US007413289B2

(12) **United States Patent**
Cornell et al.

(10) **Patent No.: US 7,413,289 B2**
(45) **Date of Patent: Aug. 19, 2008**

---

(54) **LOW ENERGY, LONG LIFE MICRO-FLUID EJECTION DEVICE**

(75) Inventors: **Robert W. Cornell**, Lexington, KY (US); **James Harold Powers**, Lexington, KY (US); **Shirish Padmakar Mulay**, Lexington, KY (US); **Robert L. Cornell**, Lexington, KY (US)

(73) Assignee: **Lexmark International, Inc.**, Lexington, KY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 430 days.

(21) Appl. No.: **11/317,575**

(22) Filed: **Dec. 23, 2005**

(65) **Prior Publication Data**

US 2007/0146436 A1 Jun. 28, 2007

(51) **Int. Cl.**
B41J 2/05 (2006.01)
(52) **U.S. Cl.** **347/63**; 347/56; 347/64
(58) **Field of Classification Search** 347/20, 347/44, 47, 56, 61–65, 67
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,794,411 A * 12/1988 Taub et al. 347/47
5,831,648 A 11/1998 Mitani et al. 347/62
6,161,924 A 12/2000 Mitani et al. 347/64
7,070,262 B2 * 7/2006 Yamamoto et al. 347/63
2005/0012791 A1 1/2005 Anderson et al. 347/85

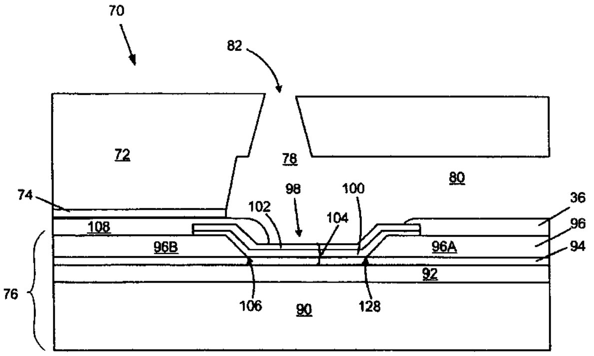
* cited by examiner

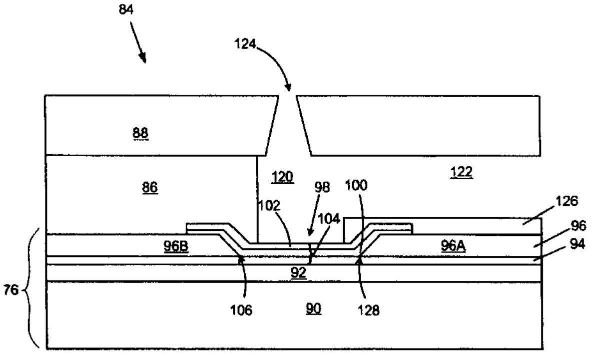
Primary Examiner—Juanita D Stephens
(74) *Attorney, Agent, or Firm*—Luedeka, Neely & Graham, PC

(57) **ABSTRACT**

Micro-fluid ejection heads and methods for extending the life of micro-fluid ejection heads. One such micro-fluid ejection head includes a substrate having a plurality of thermal ejection actuators. Each of the thermal ejection actuators has a resistive layer and a protective layer thereon. A flow feature member is adjacent the substrate and defines a fluid feed channel, a fluid chamber associated with at least one of the actuators and in flow communication with the fluid feed channel, and a nozzle. The nozzle is offset to a side of the chamber opposite the feed channel. A polymeric layer having a degradation temperature of less than about 400° C. overlaps a portion of the at least one actuator associated with the fluid chamber and positioned less than about five microns from at least an edge of the at least one actuator opposite the fluid feed channel.

20 Claims, 8 Drawing Sheets





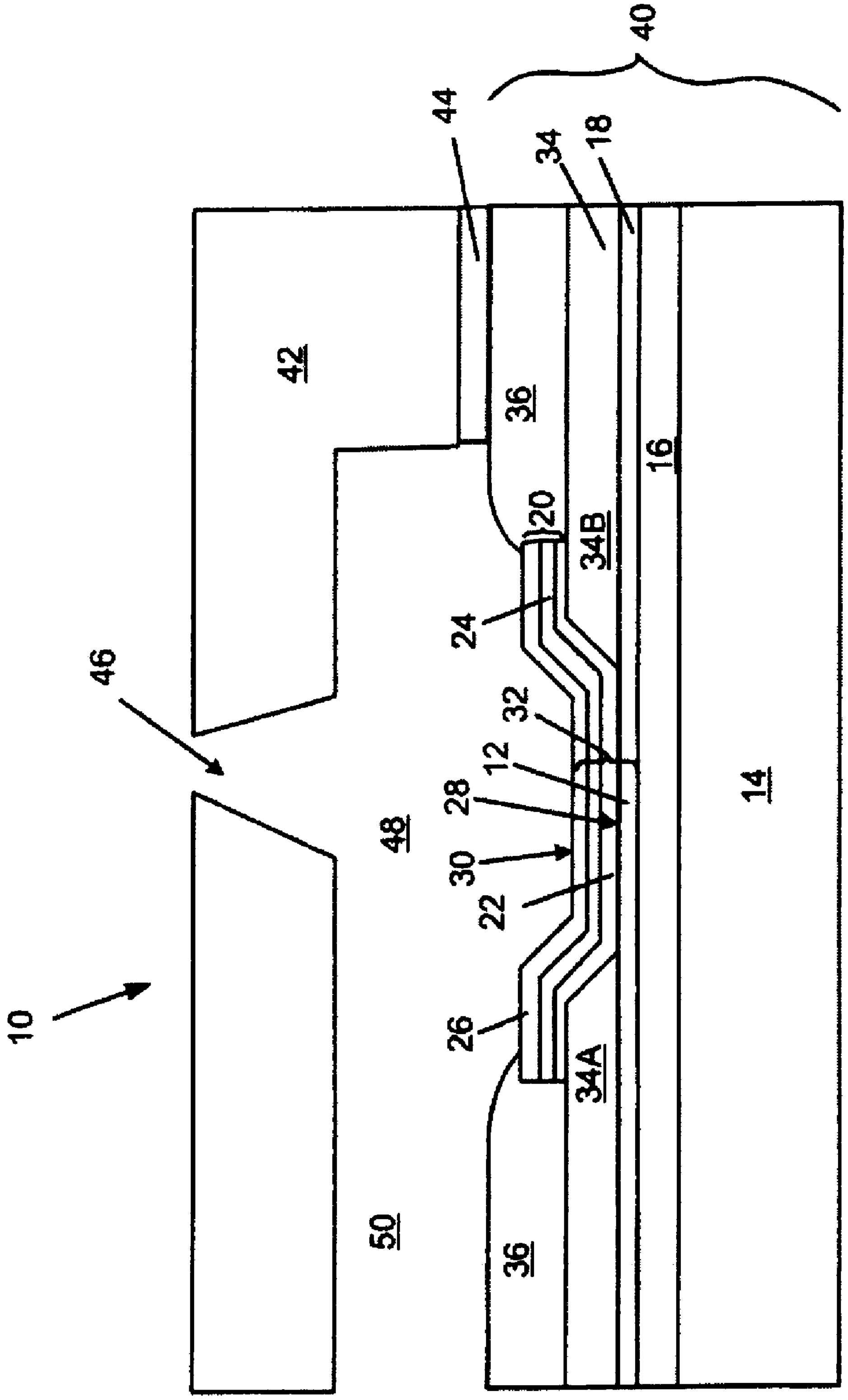


FIG. 1
Prior Art

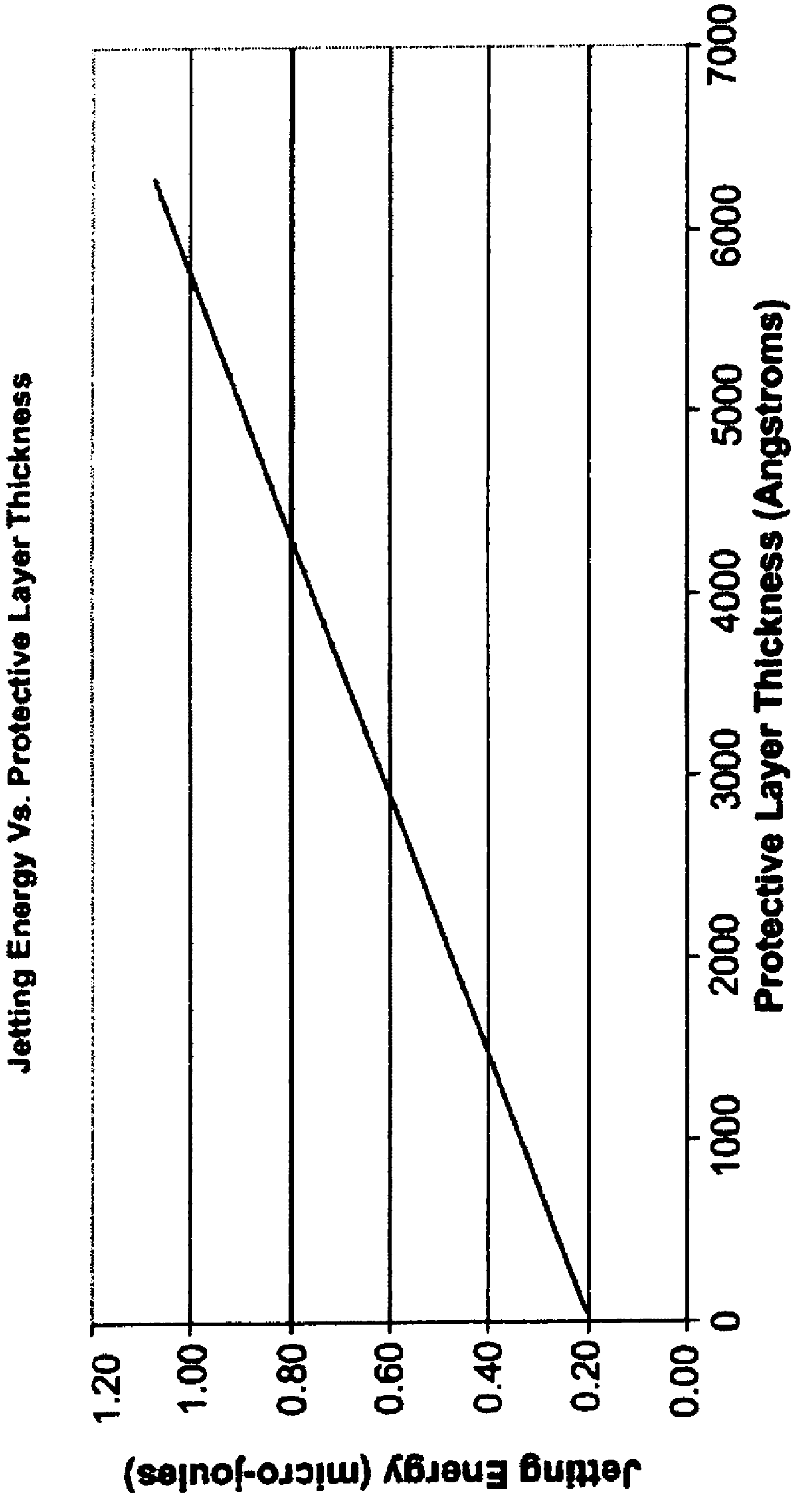

Jetting Energy Vs. Protective Layer Thickness
Jetting Energy (micro-joules)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
1000
2000
3000
4000
5000
6000
7000
Protective Layer Thickness (Angstroms)

