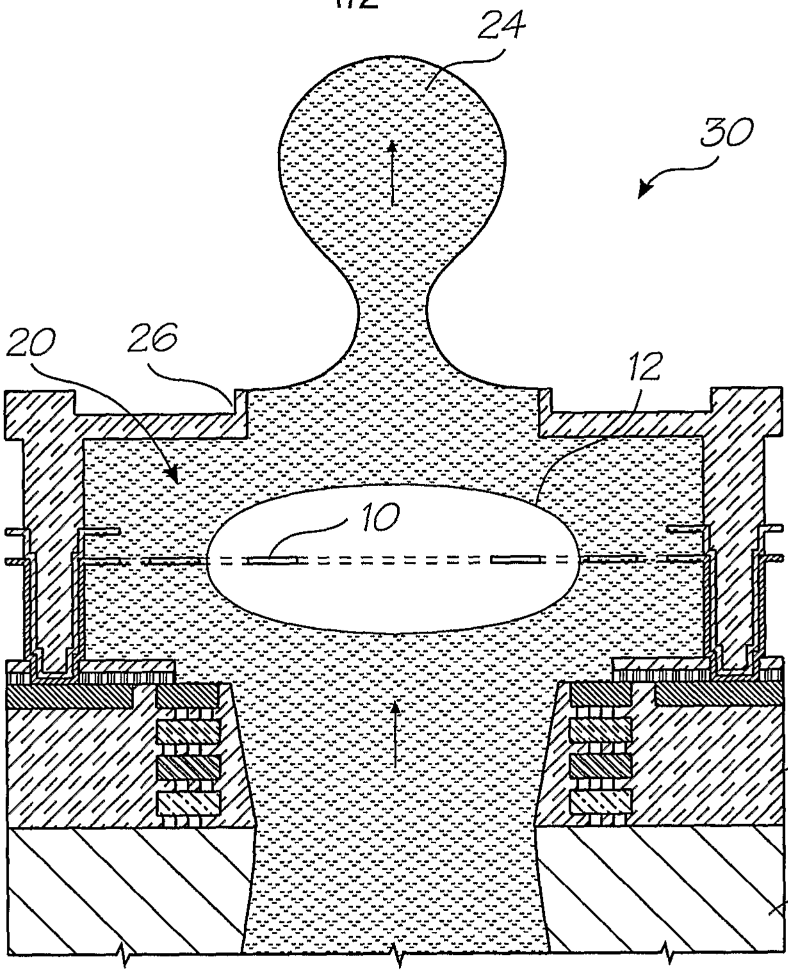

FIG. 1

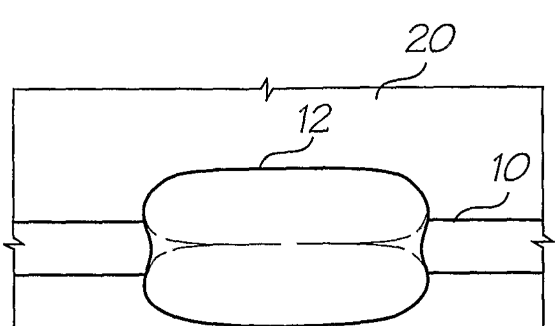

FIG. 2

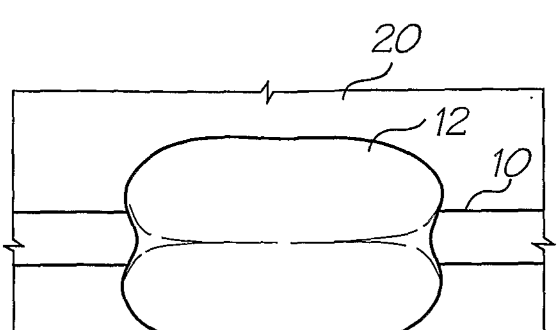

FIG. 3

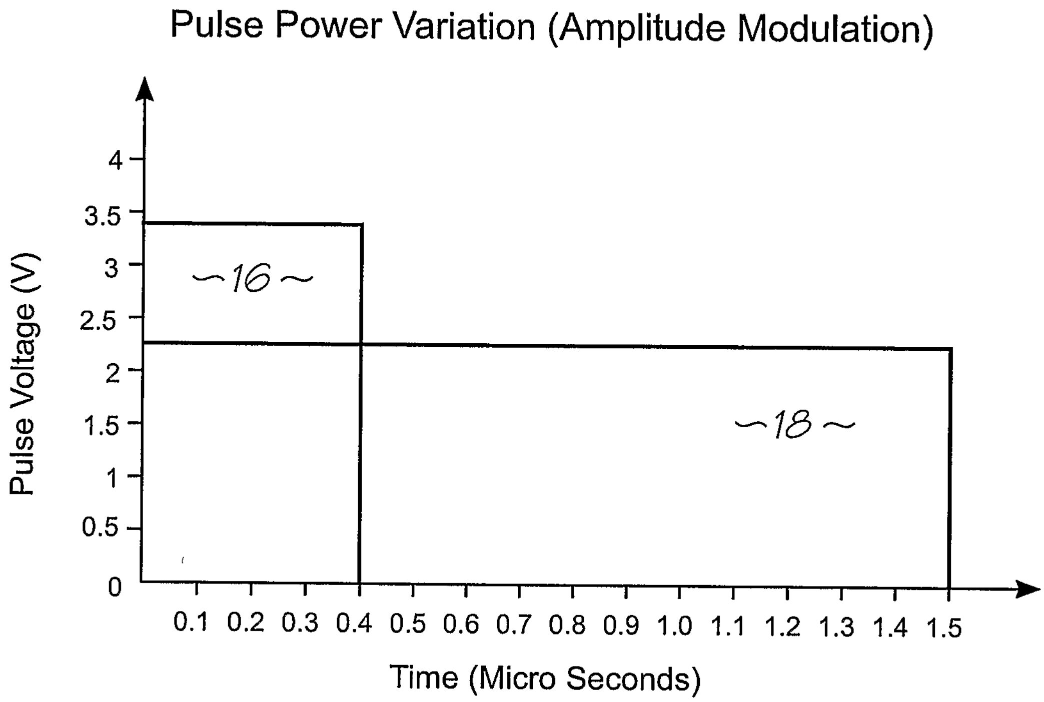
Pulse Power Variation (Amplitude Modulation)
Pulse Voltage (V)
4
3.5
3
2.5
2
1.5
1
0.5
0
16
18
