United States Patent

Yanou et al.

[15] **3,662,399**

[45] **May 9, 1972**

[54] NOZZLE FOR INK JET AND METHOD FOR MANUFACTURING THE SAME

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[73] Assignee: **Casio Computer Kabushiki Kaisha,** Tokyo, Japan

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[30] **Foreign Application Priority Data**

May 19, 1969 Japan.....44/45369

[52] **U.S. Cl.**.....**346/140,** 117/124 F, 239/DIG. 19

[51] **Int. Cl.**.....**G01d 15/18**

[58] **Field of Search**.....346/75, 140; 239/15, DIG. 19; 117/124 F

[56] **References Cited**

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Primary Examiner—Joseph W. Hartary
Attorney—Nelson H. Shapiro

[57] **ABSTRACT**

An ink jet recording device has a movable writing head which involves at least one ink nozzle for ejecting a stream of ink jet to synthesize characters on the recording medium by controlling the stream of ink jet. Such kind of nozzle comprises a capillary made of a hard glass. Over the outer surface of the capillary a coating is deposited. This coating is selected from materials, such as silicones, which have water-repellent characteristic and large angle of contact. After the coating is deposited, the coated capillary is cut into desired length to fabricate the nozzle.

5 Claims, 6 Drawing Figures

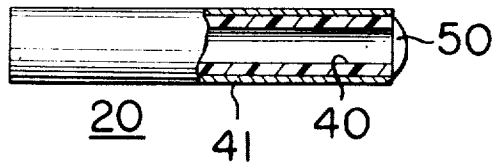


FIG. 1

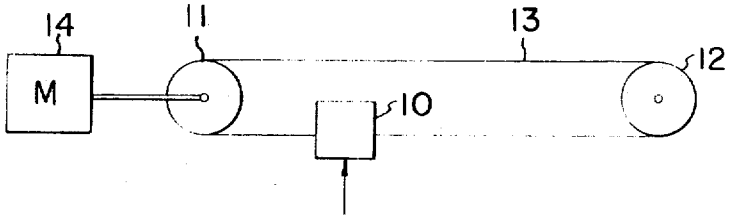


FIG. 2

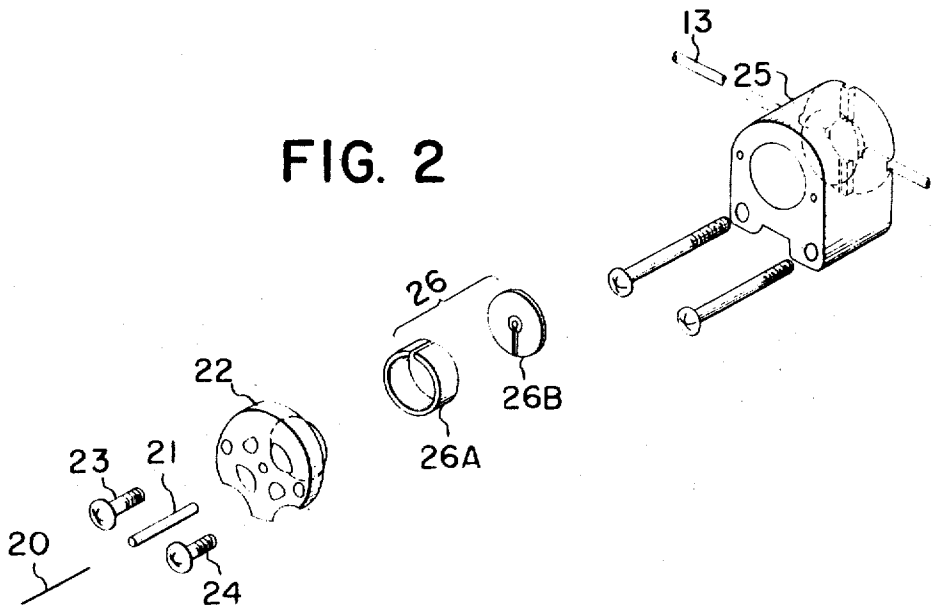


FIG. 3

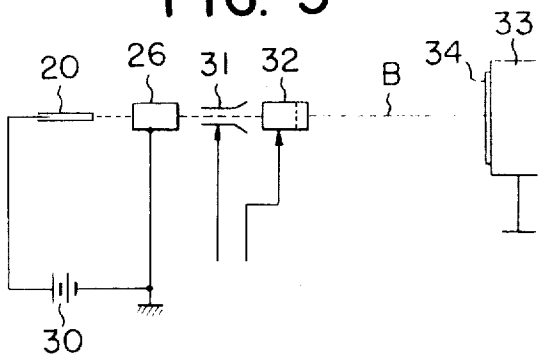


FIG. 4

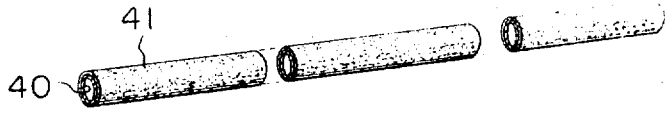


FIG. 5

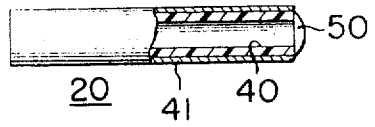
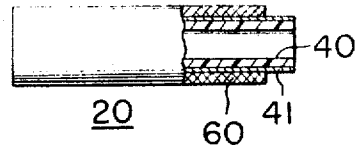


FIG. 6



NOZZLE FOR INK JET AND METHOD FOR MANUFACTURING THE SAME

The present invention relates to a nozzle for ejecting a stream of ink jet for use in an ink jet recording device and a method for making the same.

An ink jet recording device for forming the characters, alphanumerics, symbols, etc. by ink jet which consists of ink droplets electrostatically impinged upon a recording medium is disclosed for example in U.S. Pat. No. 3,060,429. Such kind of device comprises a platen bearing a recording medium thereupon and a writing head which is relatively moved with respect to the platen. The writing head comprises at least one nozzle for ejecting electrostatically a stream of charged ink jet consisting of ink droplets, an accelerating electrode for accelerating the ejected charged ink droplets and horizontal and vertical deflection electrodes for controlling the ink droplets. The ink jet consisting of ink droplets is continuously ejected from the nozzle of the writing head so as to impinge upon the desired positions upon the recording medium, thereby to synthesize the characters, alphanumerics, symbols, etc.

The ink jet ejected from the nozzle must be precisely controlled in order to synthesize the desired characters and the like. The erratic control results in the deformation of the characters and the like recorded on the medium. That is, the ejection of a stream of ink jet must be controlled under the severe conditions so that the nozzle must be made to exacting the specifications to provide desired performances. The diameter of the nozzle must be selected first depending upon the size of characters, alphanumerics, symbols, etc., which size is for example 2.6 × 1.8 mm when the ink jet recording device is used as an output equipment of an electronic computer. The diameter of the nozzle for this size is of course dependent upon the mechanical and electrical designs of the recording device and is generally of the order of microns. For example, the inner diameter of the nozzle is 80 microns while the outer diameter, 150 microns.

The materials for the nozzles therefore must be ones which may be fabricated into the nozzles having desired diameters in a simple manner. Moreover, the ink must adhere to the materials with ease so that the undesired flowing or dropping of the ink from the leading end or orifice of the nozzle may be prevented. That is, the angle of contact of ink to the nozzle may be reduced as much as possible. On the other hand, to form the uniform characters the ink droplets must be ejected uniformly from the lading end or orifice of the nozzle. More specifically a uniform meniscus of ink must be formed at the leading end of the nozzle.

It is therefore one of the objects of the present invention to provide an improved nozzle for ejecting ink droplets which may satisfy every exacting conditions described hereinabove.

It is another object of the present invention to provide a novel method for fabrication of a nozzle for ejecting ink jet or droplets which is best suited for synthesizing the characters and the like upon a recording medium without causing any deformation.

In general, the present invention is based upon the discovery that it is the glass that is the best suited material for fabrication of the nozzles as described above and the amount of an ink droplet ejected from the nozzle is held constant by disposing on the outer circumference of the glass a material having a greater contact angle relative to an ink droplet than the glass. A glass capillary having an inner and outer diameters of the order of microns may be fabricated in a simple manner and the ink droplet may contact with the capillary at a less angle of contact. The use of the glass results in the simplification of the nozzle fabrication as compared with other materials. Because of the smaller angle of contact to the nozzle, the ink droplet may be readily adhered to the nozzle.

A field of the order of 10^4 V/cm is generally applied between the nozzle and an accelerating electrode of the writing head of the ink jet type recording device. From the standpoint of deformation and strain, the glass is more stable than metals. In this connection, the discharge starting voltage of a metal in the air is of the order of 10^4 V/cm.

As pointed out above, there is an advantage that the ink may readily adhere to the glass nozzle because of the smaller angle of contact. However, the ejection of uniform ink droplets may become difficult when the configuration of meniscus formed at the leading end or orifice of the nozzle is varied when the nozzle is once wetted with the ink due to the variation in voltage and to the mechanical vibrations of the writing head. The formed characters are deformed and unclear.

In accordance with the present invention, the outer surface of a glass nozzle is coated with a material to which repels the ink at a large angle of contact. It was found out by the present inventor that silicones is a best suited coating material for this purpose. According to one aspect of the present invention, a silicones coating is applied to the outer surface of a glass capillary before it is cut into a desired nozzle length. As pointed out above, the diameter of the nozzle is exceedingly small so that it has been difficult in the prior art to avoid the formation of the coating over the inner surface and ends of the nozzle. But this problem is now completely solved by the present invention. Moreover, a meniscus uniform in configuration may be formed at the leading end or orifice of the nozzle.

The above and other objects, features and advantages of the present invention will become more apparent from the following description of one illustrative embodiments thereof taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a schematic diagram illustrating a writing part of an ink jet recording device to which is applied the present invention in one form;

FIG. 2 is an exploded perspective view of a main part of the writing head;

FIG. 3 is a schematic diagram of electrical components for producing desired electric fields between the associated parts of the ink jet recording device;

FIG. 4 is a perspective view illustrating the steps of fabricating a nozzle in accordance with the present invention;

FIG. 5 is a front view partly in section thereof; and

FIG. 6 is a front view partly in section of the nozzle shown in FIG. 5 provided with a protective tube or sheath.

Referring to FIG. 1, an ink jet writing head **10** is carried for reciprocal movement by a wire **13** wrapped around a pair of pulleys **11** and **12** which are driven by a motor **14**. When the writing head **10** is displaced in one direction, the ink jet is ejected and impinged upon a recording medium (not shown) in response to the control signals, thereby synthesizing the characters as will be described in more detail hereinafter.

FIG. 2 shows the major structural parts of the writing head **10**. The writing head **10** is provided with at least one nozzle **20** which is fitted into a nozzle pipe **21** securely fixed to a nozzle holder **22**. The holder **22** in turn is securely fixed to a writing head proper **25** by bolts **23** and **24**. An acceleration electrode **26** comprising an acceleration ring **26A** and an acceleration plate **26B** is disposed forwardly of the nozzle holder **22**. Horizontal and vertical deflecting electrodes (not shown) to which are applied the control signals are disposed forwardly of the acceleration electrode **26**.

FIG. 3 is a diagrammatical view illustrating the principle of generating the electrostatic fields between the ink nozzle **20** and the acceleration electrode **26** and between the nozzle **20** and a platen **33**. A positive electrode is placed in the nozzle **20** made of a glass. The electrically conductive ink to be supplied into the nozzle **20** is applied with a positive potential. Both of the acceleration electrode **26** and the platen **33** are grounded. A power source **30** has a high voltage of the order of for example 2,700 V. As is the case of the conventional cathode ray tube, the vertical and horizontal deflecting electrodes **31** and **32** are disposed forwardly of the acceleration electrode **26**. The ejected ink droplets are accelerated by the acceleration electrode **26**, then deflected by the vertical and horizontal electrodes **31** and **32** in response to the control signals applied thereto and impinged at a desired position upon a recording medium **34** placed upon the platen **33**. Thus, the characters each consisting of a dot pattern may be sequentially synthesized upon the recording medium **34** by the ink droplets ejected in the manner described above.

FIG. 4 is a perspective view for explanation of a method for fabrication of a glass nozzle. The glass capillary **40** is exaggerated in certain dimensions for more clearly explaining the present invention, but in practice, the inner diameter is of the order of 80 microns while the outer diameter, of the order of 150 microns. The glass of the types described below may be utilized in the present invention.

SODA GLASS

SiO_2	72%
Na_2O	15%
CaO	9%
MgO	3%
Al_2O_3	1%

BOROSILICATE GLASS

SiO_2	80%
B_2O_3	14%
Na_2O	4%
Al_2O_3	2%

QUARTZ GLASS

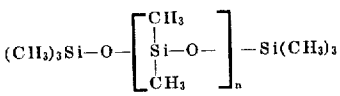
SiO_2	100%

Pyrex GLASS

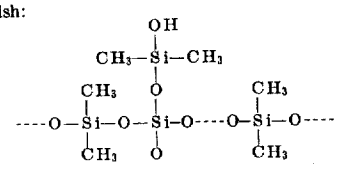
SiO_2	80.6 %
B_2O_3	11.9%
Na_2O	3.83%
Al_2O_3	2.00%
Fe_2O_3	0.16%
K_2O	1.51%

In addition to the above-mentioned hard glasses such as crystal glass including the ingredients such as ZrO_2 and P_2O_5 may be used. Especially borosilicate glass is advantageous. A water-repellent coating **41** of for example silicones is applied upon the capillary **40** made of a hard glass of the type described hereinabove. The sources of coating are silicon oil, silicon varnish, silicon rubber, silicon resin, etc., whose chemical structures are shown below:

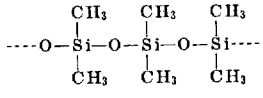
Silicon oil:



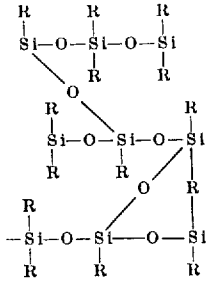
Silicon varnish:



Silicon rubber:



Silicon resin:



Where the properties of the resins vary depending upon the types of R and a R/Si ratio. R designates CH_3—, C_2H_5—, C_6H_5— Silicon resins tend to harden when heated at about 180° C.

When the coating **41** upon the glass capillary **40** is cured, it is cut into a predetermined length, thus providing a nozzle. This process is advantageous because no silicon adhesion to the both ends of the nozzle occurs. Furthermore, the complete coating is formed over the outer surface of the nozzle.

FIG. **5** depects the nozzle **20** fabricated in accordance with the present invention. As pointed out above, the nozzle **20** comprises the capillary **40** made of a hard glass and the coating **41** applied over the outer surface of the capillary **40**. As clearly seen from FIG. **5**, no coating is formed over the inner surface and ends of the capillary **40** so that the ink droplet may adhere to these uncoated portions. Because of the water-repellent coating **41**, even when the leading end of the outer surface of the capillary **40** is wetted by the ink by some reasons, the force acts upon the ink due to the difference between the angles of contact of the ink to the capillary **40** and the coating **41** so that the ink may be immediately repelled toward the leading end or orifice of the nozzle. A meniscus **50** formed as shown in FIG. **5**, therefore, will remain unchanged in configuration as long as the supply of ink is maintained constant. The meniscus **50** becomes a droplet to be ejected and impinged upon at a desired position upon the recording medium.

FIG. **6** shows the nozzle **20** fitted into a protective tube or sheath. As discussed above, the nozzle is made of a glass and its diameter is exceedingly small so that the sufficient mechanical strength is not secured. For this reason, the nozzle is fitted closely into the protective tube or sheath **60**. A resilient member may be interposed between the capillary **40** and the protective tube or sheath **60**. The tube or sheath may be made of a metal and any other suitable material. It should be noted the protective tube or sheath is partially fitted over the nozzle. In general the criterion is that the end of the protective tube or sheath must be in spaced-apart relation with the leading end of the capillary or nozzle so that the meniscus **50** having a desired configuration may be always formed at the end of the nozzle.

What is claimed is:

1. A nozzle for ejecting a stream of ink jet droplets for use in an ink jet recording device, comprising:

a tube having a capillary passageway for feeding ink to a nozzle orifice at an end face of said tube, said end face having an outer area surrounding an inner area contiguous to said orifice, said outer area being composed of a material having a greater contact angle relative to an ink droplet than the contact angle of the material of which said inner area is composed, whereby a succession of ink droplet meniscuses of uniform configuration will form on and be confined to said inner area of said end face and be ejected as ink droplets of a size determined by the diameter of said orifice.

2. A nozzle according to claim **1**, wherein said tube comprises a capillary member providing said capillary passageway and a coating of a highly water-repellent material on the outer circumference of said capillary member, said outer area of said end face being formed by said coating and said inner area of said end face being formed by said capillary member.

3. A nozzle according to claim **2**, wherein said capillary member is composed of a hard glass and said coating is a silicone coating.

4. A nozzle according to claim **2**, wherein said nozzle further comprises a protective sheath fitted about said tube in such a manner that the ink ejecting end of said tube extends beyond one end of said protective sheath by a predetermined distance.

5. A method for fabricating a nozzle for ejecting ink jet droplets for use in an ink jet recording device, comprising the steps of:

providing a capillary member having a capillary passageway, coating the outer circumference of said

member with a highly water-repellent coating, said coating having a greater contact angle relative to an ink droplet than the contact angle of the material of which said member is composed, said capillary member being longer than the desired length of said nozzle, and cutting off the coated capillary member at a desired length after said coating has cured to form an end face having an outer area composed of said water-repellent coating surrounding an inner area composed of said member contiguous to a nozzle orifice from said passageway, whereby said outer area will have a greater contact angle relative to an ink droplet than said inner area.

* * * * *