FIG. 2

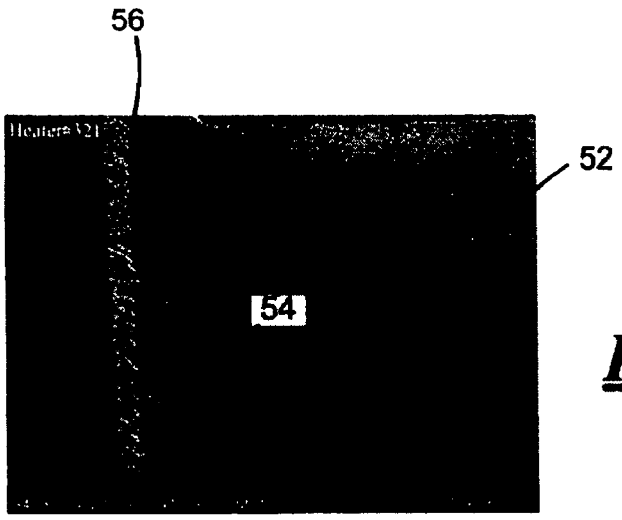


FIG. 3
Prior Art

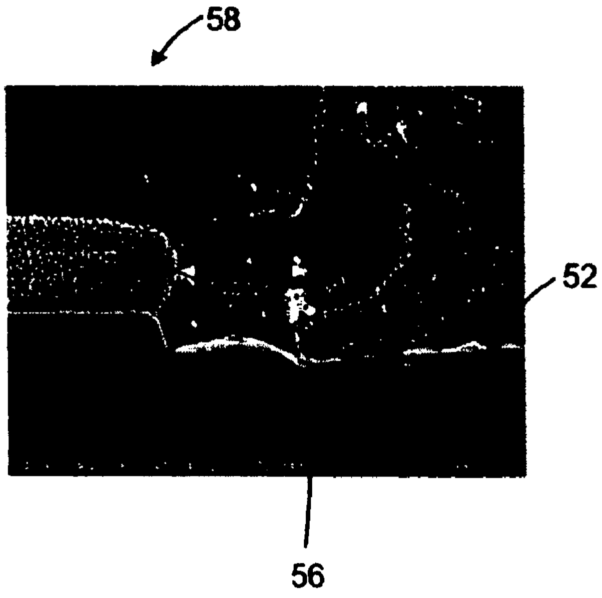


FIG. 4
Prior Art

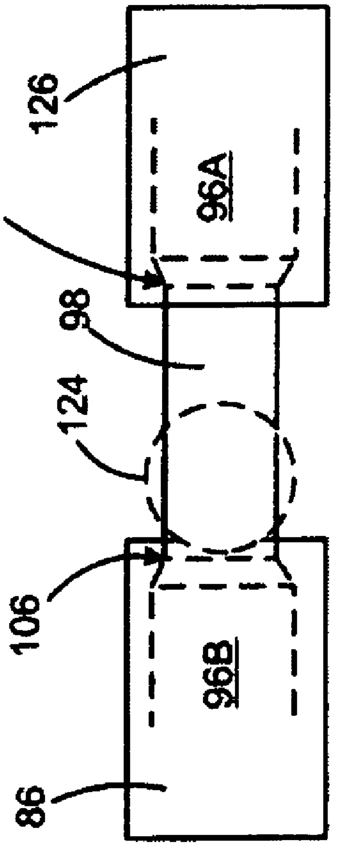


FIG. 10

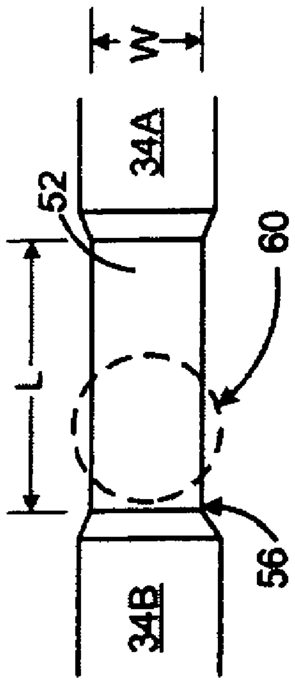


FIG. 5
Prior Art

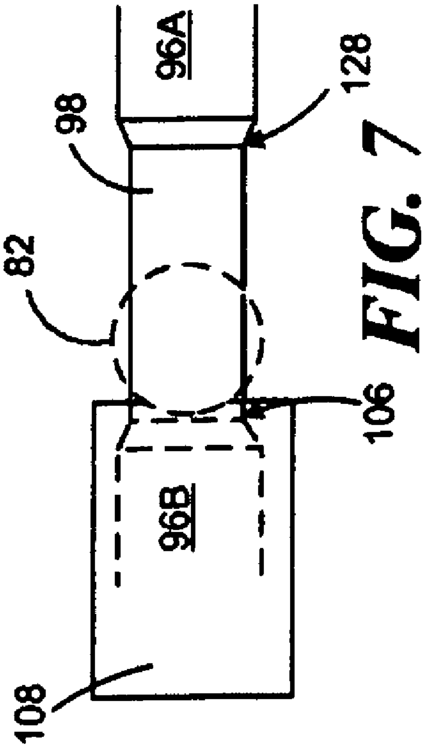


FIG. 7

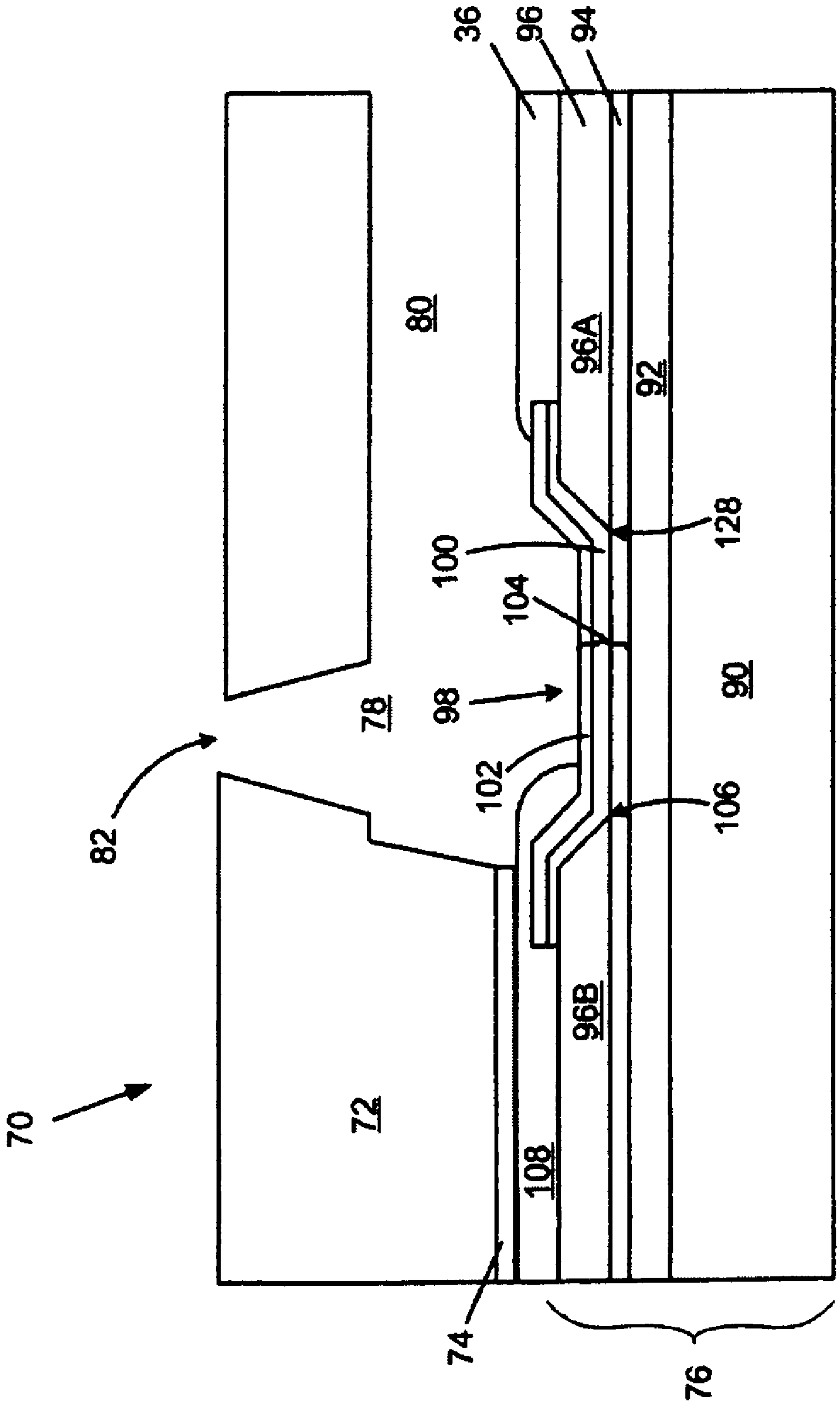

36
96
94
80
96A
92
128
100
104
90
98
78
102
106
82
96B
70
72
108
74
76

FIG. 6

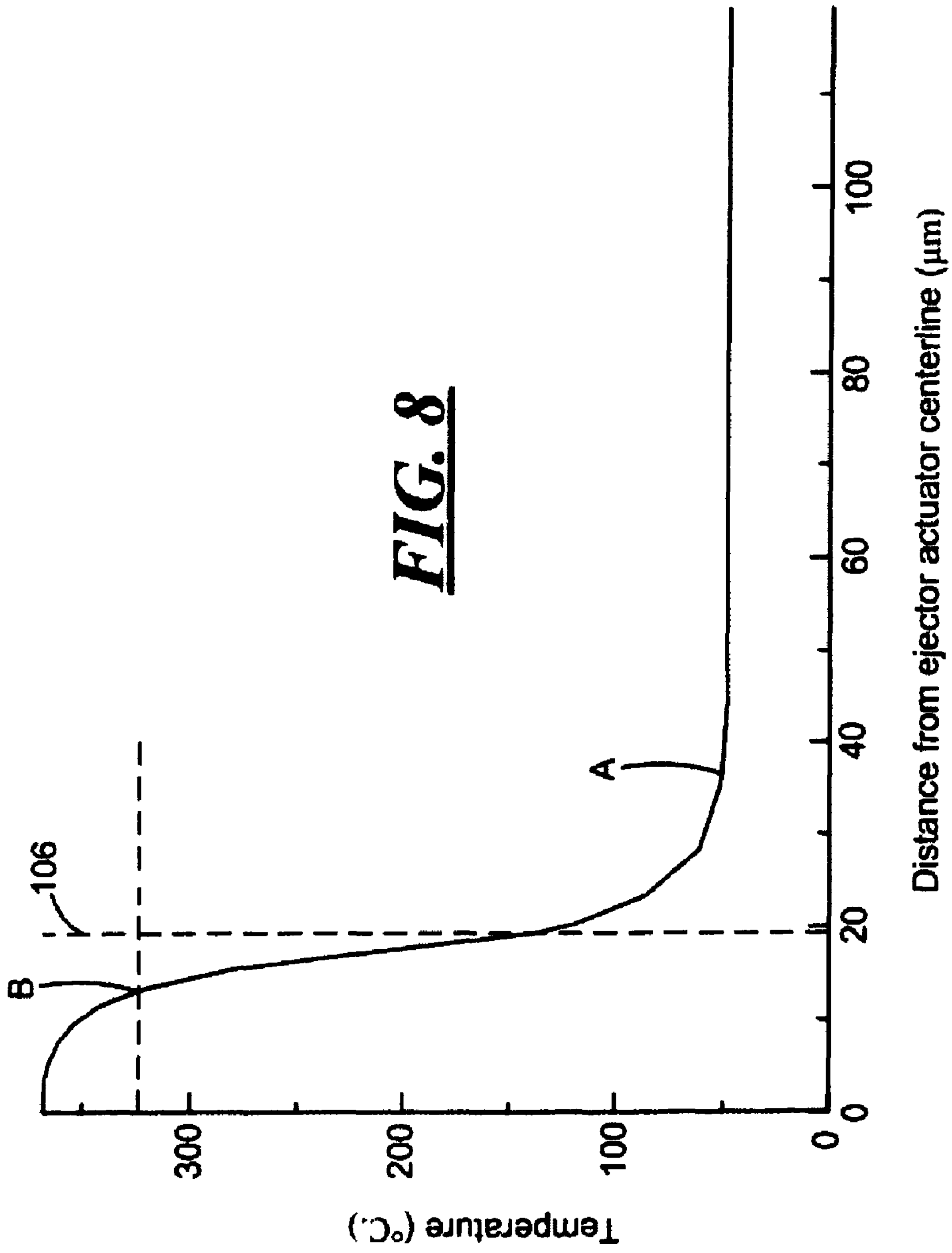

106
B
A
Temperature (°C.)
0
100
200
300
0
20
40
60
80
100
Distance from ejector actuator centerline (μm)

FIG. 8

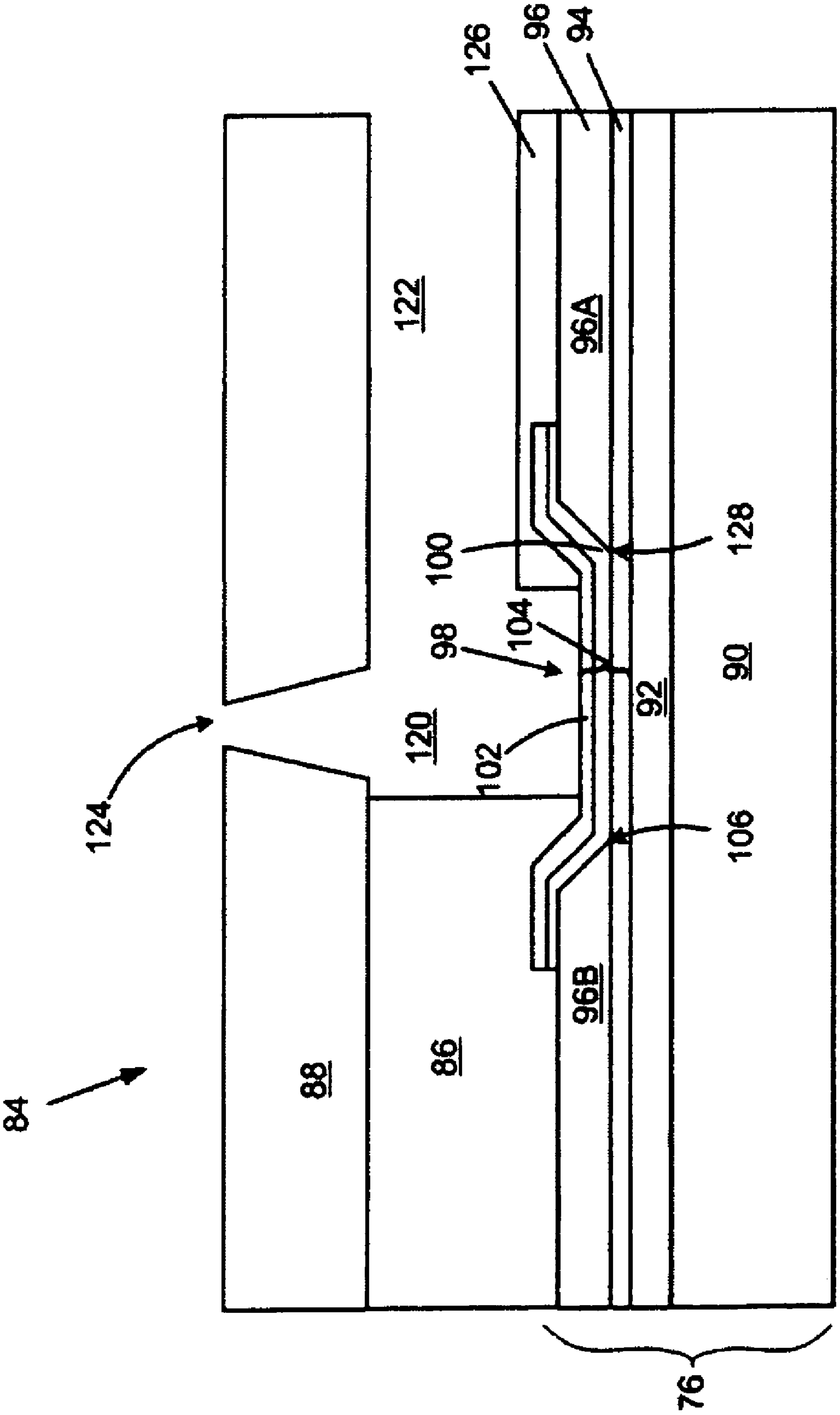

126
96
94
122
96A
128
100
98
104
90
92
120
102
124
106
96B
88
86
84
76

FIG. 9

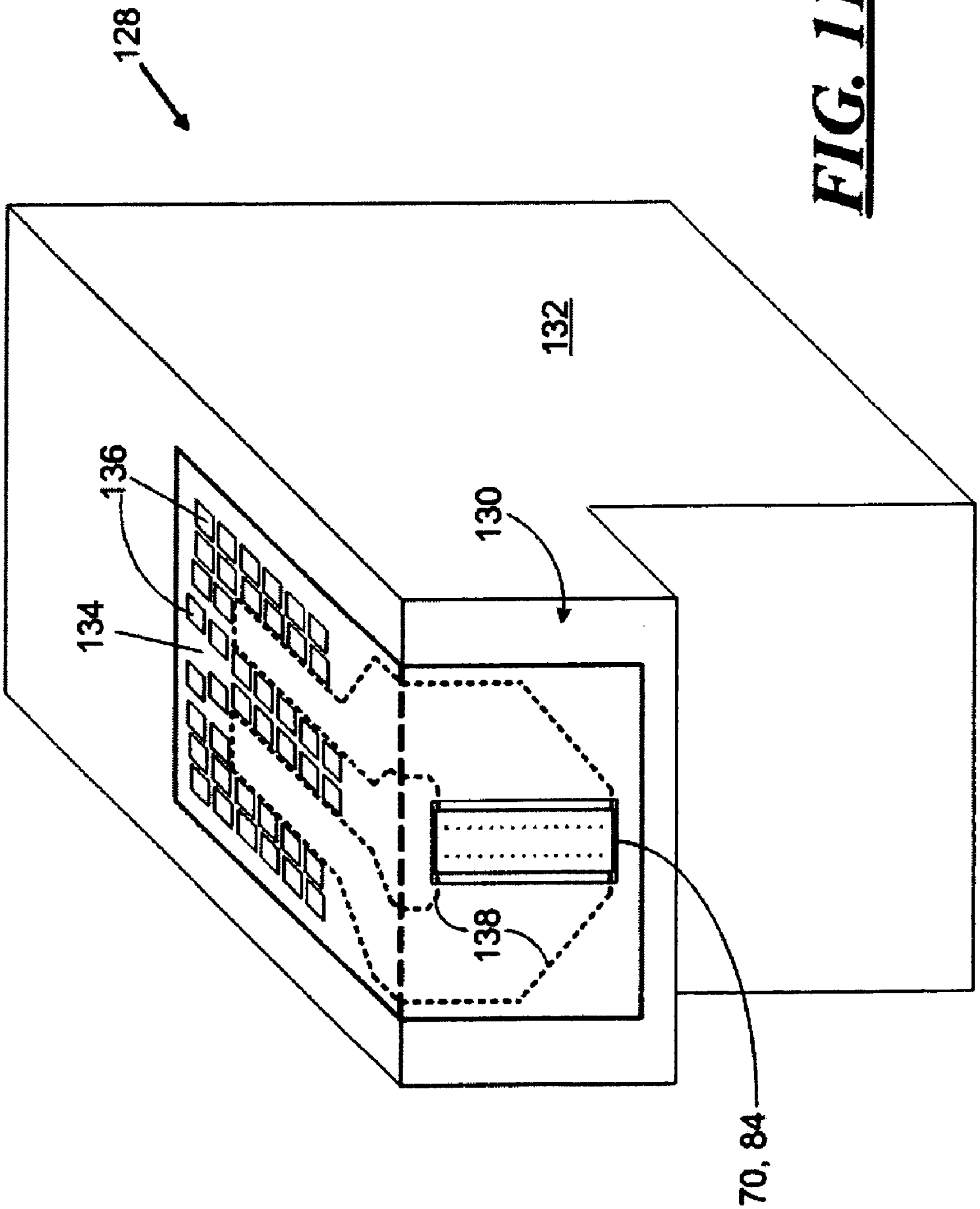


FIG. 11

LOW ENERGY, LONG LIFE MICRO-FLUID EJECTION DEVICE

FIELD OF THE DISCLOSURE

The disclosure relates to micro-fluid ejection devices and in one particular embodiment, to low energy, long life devices for ejecting small liquid droplets.

BACKGROUND AND SUMMARY

Micro-fluid ejection devices are classified by a mechanism used to eject fluid. Two of the major types of micro-fluid ejection devices include thermal actuators and piezoelectric actuators. Thermal actuators rely on an ability to heat the fluid to a nucleation temperature wherein a gas bubble is formed that expels the fluid through a nozzle. The life of such thermal actuators is dependent on a number of factors including, but not limited to, dielectric breakdown, corrosion, fatigue, electromigration, contamination, thermal mismatch, electro static discharge, material compatibility, delamination, and humidity, to name a few. A heater resistor used in a micro-fluid ejection device may be exposed to all of these failure mechanisms.

For example, it is well-known that cavitation pressures are powerful enough to pound thru any solid material, from concrete dams to ship propellers. During each fire cycle, the heater resistor may be exposed to similar cavitation impacts. As the gas bubble collapses, a local pressure is generated on the order of 10^3 to 10^4 atmospheres. Such cavitation impacts may be focused on a submicron spot of the heater resistor for several nanoseconds. After 10^7 to 10^8 cavitation impacts, the heater resistor may fail due to mechanical erosion. Furthermore, because the heater resistor requires extremely high temperatures to ensure homogeneous bubble nucleation, a distortion energy in the heater due to thermal expansion may be generated of the same order of magnitude as the distortion energy imposed by bubble collapse. A combination of thermal expansion and cavitation impacts may lead to premature heater failure.

In order to protect the fragile heater resistor films, the films may be hermitically sealed to prevent humidity driven corrosion, but the surface of the heater resistor is directly exposed to liquid. In the most critical areas of the heater, a minor surface opening due to defect, wear, step coverage, or delamination may lead to catastrophic failure of the heater resistor.

Accordingly, exotic resistor films and multiple protective layers providing a heater stack are used to provide heater resistors robust enough to withstand the cavitation and thermal expansion abuses described above. However, the overall thickness of the heater stack should be minimized because input energy is a linear function of heater stack thickness. In order to provide competitive actuator devices from a power dissipation and production throughput perspective, the heater stack should not be arbitrarily thickened to mitigate the cavitation effects, overcome step coverage issues, overcome delamination problems, reduce electro static discharge, etc. In other words, improved heater resistor reliability by overdesign of the thin film resistive and protective layers may produce a noncompetitive product.

Micro-fluid ejection heads may be classified as permanent, semi-permanent or disposable. The protective films used on the heater resistors of disposable micro-fluid ejection heads need only survive until the fluid in the attached fluid cartridges is exhausted. Installation of a fluid cartridge carries with it the installation of a new micro-fluid ejection head. A more difficult problem of heater resistor life is presented for permanent or semi-permanent micro-fluid ejection heads. There is a need, therefore, for a method and apparatus for improving heater resistor life without sacrificing jetting metrics and power consumption.

With regard to the above, exemplary embodiments of the disclosure provide micro-fluid ejection heads having extended life and relatively low energy consumption and methods of making a micro-fluid ejection heads with extended life and relatively low energy consumption. One such micro-fluid ejection head includes a substrate having a plurality of thermal ejection actuators disposed thereon. Each of the thermal ejection actuators includes a resistive layer and a protective layer for protecting a surface of the resistive layer. The resistive layer and the protective layer together define an actuator stack thickness. A flow feature member is adjacent (e.g., attached to) the substrate and defines a fluid feed channel, a fluid chamber associated with at least one of the thermal ejection actuators and in flow communication with the fluid feed channel, and a nozzle. The nozzle is offset to a side of the fluid chamber opposite the fluid feed channel. A polymeric layer having a degradation temperature of less than about 400° C. overlaps a portion of the at least one thermal ejection actuator, and positioned less than about five microns from at least an edge of the at least one actuator opposite the fluid feed channel.

In another embodiment there is provided a method for extending a life of a thermal ejection actuator for a micro-fluid ejection head. A substrate has a plurality of thermal ejection actuators and a protective layer therefor deposited thereon, and has a flow feature member defining a fluid feed channel, a fluid chamber associated with at least one of the thermal ejection actuators and in flow communication with the fluid feed channel, and a nozzle. The nozzle is offset to a side of the fluid chamber distal from the fluid feed channel. The method comprises depositing a polymeric layer having a degradation temperature of less than about 400° C. in overlapping relationship with at least a portion of the at least one thermal ejection actuator. The polymeric layer overlaps less than about five microns of the at least one actuator adjacent an edge thereof distal from the fluid feed channel.

An advantage of at least some of the exemplary embodiments of the disclosure is that heater energy is not increased while the life of the actuators is substantially enhanced. Another potential advantage of at least some of the disclosed embodiments is an ability to vary the life of an ejection actuator without significantly changing the energy requirements for ejecting fluids.

BRIEF DESCRIPTION OF THE DRAWINGS

Further advantages of the embodiments will become apparent by reference to the detailed description of exemplary embodiments when considered in conjunction with the drawings, wherein like reference characters designate like or similar elements throughout the several drawings as follows:

FIG. **1** is a cross-sectional view, not to scale, of a portion of a prior art micro-fluid ejection head;

FIG. **2** is a graphical representation of jetting energy versus protective layer thickness for micro-fluid ejection heads;

FIG. **3** is photomicrograph plan view of a prior art micro-fluid ejection actuator having cavitation damage thereon;

FIG. **4** is a photomicrograph cross-sectional view of a prior art micro-fluid ejection actuator having cavitation damage thereon;

FIG. **5** is a plan view, not to scale, of a portion of a prior art micro-fluid ejection head;

FIG. **6** is a cross-sectional view, not to scale, of a portion of a micro-fluid ejection head according to a first embodiment of the disclosure;

FIG. **7** is a plan view, not to scale, of a portion of a micro-fluid ejection head according to the first embodiment of the disclosure;

FIG. **8** is temperature profile for a micro-fluid ejection actuator according to the disclosure;

FIG. **9** is a cross-sectional view, not to scale, of a portion of a micro-fluid ejection head according to a second embodiment of the disclosure;

FIG. **10** is a plan view, not to scale, of a portion of a micro-fluid ejection head according to the second embodiment of the disclosure; and

FIG. **11** is a perspective view, not to scale, of a fluid cartridge for a micro-fluid ejection head according to the disclosure.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

In accordance with embodiments described herein, micro-fluid ejection heads having improved energy consumption and extended life will now be described.

For the purposes of this disclosure, the terms "heater stack", "ejector stack", and "actuator stack" are intended to refer to an ejection actuator having a combined layer thickness of a resistive material layer and passivation or protection material layer. The passivation or protection material layer is applied to a surface of the resistive material layer to protect the actuator from, for example, chemical or mechanical corrosion or erosion effects of fluids ejected by the micro-fluid ejection device.

In order to more fully appreciate the benefits of the exemplary embodiments, reference is first made to FIG. **1**, which is a cross-sectional view, not to scale, of a portion of a prior art micro-fluid ejection head **10**. The cross-sectional view of FIG. **1** shows one of many micro-fluid ejection actuators **12** contained on a micro-fluid ejection head. The ejection actuators **12** are formed on a substrate **14**. The substrate **14** may be made from a wide variety of materials including plastics, ceramics, glass, silicon, semiconductor material, and the like. In the case of a semiconductor material substrate, a thermal insulating layer **16** is applied to the substrate between the substrate **14** and the ejection actuators **12**. The ejection actuators **12** may be formed from an electrically resistive material layer **18**, such as TaAl, Ta_2N, TaAl(O,N), TaAlSi, TaSiC, Ti(N,O), WSi(O,N), TaAlN, and TaAl/Ta. The thickness of the resistive material layer **18** may range from about 300 to about 1000 Angstroms.

The thermal insulation layer **16** may be formed from a thin layer of silicon dioxide and/or doped silicon glass overlying the relatively thick substrate **14**. The total thickness of the thermal insulation layer **16** may range from about 1 to about 3 microns thick. The underlying substrate **14** may have a thickness ranging from about 0.2 to about 0.8 millimeters thick.

A protective layer **20** overlies the micro-fluid ejection actuators **12**. The protective layer **20** may be a single material layer or a combination of several material layers. In the illustration in FIG. **1**, the protective layer **20** includes a first passivation layer **22**, a second passivation layer **24**, and a cavitation layer **26**. The protective layer **20** is effective to prevent the fluid or other contaminants from adversely affecting the operation and electrical properties of the fluid ejection actuators **12** and provides protection from mechanical abrasion or shock from fluid bubble collapse.

The first passivation layer **22** may be formed from a dielectric material, such as silicon nitride, or silicon doped diamond-like carbon (Si-DLC) having a thickness ranging from about 1000 to about 3200 Angstroms thick. The second passivation layer **24** may also be formed from a dielectric material, such as silicon carbide, silicon nitride, or silicon-doped diamond-like carbon (Si-DLC) having a thickness ranging from about 500 to about 1500 Angstroms thick. The combined thickness of the first and second passivation layers **22** and **24** typically ranges from about 1000 to about 5000 Angstroms.

The cavitation layer **26** is typically formed from tantalum having a thickness greater than about 500 Angstroms thick. The cavitation layer **26** may also be made of TaB, Ti, TiW, TiN, WSi, or any other material with a similar thermal capacitance and relatively high hardness. The maximum thickness of the cavitation layer **26** is such that the total thickness of protective layer **20** is less than about 7200 Angstroms thick. The total thickness of the protective layer **20** is defined as a distance from a top surface **28** of the resistive material layer **18** to an outermost surface **30** of the protective layer **20**. An ejector stack thickness **32** is defined as the combined thickness of layers **18** and **20**.

The ejection actuator **12** is defined by depositing and etching a metal conductive layer **34** on the resistive layer **18** to provide power and ground conductors **34**A and **34**B as illustrated in FIG. **1**. The conductive layer **34** is typically selected from conductive metals, including but not limited to, gold, aluminum, silver, copper, and the like and has a thickness ranging from about 4,000 to about 15,000 Angstroms.

Overlying the power and ground conductors **34**A and **34**B is another insulating layer or dielectric layer **36** typically composed of epoxy photoresist materials, polyimide materials, silicon nitride, silicon carbide, silicon dioxide, spun-on-glass (SOG), laminated polymer and the like. The insulating layer **36** and has a thickness ranging from about 5,000 to about 20,000 Angstroms and provides insulation between a second metal layer and conductive layer **34** and corrosion protection of the conductive layer **34**.

Layers **14**, **16**, **18**, **20**, **34**, and **36** provide a semiconductor substrate **40** for use in the micro-fluid ejection head **10**. A nozzle plate **42** is adjacent (e.g., attached, as by an adhesive **44** to) the semiconductor substrate **40**. In the prior art embodiment illustrated in FIG. **1**, the nozzle plate **42** contains nozzles **46** corresponding to respective ones of the plurality of ejection actuators **12**. During a fluid ejection operation, a fluid in fluid chamber **48** is heated by the ejection actuators **12** to a nucleation temperature of about 325° C. to form a fluid bubble which expels fluid from the fluid chamber **48** through the nozzles **46**. A fluid supply channel **50** provides fluid to the fluid chamber **48**.

One disadvantage of the micro-fluid ejection head **10** described above is that the multiplicity of protective layers **20** within the micro-fluid ejection head **10** increases the ejection stack thickness **32**, thereby increasing an overall jetting energy required to eject a drop of fluid through the nozzles **46**.

Upon activation of the ejection actuator **12**, some of the energy ends up as waste heat energy used to heat the protective layer **20** via conduction, while the remainder of the energy is used to heat the fluid adjacent the surface **30** of the cavitation layer **26**. When the surface **30** reaches a fluid superheat limit, a vapor bubble is formed. Once the vapor bubble is formed, the fluid is thermally disconnected from the surface **30**. Accordingly, the vapor bubble prevents further thermal energy transfer to the fluid.

It is the thermal energy transferred into the fluid, prior to bubble formation, that drives the liquid-vapor change of state of the fluid. Since thermal energy must pass through the protective layer **20** before heating the fluid, the protective layer **20** is also heated. It takes a finite amount of energy to heat the protective layer **20**. The amount of energy required to heat the protective layer **20** is directly proportional to the thickness of the protective layer **20** and the thickness of the resistive layer **18**. An illustrative example of the relationship between the protective layer **20** thickness and jetting energy requirement for a specific ejection actuator **12** size is shown in FIG. **2**.

Jetting energy is related to power (power being the product of energy and firing frequency of the micro-fluid ejection actuators **12**). The temperature rise experienced by the substrate **40** is also related to power. Adequate jetting performance and fluid characteristics, such as print quality in the case of an ink ejection device, are related to the temperature rise of the substrate **40**.

For disposable micro-fluid ejection heads, the thickness of the protective layer **20** may be minimized in order to reduce power consumption. However, for longer life micro-fluid ejection heads, such as permanent or semi-permanent ejection heads, increasing the protective layer **20** thickness to extend the life of the ejection heads may adversely affect the power consumption of the ejection heads as described above. For example, a disposable ejection head may provide up to about 10 million ejection cycles before failure of the ejection head. However, longer life ejection heads may require up to 1 billion ejection cycles or more before failure. Accordingly, methods and apparatus for extending the life of the ejection heads without adversely affecting the ejection energy requirements may be provided, such as by the following exemplary embodiments.

As described above, thermal expansion distortions and cavitation impacts combine to reduce the life of micro-fluid ejection actuators. Evidence of the destructive effects of cavitation and thermal expansion may be seen in the photomicrographs of a prior art micro-fluid ejection actuator illustrated in FIGS. **3** and **4**. FIG. **3** is a plan view of a prior art micro-fluid ejection actuator **52** showing a wear pattern **54** adjacent an edge **56** distal from the fluid supply channel **50** (FIG. **1**). FIG. **4** is a cross-sectional view of a prior art micro-fluid ejection head **58** showing the erosion pattern adjacent the edge **56** of the micro-fluid ejection actuator **52**.

As shown more clearly in FIG. **5**, the prior art micro-fluid ejection actuator **52** is an elongate heater resistor have a length L greater than a width W. Typically the actuator **52** has a length to width ratio ranging from about 1.5:1 to about 3:1. The overall heating area of the actuator **52** may range from about 200 square microns to about 1200 square microns.

A nozzle **60** can be biased toward the distal edge **56** of the micro-fluid ejection actuator **52**, such as in order to reduce air entrapment in the fluid chamber **48** (FIG. **1**). However, biasing the nozzle **60** toward the distal edge **56** increases the cavitation and thermal expansion damage adjacent the distal edge **56** of the micro-fluid ejection actuator, as shown in FIGS. **3** and **4**.

Methods and apparatus for reducing or eliminating thermal expansion and cavitation damage to micro-fluid ejection actuators will now be described with reference to FIGS. **6**-**9**. FIG. **6** is a cross-sectional view, not to scale, of a micro-fluid ejection head **70** according to a first embodiment of the disclosure. In this embodiment, the ejection head **70** includes a flow feature member **72** attached, as by an adhesive **74**, adjacent (e.g., to) a semiconductor substrate **76**. The flow feature member **72** has a thickness ranging from about 5 to 65 microns, and can be made from a chemically resistant polymer such as polyimide. Flow features, such as a fluid chamber **78**, fluid supply channel **80** and nozzle **82**, can be formed in the flow feature member **72** by conventional techniques, such as laser ablation. The embodiments described herein are not limited by the foregoing flow feature member **72**. In an alternative embodiment, the flow feature member may comprise fluid chambers and the fluid supply channel in a thick film layer to which a nozzle plate is attached, or the flow features may be formed in both a thick film layer and a nozzle plate. FIG. **9**, described below, illustrates an embodiment of a micro-fluid ejection head **84** having a thick film layer **86** and nozzle plate **88** attached to the thick film layer **86**.

The semiconductor substrate **76** to which the flow feature member **72** is attached includes a support substrate **90** made of an insulating or semiconductive material as described above with reference to FIG. **1**. In the case of a semiconductive material for substrate **90**, an insulating layer **92** similar to layer **16** is applied to the substrate **90**. A resistive layer **94** similar to resistive layer **18**, described above, is applied to the insulating layer **92**. Likewise, a conductive layer **96** similar to conductive layer **34** is applied to the resistive layer **94** and is etched to provide the power and ground conductors **96**A and **96**B for activating a micro-fluid ejection actuator **98** defined between the conductors **96**A and **96**B.

An advantage of at least some of the disclosed embodiments is that a number and thickness of protective layers for the micro-fluid ejection actuator **98** may be reduced in order to reduce power consumption without adversely affecting the life of the micro-fluid ejection actuators **98**.

Unlike the ejection head **10** illustrated in FIG. **1**, the ejection head **70** has a single protective layer **100** and, optionally, a relatively thin cavitation layer **102**. The protective layer **100** may be provided by a material selected from the group consisting of diamond-like carbon (DLC), silicon doped diamond-like carbon (Si-DLC) titanium, tantalum, silicon nitride and an oxidized metal. The thickness of the protective layer **100** may range from about 400 to about 3000 Angstroms. Such a protective layer **72** thickness provides an ejection actuator stack **104** having a thickness ranging from about 1200 to about 6500 Angstroms. When used, the cavitation layer **102** may have a thickness ranging from about 500 to about 3000 Angstroms.

In order to, for example, reduce damage caused by thermal expansion and cavitation adjacent a distal edge **106** of the micro-fluid ejection actuator **98**, a polymeric layer **108** having a degradation temperature of less than about 400° C. is applied to the protective layers **100** and **102** and conductive layer **96** so that the polymeric layer overlaps a portion of the micro-fluid ejection actuator **98** as shown in plan view in FIG. **7** adjacent the distal edge **106** thereof. Due to the relatively low degradation temperature of the polymeric layer **108**, the overlapped portion of the actuator **98** should be less than about five microns. Typically, the overlapped portion of the actuator **98** will range from about one to about four microns.

A temperature profile for the micro-fluid ejection actuator **98** is shown by Curve A in FIG. **8**. As shown in FIG. **8**, the micro-fluid ejection actuator **98** has a temperature of about 400° C. in a central portion of the actuator whereas, the edge **106** of the actuator has a temperature of about 150° C. At about five microns from the edge **106** of the actuator **98**, point B on Curve A, the temperature is about 325° C. which is the nucleation temperature indicated by dashed line **110** for ejecting fluid from the micro-fluid ejection head **70**. Accordingly, if less than five microns of the actuator **98** adjacent edge **106** is overlapped with the polymeric layer **108**, the polymeric layer may be below its decomposition temperature.

A suitable polymeric layer **108** having a degradation temperature below about 400° C. is a cross-linked epoxy material such as described in U.S. Pat. No. 6,830,646 to Patil et al., the disclosure of which is incorporated herein by reference. The polymeric layer **108**, in the case of micro-fluid ejection head **70**, may be applied as a planarization layer having a thickness averaging from about one to about ten microns. Spin coating, spraying, dipping, or roll coating processes may be used to apply the polymeric layer **108** to the conductive layer **96** and protective layers **100** and **102**. It will be appreciated that the overlapped portion of the actuator **98** may have a greater thickness of polymeric layer **108** so that a relatively smooth planarization layer may be obtained.

With reference now to FIGS. **9** and **10**, alternate embodiments of the disclosure will now be described. As set forth above, the micro-fluid ejection head **84** illustrated in FIGS. **9** and **10** includes a thick film layer **86** providing the flow feature member containing a fluid chamber **120** and fluid supply channel **122**. The thick film layer **86** may also be made of a cross-linked epoxy material as set forth above. However, the thick film layer **86** has a thickness ranging from about 4 to about 40 microns or more. As with the polymeric layer **108**, the thick film layer overlaps a portion of the micro-fluid ejection actuator **98** as shown in FIGS. **9** and **10**. The overlapped portion, adjacent the distal edge **106** may also be less than about five microns and may range from about one to about four microns.

The thick film layer **86** may be made of the same material as the polymeric layer **108**; in which case there may be no need for a separate polymeric layer **108** between the thick film layer **86** and the conductive layer **96** and protective layers **100** and **102**. The thick film layer **86** may be applied in the same manner as the polymeric layer **108** described above. Each of the polymeric layer **108** and thick film layer **86** may be photoimaged and developed using conventional photoimaging and developing techniques to provide the less than five micron overlap of the actuator **98**. In the case of the thick film layer **86**, the photoimaging and developing techniques may also be used to provide the fluid chamber **120** and fluid supply channel **122** therein.

After imaging and developing the thick film layer **86**, a nozzle plate **88** made of a polyimide material or a photoresist material may be attached to the thick film layer **86**. In the case of a polyimide nozzle plate **88**, a nozzle **124** for each of the actuators may be laser ablated in the nozzle plate **88**. If the nozzle plate **88** is made of a photoresist material, photoimaging and developing techniques may be used to make the nozzle **124**.

In another alternative embodiment, illustrated in FIGS. **9** and **10**, a polymeric layer **126** may overlap a proximal edge **128** of the actuator **98** so that both the distal edge **106** and the proximal edge **128** of the actuator **98** are overlapped less than about five microns, typically from about one to about four microns. The polymeric layer **126**, as illustrated in FIGS. **9** and **10**, may likewise be applied to overlap the proximal edge **128** of the actuator illustrated in FIGS. **6** and **7**. In the embodiment illustrated in FIGS. **9** and **10**, the polymeric layer **126** may be the same as the thick film layer **86** except that the thickness of the polymeric layer **126** will be reduced in the fluid supply channel **122** of the ejection head **84** by imaging and developing the polymeric layer **126**.

The micro-fluid ejection head **70** or **84** may be permanently or removably attached to a fluid supply cartridge **128** as shown in FIG. **11**. As shown in FIG. **5**, the ejection head **70** or **84** may be attached to an ejection head portion **130** of the fluid cartridge **128**. A main body **132** of the cartridge **128** includes a fluid reservoir for supply of fluid to the micro-fluid ejection head **70** or **84**. A flexible circuit or tape automated bonding (TAB) circuit **134** containing electrical contacts **136** for connection to an ejection head control device, such as an ink jet printer, is attached to the main body **132** of the cartridge **128**. Electrical tracing **138** from the electrical contacts **136** are attached to the substrate **76** (FIGS. **6** and **9**) to provide activation of micro-fluid ejection actuator **98** on demand from the control device to which the fluid cartridge **128** is attached. The disclosure, however, is not limited to the fluid cartridges **128** as illustrated in FIG. **11** as the micro-fluid ejection head **70** or **84** according to the disclosure may be used for a wide variety of fluid cartridges, wherein the ejection head **70** or **84** may be remote from the fluid reservoir of main body **128**.

It is contemplated, and will be apparent to those skilled in the art from the preceding description and the accompanying drawings, that modifications and changes may be made in the embodiments of the disclosure. Accordingly, it is expressly intended that the foregoing description and the accompanying drawings are illustrative of exemplary embodiments only, not limiting thereto, and that the true spirit and scope of the present disclosure be determined by reference to the appended claims.

What is claimed is:

1. A micro-fluid ejection head, comprising:

a substrate having a plurality of thermal ejection actuators disposed thereon, each of the thermal ejection actuators including a resistive layer and a protective layer for protecting a surface of the resistive layer, the resistive layer and the protective layer together defining an actuator stack thickness;

a flow feature member adjacent the substrate defining a fluid feed channel, a fluid chamber associated with at least one of the thermal ejection actuators and in flow communication with the fluid feed channel, and a nozzle, wherein the nozzle is offset to a side of the fluid chamber opposite the fluid feed channel; and

a polymeric layer having a degradation temperature of less than about 400° C. overlapping a portion of the at least one thermal ejection actuator associated with the fluid chamber and positioned less than about five microns from at least an edge of the at least one actuator opposite the fluid feed channel.

2. The micro-fluid ejection head of claim **1**, wherein the actuator stack thickness ranges from about 1200 to about 6500 Angstroms and provides an ejection energy per unit volume of from about 2 to about 4 gigajoules per cubic meter.

3. The micro-fluid ejection head of claim **1**, wherein the resistive layer has a thickness ranging from about 300 to about 1000 Angstroms.

4. The micro-fluid ejection head of claim **1**, wherein each of the thermal ejection actuators has a fluid heating area ranging from about 200 square microns to about 1200 square microns.

5. The micro-fluid ejection head of claim **1**, wherein the protective layer has a thickness ranging from about 900 to about 5500 Angstroms.

6. The micro-fluid ejection head of claim **1**, wherein the resistive layer comprises a tantalum-aluminum alloy and the protective layer comprises a material selected from the group consisting of diamond like carbon, silicon doped diamond like carbon, silicon nitride, titanium, tantalum, and an oxidized metal layer.

7. The micro-fluid ejection head of claim **6**, wherein the resistive layer comprises a material selected from the group consisting of tantalum-aluminum (TaAl), tantalum-nitride (TaN), tantalum-aluminum-nitride (TaAl:N), and composite layers of tantalum and tantalum-aluminum (Ta+TaAl).

8. The micro-fluid ejection head of claim **1**, wherein the polymeric layer comprises a cross-linked epoxy material.

9. The micro-fluid ejection head of claim **1**, wherein the polymeric layer overlaps an edge of the at least one actuator in an amount ranging from about 1 to about 4 microns.

10. The micro-fluid ejection head of claim **1**, wherein the polymeric layer overlaps the at least one ejection actuator adjacent opposing edges thereof in an amount ranging from about 1 to about 4 microns.

11. The micro-fluid ejection head of claim **1**, wherein the actuators are elongate actuators having a length to width ratio ranging from about 1.5:1 to about 5:1.

12. A method for extending a life of a thermal ejection actuator for a micro-fluid ejection head comprising a substrate having a plurality of thermal ejection actuators and a protective layer therefor deposited thereon, and having a flow feature member defining a fluid feed channel, a fluid chamber associated with at least one of the thermal ejection actuators and in flow communication with the fluid feed channel, and a nozzle, wherein the nozzle is offset to a side of the fluid chamber distal from the fluid feed channel, the method comprising:

depositing a polymeric layer having a degradation temperature of less than about 400° C. in overlapping relationship with at least a portion of the at least one thermal ejection actuator, wherein the polymeric layer overlaps less than about five microns of the at least one actuator adjacent an edge thereof distal from the fluid feed channel.

13. The method of claim **12**, wherein the flow feature member comprises a polymeric thick film layer.

14. The method of claim **13**, wherein the act of depositing a polymeric layer provides the polymeric thick film layer.

15. The method of claim **12**, wherein the flow feature member comprises a unitary polyimide member having fluid feed channels, fluid chambers, and nozzles.

16. The method of claim **15**, wherein the polymeric layer comprises a planarization layer having a thickness ranging from about 1 to about 6 microns.

17. The method of claim **16**, wherein the planarization layer comprises a cross-linked epoxy material.

18. The method of claim **12**, wherein the polymeric layer is deposited so that the polymeric layer overlaps opposing edge portions of the at least one actuator.

19. The method of claim **18**, wherein the polymeric layer is deposited on the at least one actuator so that the overlapped portions extend from about 1 to about 4 microns from the opposing edge portions thereof.

20. A micro-fluid ejection head made by the method of claim **12**.

* * * * *