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
Time (Micro Seconds)

FIG. 4

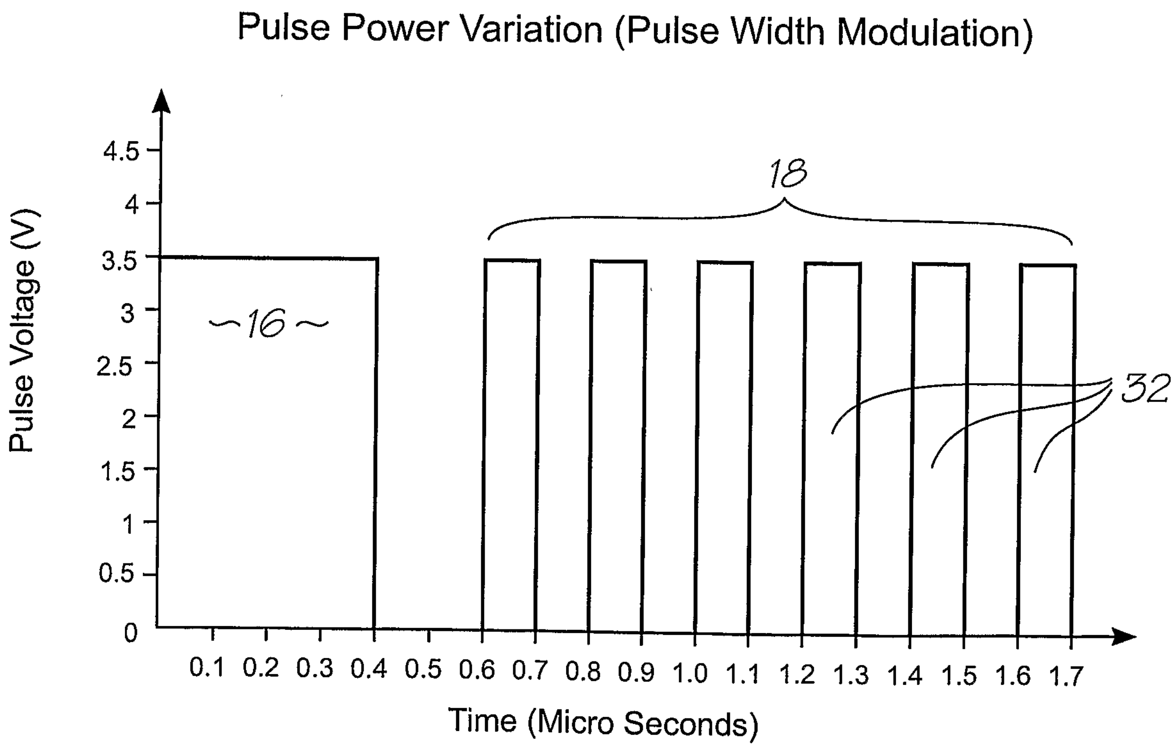
Pulse Power Variation (Pulse Width Modulation)
Pulse Voltage (V)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
16
18
32
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7
Time (Micro Seconds)

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2006/001476

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

B41J 2/05 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DWPI - IPC B41J/IC; & keywords (inkjet, bubblejet, printhead, MEMS, heat+, thermal+, vapor+, nucleat+, gas+, bubble+, driv+, +circuit+, electric+, control+, pulse, duty, period, frequency, duration, cycle, adjust, vari+, vary, chang+, alter+, regulat+, pwn, modulat+, nozzle, aperture, outlet, plural+, many, multi+, several)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/0280671 A1 (SILVERBROOK et al.) 22 December 2005 See in particular figures 1 to 9 and 50 and paragraphs [0364-0365] and [0542-0543].	1 to 11
X	US 2006/0221136 A1 (SILVERBROOK et al.) 5 October 2006 See in particular figures 1 to 5 and 50 and paragraphs [0346-0347] and [0500-0501].	1 to 11
X	US 6,974,209 B2 (SILVERBROOK) 13 December 2005 See in particular figures 1 to 5 and column 18 lines 12 to 43.	1 to 11

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 November 2006	24 NOV 2006

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C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/0007267 A1 (SILVERBROOK et al.) 12 January 2006 See in particular figures 1 to 5 and paragraphs [0184-0185].	1 to 11
X	US 2006/0087533 A1 (SILVERBROOK) 27 April 2006 See in particular figures 1 to 5 and paragraphs [0200-0201].	1 to 11
X	US 2006/0092233 A1 (SILVERBROOK) 4 May 2006 See in particular figures 1 to 5 and paragraphs [0191-0192].	1 to 11
X	US 2006/0125883 A1 (SILVERBROOK) 15 June 2006 See in particular figures 1 to 5 and paragraphs [0175-0176].	1 to 11

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	2005280671	AU	2003275797	CA	2506725	CN	1713994
		EP	1567349	US	6736489	US	6974209
		US	2004100525	US	2004212662	US	2006125883
		WO	2004048106				
US	2006221136	AU	2003275797	CA	2506725	CN	1713994
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		US	2004100525	US	2004212662	US	2005280671
		US	2006125883	WO	2004048106		
US	2006007267	AU	2003280215	CA	2506731	CN	1713996
		EP	1565317	US	6692108	US	7086719
		US	7101025	US	2004246307	US	2006055736
		WO	2004048108				
US	2006087533	AU	2003275793	CA	2506702	CN	1713990
		EP	1567347	US	7086718	US	2004100527
		US	2006238574	WO	2004048103		
US	2006092233	AU	2003275792	CA	2506701	CN	1713993
		EP	1565318	US	6755509	US	6830318
		US	6991322	US	7018021	US	7108355
		US	7108356	US	7111926	US	7118197
		US	7118198	US	7118201	US	7118202
		US	7128400	US	7128402	US	2004100523
		US	2004100531	US	2004100532	US	2004100533
		US	2004113985	US	2004113987	US	2004113988
		US	2004119786	US	2004155929	US	2004155932
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		US	2004160490	US	2004160491	US	2004160492
		US	2004160493	US	2004183863	US	2004183864
		US	2005099464	US	2005179741	US	2005264616
		US	2006077234	US	2006092232	US	2006109318

		WO	2004048102				
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		EP	1567349	US	6736489	US	6974209
		US	2004100525	US	2004212662	US	2005280671
		WO	2004048106				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX