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(54) Title: MICROSCOPE-SLIDE DRYER

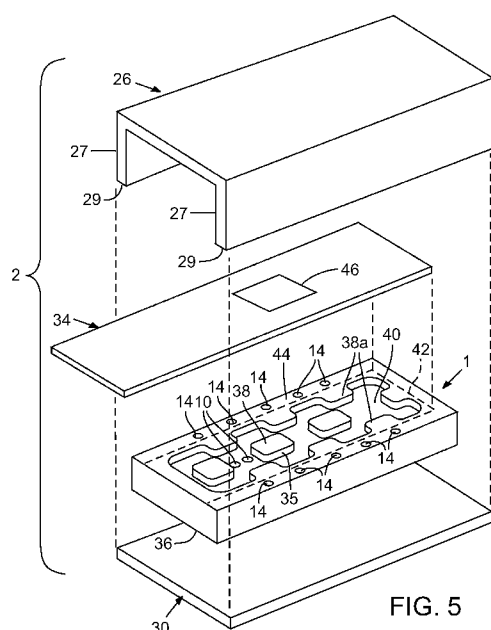


FIG. 5

(57) Abstract: This disclosure relates to apparatus for and methods of drying microscope slides. Some apparatus are microscope-slide dryers comprising a jet-pump body having a first side defining a flow channel and an exhaust port, and a second side defining a vacuum channel, an exhaust region and a heat-transfer surface. The exhaust port can fluidly couple the flow channel and the exhaust region. A top member can adjoin the first side. A flow of gas can be passed through the flow channel for inducing a low pressure in a first region at least partially defined by a second side of the jet-pump body. The jet-pump body can be heated. A difference in pressure can urge a slide against the jet-pump body. A portion of the flow can be directed over the slide.



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## **MICROSCOPE-SLIDE DRYER**

### **CROSS REFERENCE TO RELATED APPLICATION**

This application claims priority to and benefit of U.S. Provisional Patent  
5 Application No. 61/140,777, filed December 24, 2008, which is incorporated herein  
in its entirety.

### **FIELD**

This disclosure relates to embodiments of an apparatus for drying  
microscope slides and associated methods, with drying microscope slides having  
10 stained samples disposed thereon being but one example.

### **BACKGROUND**

Staining and other wet processes can be used for histological diagnoses and  
studying tissue morphology. Many variations of such wet processes exist (and are  
expected to be developed) and typically comprise exposing a tissue sample mounted  
15 to a microscope slide with one or more reagents, followed by one or more rinsing  
processes e.g., for rinsing unused reagents from the sample. Such exposing-rinsing  
cycles can be repeated on the same sample several times using one or more reagents.

In some instances, such processes are automated and can include drying the  
slides upon completion of processing and/or as an intermediate act of processing the  
20 microscope slide.

### **SUMMARY**

As described more fully below, a microscope-slide dryer can comprise a jet-  
pump body having a first side defining a flow channel and an exhaust port, and a  
second side defining a vacuum channel, an exhaust region and a heat-transfer  
25 surface. The exhaust port can fluidly couple the flow channel and the exhaust  
region. A top member can adjoin the first side, as to comprise a top-side for the  
flow channel.

Microscope-slide dryers can also comprise a bottom member positioned  
adjacent to and at least partially spaced from the second side to at least partially  
30 define an exhaust plenum. The exhaust plenum is fluidly coupled with the exhaust  
region.

Slide dryers can further comprise a heater for heating a microscope slide positioned adjacent the second side. Such a heater can comprise one or more of the following: (1) an electrically resistive heater fixedly attached to the jet pump body; (2) an electrical connector for supplying the jet-pump body with electricity for resistively heating the jet-pump body directly (e.g., the jet-pump body can comprise an electrically-conductive material); (3) a fluid connector for supplying the flow channel with a heated stream of gas; (4) a convective-heat-transfer-surface extending from a bottom-side of the flow channel for heat exchange between a flow in the flow channel and the jet-pump body; and (5) a thermally conductive member for conducting heat from the jet-pump body to the slide. Such a thermally conductive member can comprise one or more of at least a portion of the jet-pump body and a thermally conductive interface material for enhancing thermal contact between adjacent surfaces.

Some vacuum channels defined by a jet-pump body comprise a floor, and a heat transfer surface can comprise a plurality of heat transfer surfaces each being distally located from the floor. In some examples, one or more members can extend from the floor and at least one of the one or more members can define one or more respective heat transfer surfaces.

Some jet-pump bodies also define a vacuum orifice fluidly coupling the respective flow channel and the respective vacuum channel. A flow of gas through the flow channel can induce a first pressure in a region adjacent the vacuum orifice and can exhaust adjacent the at least one exhaust region in an exhaust stream. The first pressure can be greater than an exhaust pressure in an exhaust plenum. In some instances, a force applied to a microscope slide being positioned in the exhaust plenum and disposed adjacent the first side by a difference between the first pressure and the exhaust pressure applied across the microscope slide is greater than the microscope-slide's weight. Such a force can suspend the slide against gravity and urge the slide against at least a portion of the jet-pump body.

Embodiments of a method for drying a microscope slide are also described. For example, a low pressure can be induced in a first region at least partially defined by a second side of a jet-pump body by passing a flow of gas through a flow channel

defined by a first side of the jet-pump body and being fluidly coupled with the first region. A microscope slide can be placed in a drying position adjacent the first region. A portion of the flow (e.g., an exhaust stream) of gas can be directed over the slide. In some embodiments, the microscope slide can be heated.

- 5           An average static pressure of the portion of the flow being directed over the slide can be greater than an average total pressure of the first region. The average total pressure can be substantially identical to the low pressure being induced in the first region.

- 10           Heating the microscope slide can comprise heating the gas. Heating the flow of gas can comprise heating the jet-pump body. Heating the microscope slide can comprise heating the jet-pump body, as by, for example, passing an electrical current through at least a portion of the jet-pump body.

- 15           Some jet-pump bodies comprise a first side having one or more recessed regions. These regions can define an inlet for receiving pressurized gas, a primary flow region, a flow channel fluidly coupling the inlet and the primary flow region and extending therebetween, a backflow branch extending from the flow channel, and an exhaust manifold fluidly coupled to and downstream of the primary flow region. A jet-pump body can also comprise a second side comprising one or more heat transfer surfaces and having one or more recessed regions defining a vacuum channel extending about the one or more heat transfer surfaces. A vacuum port can extend through the jet-pump body and fluidly couple the backflow branch and the vacuum channel. An exhaust port can extend through the jet-pump body and fluidly couple the exhaust manifold with the second side.

- 20           Some disclosed embodiments of jet-pump bodies also comprise one or more elongate members extending into the primary flow region from one or more of the recessed regions of the first side. Some jet-pump bodies are substantially unitary bodies. Some of these unitary bodies can comprise the elongate members.

- 25           In some instances, the jet-pump body can be at least partially formed from a material having a thermal conductivity of at least about 100 W/m-k, such as a material having a thermal conductivity of at least about 200 W/m-k. Some jet-pump bodies can be at least partially formed of a material having a thermal conductivity of
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at least about 400 W/m-k. For example, some embodiments can comprise a polymeric material, a plastic material or a composite material having a filler material (e.g., aluminum oxide particles) dispersed throughout a matrix of polymeric material or plastic material. Some embodiments comprise a metallic alloy (e.g., an alloy of copper, an alloy of aluminum).

The foregoing and other features, and advantages will become more apparent from the following detailed description, which proceeds with reference to the accompanying figures.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an end elevation illustrating one embodiment of an exemplary microscope-slide dryer.

FIG. 2 is a top-plan view illustrating one embodiment of an exemplary jet-pump body being a part of the slide-dryer shown in FIG. 1.

FIG. 3 is a top-plan view illustrating one embodiment of a slide-dryer having a microscope slide in a drying position.

FIG. 4 is an exploded isometric view illustrating one embodiment of the slide dryer shown in FIG. 1 with a first side of the jet-pump body shown in FIG. 2 being visible.

FIG. 5 is an exploded isometric view illustrating the embodiment of the slide dryer shown in FIG. 1 with a second side of the jet-pump body shown in FIG. 2 being visible.

FIG. 6 is an end elevation illustrating one embodiment of a microscope-slide dryer incorporating a jet-pump body having an alternative configuration.

FIG. 7 is an end elevation illustrating one embodiment of a jet-pump body incorporating a distinct heater.

FIG. 8 is an isometric view illustrating embodiments of several alternative configurations for elongate members having heat transfer surfaces, such as can be incorporated in a jet-pump body to improve convective heat exchange between a fluid flow and the jet-pump body as compared to a jet-pump body without such elongate members.

## DETAILED DESCRIPTION

The following describes embodiments of apparatus for drying microscope-slides and associated methods. Some embodiments described below are described in the context of evaporating a particular fluid from a microscope slide having a tissue sample mounted thereto, as the tissue is subjected to various staining protocols. A person of ordinary skill in the art will appreciate that the scope of this disclosure is neither limited to these embodiments nor this context. For example, some embodiments can be used as an industrial dryer, as might be used to dry a slide, which may have been exposed to a wet process, such as a rinsing process.

The following makes reference to the accompanying drawings, wherein like numerals designate like parts throughout. The drawings illustrate specific embodiments, but other embodiments may be formed and structural changes may be made without departing from the intended scope of this disclosure. Directions and references (e.g., up, down, top, bottom, left, right, rearward, forward, etc.) may be used to facilitate discussion of the drawings but are not intended to be limiting. For example, certain terms may be used such as "up," "down," "upper," "lower," "horizontal," "vertical," "left," "right," and the like. These terms are used, where applicable, to provide some clarity of description when dealing with relative relationships, particularly with respect to the illustrated embodiments. Such terms are not, however, intended to imply absolute relationships, positions, and/or orientations. For example, with respect to an object, an "upper" surface can become a "lower" surface simply by turning the object over. Nevertheless, it is still the same surface and the object remains the same.

As used herein, "a" and "an" mean "one and/or one or more." As used herein, "and/or" means "and" and "and or or."

Accordingly, the following detailed description shall not be construed in a limiting sense. Those of ordinary skill in the art will appreciate the wide variety of substantially planar surfaces that can be dried using the apparatus and methods described herein.

### OVERVIEW

As shown in FIG. 1, a slide dryer can comprise a jet-pump body 1 having a bottom side 44 for engaging a slide 34 in a drying position 42 (see FIG. 5). The illustrated slide dryer 2 also comprises a shroud 26 being spaced from the side 44 to define a convection plenum 28 through which a gas flow can pass. A portion of such a flow can pass over a slide 34, or a region of a slide, when the slide is positioned in a drying position, such as the slide engaging region 42. Passing a portion of a flow over the slide 34 can increase a fluid-evaporation rate as compared to a slide exposed to only stagnant air.

10 In some embodiments, the slide 34 can also be heated, as by convective heat transfer from the portion of the flow passing over the slide, conductive heat transfer from contact with the bottom side 44 and/or radiative heat transfer (e.g., from the shroud, from the flow through the convection plenum and/or from a recessed surface of the jet-pump body). By heating the slide 34, a fluid-evaporation rate from a surface of the slide 34 can be increased as compared to an unheated slide.

Slide dryers that heat a slide using a plurality of modes of heat transfer, together with advective-dispersive mass transfer, can significantly shorten the time necessary to dry a microscope slide as compared to prior art slide dryers.

### JET-PUMP BODY: SLIDE-ENGAGING SIDE

20 With reference to FIGS. 2, 4 and 5, a jet-pump body 1 having features for holding a slide in a drying position 42 will now be described. The jet-pump body 1 can provide a pressure difference across the slide 34 sufficient to hold the slide in contact with at least a portion of one side (e.g., bottom-side 44) of the jet-pump body.

25 With reference to FIG. 5, which shows the slide dryer shown in FIG. 1 inverted so as to view otherwise hidden features, a jet-pump body 1 can define a bottom-side 44 having one or more heat transfer surfaces 38 and one or more recessed regions defining one or more vacuum channels 40 extending about the one or more heat transfer surfaces. As used herein, a surface that is "substantially flat" means the surface is flat to within less than about 0.010 inches per inch along the

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surface. As used herein, surfaces are said to be “substantially coplanar” when the surfaces are coplanar to within less than about 0.010 inches per inch between the surfaces. In the illustrated embodiment, the heat transfer surfaces 38, 38a are substantially flat and substantially coplanar with a slide-engaging region 42 defined by the bottom-side.

As illustrated, a heat transfer surface 38a can be substantially contiguous with the slide engaging region 42. As also illustrated, a heat transfer surface 38 can alternatively be isolated from the slide engaging region 42, such as by being defined by a side of a member extending from the jet-pump body 1. For example, a member 35 extending from a floor-side of the illustrated vacuum channel 40 can define a side being distally located from the floor-side and comprise the heat transfer surface 38.

A slide engaging region 42 can be slightly recessed from the bottom-side 44 (e.g., into the surface) so as to form a shoulder (e.g., a stop) for aligning a microscope slide 34 being positioned adjacent the slide engaging region. In some embodiments, a compliant gasket member (not shown) can be located adjacent a periphery of the slide engaging region 42 for promoting sealing engagement between the slide engaging region and microscope slide 34. Such gasket members can comprise an o-ring set in a groove, a compliant gasket such as a silicone rubber gasket or any of myriad other gasket types. A substantially flat and substantially coplanar slide engaging region (including heat transfer surface 38, 38a) can sealingly engage a slide positioned in a slide-drying position 42.

A microscope slide 34 positioned in a slide-drying position, e.g., located substantially within the slide engaging region 42, can be in physical or thermal contact with one or more of the one or more heat transfer surfaces 38, 38a. Such contact, when the jet pump body 1 is heated to a temperature greater than a temperature of the slide 34, can heat the slide by conductive heat transfer from the jet-pump body (e.g., through the heat transfer surface(s) in contact with the slide). When heat is being conducted from one surface to another through direct contact as just described, a difference (e.g., a discontinuity) in average surface temperature exists between the two surfaces in contact (e.g., giving rise to the notion of a so-called “thermal resistance”). Such a temperature difference can be reduced by

improving flatness of the respective surfaces coming into contact with each other and/or by treating one or both surfaces with a thermally conductive and physically compliant material (as by, for example, adhering a compliant pad having thermally conductive fibers and/or particles dispersed throughout the pad to one or both  
5 surfaces).

In the illustrated embodiment (see FIG. 5), two vacuum orifices 10 are provided to fluidly couple the vacuum channels 40 to a region of relatively low pressure, such as to at least partially evacuate the one or more vacuum channels. The vacuum orifices 10 and establishing such a low pressure region are discussed  
10 more fully below.

A flow obstruction, such as a microscope slide 34, can be placed adjacent the slide engaging region 42 and can substantially cover the recessed vacuum channels 40. The vacuum channels 40 can distribute a low-pressure field throughout the recessed region in some embodiments. In some embodiments, a slide so positioned  
15 (e.g., in a drying position) can be held against the jet-pump body 1 with sufficient force as to urge the slide against the surface despite the pull of gravity. In other words, a sufficient vacuum can be applied to the vacuum channels 40, together with a sufficient sealing engagement between the slide 34 and the jet-pump body 1, such that a pressure difference between an exterior pressure and a pressure in the vacuum  
20 channels exerts a force on the slide greater than a weight of the slide having a sample mounted thereto.

#### JET-PUMP BODY: INLET

As shown in FIGS. 2 and 4, a top-side 36 of the exemplary jet-pump body 1 can define a recessed inlet 11 for receiving a pressurized flow of gas. In some  
25 embodiments, the inlet 11 can fluidly couple to (e.g., engage a hose extending from) a supply of pressurized gas (e.g., a tank). Such an inlet 11 can be a conduit through which a flow of gas can pass into the channels of a jet-pump body, as described more fully below.

### JET-PUMP BODY: BACKFLOW BRANCHES

A recessed region can define a primary flow region 22 being positioned downstream of the inlet 11, and a flow channel 15 extending therebetween. The flow channel 15 can fluidly couple the inlet 11 and the primary flow region 22 such that a flow of gas received by the inlet can pass through the flow channel into the primary flow region.

A backflow branch 13 having a configuration as described below (as well as others as will be apparent to those of ordinary skill based on this description) can have an average pressure that is about the same as an average static pressure of a flow passing through the channel 15. For example, one or more backflow branches 13 can extend from the channel 15 at an angle of greater than about 90-degrees, such as between about 100-degrees to about 150-degrees, measured relative to a general flow-direction from the inlet 11 to the primary flow region 22 (e.g., along a longitudinal axis of the channel 15). Such a configuration of a backflow branch can reduce or eliminate flow from the channel 15 into the backflow branch 13, as might occur if the angle were selected to be less than about 90-degrees. Of course, in some embodiments, such a backflow branch 13 can extend at an angle less than about 90-degrees and still provide a functional pressure therein, as described below. One or more of the backflow branches 13 can be curved as illustrated, and can fluidly couple a vacuum orifice 10 to the flow channel 15.

If flow through a vacuum orifice 10 (and thus the corresponding backflow branch 13) is obstructed (as from a microscope slide 34 being positioned in a drying position as shown in FIG. 5), or at least substantially obstructed, the average pressure in the backflow branch can be characterized as being a total pressure. Thus, as a gas flow passes by the backflow branch, a pressure field in a region adjacent the vacuum orifices 10 can have an average total pressure roughly equal to a static pressure of the flow. As used herein, "total pressure" means a pressure comprising a static pressure component and a dynamic pressure component corresponding, at least in part, to a kinetic energy of the flow.

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### JET-PUMP BODY: PRIMARY FLOW REGION

As shown in FIG. 4, the primary flow region 22 can be formed as yet another recessed region and can have a cross-sectional area (e.g., relative to a flow direction as indicated by arrows 24 in FIG. 2) greater than a cross-sectional area of the flow channel 15. Accordingly, as a gas flow passes through the flow channel 15 into the primary flow region 22, the gas flow can expand and decelerate. Such deceleration and expansion, if controlled, can recover at least some of the flow's dynamic pressure component as an increase to the flow's static pressure.

However, some portions of an expanding flow can have one or more regions of recirculation and/or areas of flow separation in certain sub-regions defined within the primary flow region 22. To mitigate the effects of such recirculation and separation, at least some of the primary flow region 22 can have additional flow-control features, such as, for example, elongate members 16 that extend into the primary flow region (e.g., turning vanes (not shown)). Elongate members 16 typically are positioned adjacent a transition region from the flow channel 15 to the primary flow region 22. In some embodiments, one or more elongate bodies 16 can be configured to affect expansion of gas into the primary flow region 22, as well as or alternatively to affect rates of convective heat transfer between the jet-pump body 1 and a flow through the primary flow region, as described more fully below.

### JET-PUMP BODY: EXHAUST MANIFOLD

A jet-pump body 1 can also define one or more recessed exhaust manifolds 12. In the embodiment illustrated in FIGS. 2 and 4, a pair of exhaust manifolds 12 are fluidly coupled in parallel to each other and together coupled in series with (e.g., downstream of) the primary flow region 22. The exemplary jet-pump body 1 defines a turning vane 20 (or in other embodiments plural turning vanes) adjacent each inlet to each respective exhaust manifold 12. Such turning vanes can turn a flow, in this example, by about 180-degrees.

Each of the exemplary exhaust manifolds 12 define a tapering cross-sectional area that tapers from a larger area at an inlet end of the exhaust manifold to a terminal end. Of course, in some embodiments, the cross-sectional area is

substantially uniform along a length of the manifold. In other embodiments, the cross-sectional area increases from the inlet to a terminal end.

The illustrated jet-pump body 1 comprises a plurality of exhaust ports 14 positioned along a wall of each exhaust manifold 12. In this embodiment, each exhaust port 14 is simply a through hole extending through the jet-pump body and fluidly coupling the exhaust manifold with the second side. See FIGS. 4 and 5 and the hidden features shown in the end-elevation of FIG. 1. As a flow of gas passes through the respective exhaust manifolds 12, a corresponding exhaust stream exhausts from each manifold into an exhaust region defined by the bottom side 44.

With reference to FIG. 5, the exhaust ports 14 are positioned outside a periphery of the slide engaging area 42. Such an arrangement allows an exhaust stream (indicated by the arrows 12 in FIG. 1) to exhaust into an exhaust region defined by the bottom-side 44 and remain substantially fluidly isolated from the vacuum channels 40 when an obstruction (e.g., a slide 34) is positioned in the slide engaging region 42.

Although the illustrated embodiments comprise exhaust manifolds 12 having discrete exhaust ports 14, some embodiments combine the exhaust manifold and exhaust port into a single structure. For example, a single elongated slot (not shown) extending through the jet-pump body 1 can be located downstream of the primary flow region 22 and outside a periphery of the slide engaging region 42. Such a slot can provide an exhaust stream having a sheet-like velocity profile at an exhaust plane of the slot.

#### TOP CAP

As noted above, each of the features defined by the top side 36 of the jet-pump body 1 can be formed as one or more contiguous and/or fluidly coupled recessed regions. In the embodiment illustrated in FIGS. 1, 4 and 5, a top cap 30 sealingly engages at least a portion of the top side 36 to sufficiently prevent leakage of a flow of gas from one flow feature (e.g., the primary flow channel 22, turning vanes 20, elongate bodies 16, backflow channels 13) to another flow feature and/or the environment. Such leakage can result in the flow by-passing some or all of the

flow features. In the illustrated embodiments, the top cap 30 is substantially planar and sealingly engages a correspondingly flat top side 36.

Alternative embodiments (not shown) of the top cap 30 have portions extending out of a plane defined by the top cap 30. Such portions can matingly engage one or more corresponding recesses defined by, e.g., the top-side 36 of the jet-pump body 1. For example, the jet-pump body 1 and one or more corresponding recessed features of the top-side can be extruded in an extrusion process. Such extrusion processes typically lead to substantially linear features. One or more transverse operations (e.g., cross-cutting as with a saw) can be performed on the extrusions to provide one or more recesses oriented transverse to the longitudinally oriented extrusion features. Portions extending from the top cap 30 can matingly engage with one or more recessed features to define one or more flow features described herein as being a recessed feature defining a flow channel.

#### HEATERS FOR HEATING THE JET-PUMP BODY

As noted above, an exemplary jet-pump body 1 can be heated so as to conduct heat to a slide 34. In some embodiments, e.g., the embodiment shown in FIGS. 2, 4 and 5, the jet-pump body 1 can be substantially formed of an electrically conductive material (e.g., an alloy of copper, an alloy of aluminum, an alloy of nickel). Plural electrical connections 18 can be provided for connecting the jet-pump body 1 to an electrical current source. In embodiments of this type, passing a current through the body 1 can resistively heat the body. Heat can be conducted to the slide 34 when it comes into direct or thermal contact with one or more of the heat transfer surfaces 38.

In another embodiment, a heater, such as for example a heater 7 (FIG. 7), can contact (e.g., direct contact, thermal contact) one or more surfaces of the jet-pump body 1. In some embodiments, a heater can be located at least partially within the jet-pump body. As shown by FIG. 7, the heater 7 can be positioned between adjacent portions 3,5 of a jet-pump body 1". The heater 7 in this embodiment can be resistively heated as by electric current, or can be a heat exchanger heated by a heating fluid, e.g., convectively heated. In some embodiments, the heater 7 is a

resistively heated cartridge heater received in a socket defined by the jet-pump body 1”.

In yet another embodiment, the jet-pump body can at least partially be heated by a heated gas flow, such as, for example, a heated gas flow passing through the flow features (e.g., primary flow region 22). In such an embodiment, a flow of gas (illustrated by arrows 24) being supplied to the inlet 11 (see FIG. 1) can be heated before passing into a flow region of the jet pump body 1. Thus, the jet-pump body can be convectively heated (e.g., heat can be transferred to the jet-pump body from the pre-heated gas). As noted above and described more fully below, one or more features such as one or more elongate bodies 16 can extend into the primary flow region 22 and improve heat exchange between the jet-pump body 1 and the gas (e.g., from the gas to the body or from the body to the gas).

Some embodiments combine one or more of these modes of heating the jet-pump body. For example, a discrete heater (e.g., the heater 7) can be used in combination with resistively heating one or more portions of the jet-pump body.

#### HEAT EXCHANGE BETWEEN THE JET-PUMP BODY AND A FLOW OF GAS

As noted above, one or more features, such as one or more elongate bodies 16 can extend into the primary flow region 22. Such elongate bodies can increase a surface area being available for convective heat transfer (i.e., “convective heat transfer area”) relative to a surface of the primary flow region 22 without such elongate bodies.

As used herein, “heat transfer coefficient” means a unit of measure for quantifying a potential rate of heat transfer for a unit of area and a unit of temperature difference that can be achieved for a given gas flow. A heat transfer coefficient can be expressed in units of  $W/(m^2 \cdot K)$ . Given a constant temperature difference between a gas and a convective heat transfer surface, and a constant heat transfer coefficient, an increase in convective heat transfer area can increase a rate of heat transfer between the surface and the gas. Consequently, increased heat exchange between a body and a gas can be achieved by providing an increase in available convective heat transfer area. Providing one or more elongate bodies 16 as

extended heat transfer surfaces (e.g., heat exchanger fins) can provide an increase in available heat exchange between the jet-pump body 1 and a gas flow through the channels defined by the jet-pump body.

Many configurations of elongate bodies 16 are possible, such as, for  
5 example, cylindrical or conical “pin-fins”, rectangular bodies 16’ such as “plate-fins” (note that such plate fins can be corrugated for locally enhancing a heat transfer coefficient), and fins 16” having a rounded cross-section (e.g., an elliptical cross-section) as might be used to channel a flow through an array of such fins 16” and reduce flow losses (e.g., loss in pressure head) associated with local wake  
10 shedding downstream of the elongate body 16.

Generally, heat energy moves from a region of higher temperature to a region of lower temperature. Accordingly, if a gas flowing through the primary flow channel 22 has a temperature greater than a surface temperature of the flow channel 22, heat will generally move into the jet-pump body from the gas (as can be  
15 the case when a heated gas flow is provided to the inlet 11 and the jet-pump body 1 is left otherwise unheated). Alternatively, if a gas flowing through the primary flow channel has a temperature less than a surface temperature of the flow channel, heat will generally move into the gas from the jet-pump body (as can be the case when an unheated flow is provided to the inlet 11 and the jet-pump body 1 is resistively  
20 heated).

In the case of heating a gas passing through the flow channels, a temperature of the gas in (and/or exhausting from) the exhaust manifold 12 can be higher than a temperature of the gas at an inlet 11. In some instances, however, Joule-Thompson cooling (e.g., cooling of a gas resulting from expansion of the gas) can lower a gas  
25 temperature sufficiently such that heating as described above does not raise the temperature of the exhaust stream above the temperature of the gas at or near the inlet 11. Such Joule-Thompson cooling can, in some embodiments, occur as a gas expands into the primary flow channel 22.

### SLIDE DRYER: CONVECTION PLENUM

Jet-pump bodies as described above can be incorporated into apparatus for drying slides. For example, a bottom cap 26 can form a shroud or duct member. Such a shroud can have a web-member spanning a distance between substantially  
5 parallel sidewalls 27. The side-walls can define engaging surfaces 29 for engaging the top cap 30, as illustrated in the end-elevation of FIG. 1. Alternatively, with respect to FIG. 6, the engaging surfaces 29 can mate with a shoulder defined by the jet-pump body 1'.

Such shroud configurations at least partially surround a bottom-side 44 of the  
10 jet-pump body 1 with the bottom cap 26 to form a convection plenum 28 having two open ends opposing each other. An exhaust stream can exhaust from the exhaust ports 14 (refer to arrows 24 indicating flow direction) into the convection plenum, as shown in the end-elevation of FIG. 1, and pass to the local environment through, for example, the opposing open ends of the plenum 28.

15 In the illustrated embodiments, after the flow exhausts from the exhaust ports 14 into the convection plenum 28, a slide 34 positioned in a drying position 42 (together with a sample 46 mounted thereto) can be exposed to at least a portion of the exhaust flow through the convection plenum 28. See for example FIG. 4 and FIG. 5. In many instances, increased rates of evaporation can be obtained by  
20 passing a portion of the exhaust stream over the slide as compared to a slide exposed merely to stagnant air (e.g., evaporation can be improved using advective-dispersive mass transfer).

Although a pressure gradient can exist throughout the convection plenum 28 (e.g., a higher pressure near the exhaust region and a lower pressure near an open  
25 end of the plenum), an average static pressure near the slide-engaging region 42 can be greater than an average total pressure throughout the vacuum channels 40 (e.g., less than a static pressure of the flow passing through the channel 15). For example, a slide 34 can be positioned in a slide-drying position (and/or seated in a slide engaging region 42) such that the slide at least partially obstructs the flow passing  
30 through the convection plenum 28 from recirculating (e.g., being drawn into the

vacuum channels 40). In some instances, a pressure difference across a slide positioned between the convection plenum 28 and the vacuum channels 40 is sufficient to suspend the slide 34 and a sample 46 mounted thereto against a force of gravity.

5                    CLOSED-LOOP CONTROL: BODY TEMPERATURE

Some embodiments of jet-pump bodies include one or more temperature sensors for indicating whether given heating rate should be maintained, increased or decreased, e.g., whether the given heating rate is sufficient for drying a slide. For example, one or more temperature sensors, e.g., thermistors, thermocouples,  
10 resistance thermal devices (RTD), can be positioned in and/or on a jet-pump body to sense the temperature at or near the corresponding jet-pump-body locations. An ammeter can measure an electrical current (and thus the amount of energy being supplied through a particular electrical circuit) to the body. As a body-temperature reaches a predetermined threshold, the rate of heating (e.g., amount of electrical  
15 current supplied to a resistive heater) can be varied to maintain the body-temperature near the threshold. Such rates of heating can be selected in response to for example one or more temperature and/or current measurements.

In some embodiments, one of the described heaters (e.g., a resistive heater) can be combined with a chilling (e.g., heat removal) heat exchanger (not shown) for  
20 accurately controlling a temperature of the jet-pump body. For example, the jet-pump body can be heated using an electrically resistive heater to a pre-defined temperature. Since the jet-pump body has some non-zero mass, at least a portion of the body will tend to increase in temperature until all of the energy input to the jet-pump body by the heater has diffused into the body and heated the mass.

25                    For some embodiments, accurate control of, e.g., a heat transfer surface 38, temperature (e.g., critically dampening a temperature rise) may be desired. A chiller (e.g., a heat exchanger through which chilled water can pass) in thermal contact with the jet-pump body can remove excess heat supplied to the body after a desired temperature has been reached. For example, if a body-temperature is at or near a  
30 desired threshold, but is increasing, a rate of heating can be decreased, and in some

instances a chiller can remove excess heat. Such a chiller can dampening a temperature response (e.g., control over-shoot and/or critically dampen a temperature response).

#### CLOSED-LOOP CONTROL: SENSING COMPLETION OF DRYING

5           Some closed-loop control systems for controlling a body temperature can also indicate a slide's presence (as described more fully below) or completion, or substantial completion, of a drying process, for example, by detecting a shift in energy-supply (e.g., heat-transfer) rates at a given temperature. For example, as evaporation slows, less energy can be supplied to maintain the body-temperature  
10       near the given temperature. Such a shift in heating rate can indicate that a slide is dry (or substantially dry).

          When at a steady-state temperature, the amount of heat supplied by a heater to a jet-pump body and slide is substantially the same as the amount of heat rejected by the body and slide to the environment (as described in connection with the jet-  
15       pump body and slide dryer embodiments above). But, as a fluid evaporates, at least a portion of the heat supplied to the body and slide can be absorbed by the evaporating fluid (e.g., as a heat of vaporization). As more heat is supplied, the evaporation rate can increase while maintaining an approximately uniform body and slide temperature. After all (or substantially all) of the fluid has evaporated, the  
20       body and slide temperatures can increase asymptotically to a steady-state temperature (assuming the heating rate remains the same) corresponding to the rate of heating during evaporation. Detecting a period of nearly constant temperature followed by a period of rising temperature under a substantially uniform rate of heating can indicate completion of a drying process.

#### 25           CLOSED-LOOP CONTROL: SENSING PRESENCE OF A SLIDE

          Various methods for sensing a slide's presence in a drying position (e.g., near the slide-engaging region 42) will now be described.

          A pressure transducer (e.g., a differential pressure transducer) can be used to sense changes in pressure. For example, a difference between two pressures, each  
30       being measured at a corresponding location capable of being isolated from each

other by a slide 34 when the slide is positioned in a slide drying position (e.g., a first position adjacent an exhaust port 14 and a second position adjacent a vacuum orifice 10), can change in the presence or absence of a slide. Such a change can be measured and recorded. In use, these pressures can be monitored and compared to the measured and recorded change. A slide's presence can be indicated when such a comparison yields a substantially identical pressure as (e.g., within a selected range from) the measured and recorded value.

Alternatively, a reflective optical sensor can be positioned so as to detect an edge of a slide when the slide is positioned in a slide-drying position.

As noted above, rates of heating (e.g., amount of electrical current supplied to a resistive heater) can be monitored, such as for controlling energy being supplied to a jet-pump body for maintaining the body-temperature near a desired threshold. Since rates of heating can be monitored, shifts in rates of heating can also be monitored to indicate the presence of a slide. For example, in the presence of a slide (and any corresponding mass of the slide), more energy may be necessary to achieve a given change in temperature (e.g., thermal capacitance can increase with mass). Similarly, a thermal time-constant can increase when a slide is present. Thus, for a given change in a rate of heating, a reduced rate of change in temperature can indicate that a slide is present. Of course, a reduced rate of change in temperature can also indicate that a slide has not yet completed drying (as described above). Similarly, if a jet-pump body is heated to a given temperature, and a cooler slide is brought into contact with the body, a portion of the body will decrease in temperature. Such a change in temperature of a portion of a jet-pump body can indicate that a slide is present.

Some embodiments include ultrasonic sensors (e.g., piezo-electric sensors) for detecting shifts in dynamic vibrations. Such shifts can be caused by changes in system mass arising from engaging and disengaging a slide from thermal contact with the conductive surface. In some embodiments, vibrations from the ultrasonic sensor can "shake" droplets from the slide, further enhancing evaporative drying.

A change in mass resulting from the presence of a slide can also affect a mechanical vibration frequency (e.g., a natural frequency), which can be used to

detect the presence of a slide. For example, a combined mass of a piezo-electric transducer and a slide being in contact with the piezo-electric transducer is larger than a mass of the piezo-electric transducer alone. Consequently, a natural frequency of the slide and piezo-electric transducer can be lower than a natural frequency of the transducer alone. Such a change in natural frequency can be detected by changes in, for example, electrical drive currents used to power the piezo-electric device. Alternatively, a piezo drive frequency can be swept through a range of frequencies (e.g., in discrete steps, continuously) to identify a resonant frequency of the combined system, such as can be signified by an increase in power delivered by the combined system relative to the power used to drive the system. Alternatively, the piezo-electric transducer can be excited (or pulsed) and a ring-decay time can be measured. A shorter ring-decay time can indicate the presence of a slide since ring-decay time typically decreases with increased mass.

#### SLIDE DRYER: OPERATION

A slide dryer 2 (FIGS. 4 and 5) as described above can be used to dry a microscope slide 34 having a tissue sample 46 mounted thereto.

A supply of gas (e.g., air, an inert gas such as nitrogen, with dry nitrogen being but one example) can be supplied to the inlet 11. As the gas passes through the flow channels (e.g., channel 15, primary flow region 22, exhaust manifolds 14) defined by the jet-pump body 1 and described above, a low pressure region can form near the slide-engaging region 42. As noted above, an average static pressure of the exhaust stream can be greater than an average total pressure in the region adjacent the vacuum orifices 10 (e.g., within the vacuum channels 40) and some recirculation of the gas can occur (e.g., exhaust from the exhaust ports 14 can be drawn into one or more vacuum orifices and again pass through the primary flow region 22) in the absence of a slide. In some embodiments, the gas can be supplied in response to a sensed presence of a slide. Such sensing is described more fully below.

Alternatively, the gas can be supplied before a slide is presented for drying.

A slide 34 having a sample 46 to be dried can be positioned in a slide-drying position, such as for example near the slide engaging region 42. Positioning a slide

34 as just described can reduce and/or eliminate recirculation of the exhaust stream and a relatively low pressure can be established throughout the vacuum channels 40. The correspondingly higher pressure in the convection plenum 28 can urge the slide into against one or more heat transfer surfaces 38, 38a.

5           Any (or none) of the various heaters described above can be employed to heat the jet-pump body 1 (and thus one or more of the heat transfer surfaces 38). By heating the body 1 (e.g., by supplying a heated gas flow among the fins, passing an electrical current through the body, etc.) and placing a slide 34 in direct (or thermal) contact with the body, e.g., a heat transfer surface 38, 38a, heat energy can be  
10 transferred by conductive heat transfer (and to some degree radiative heat transfer) from the body to the slide, thereby heating the slide and any tissue sample 46 mounted thereto.

As previously noted, a slide 34 positioned in the convection plenum 28 can be exposed to at least a portion of an exhaust stream exhausting from the jet-pump  
15 body 1. As also noted above, the flow can be heated, for example, as it passes through the channels of the body 1 (e.g., among a plurality of fins located throughout the primary flow channel 22) if the body is internally heated, and/or a heated flow of gas can be supplied to the jet-pump body 1. Accordingly, the flow of the exhaust stream through the convection plenum can convectively heat the slide in  
20 some embodiments.

Such heating (conductive, convective, radiative) can improve rates of evaporation from the slide 34 as compared to achievable rates of evaporation from the slide when the slide has been left unheated. In addition, passing a portion of the exhaust stream over the slide can further increase rates of evaporation as compared  
25 to a slide positioned in stagnant air. Slide dryers 2 as described herein can provide conductive, convective and radiative heat transfer, and advective-dispersive mass transfer and accelerate drying as compared to conventional slide-dryers. Since such slide dryers can significantly shorten the time necessary to dry a microscope slide, increases in rates of production of slides having stained samples mounted thereto are  
30 possible.

### MANUFACTURING

Various methods of manufacturing can be employed for the slide-dryer components described herein. For example, the recessed features of the jet-pump body can be formed using an impact extrusion (e.g., a cold-forging) process. In  
5 some instances, such a cold-forging process can even be used to form through holes, such as for example the vacuum orifices 10, the exhaust ports 14.

Alternatively to (or in combination with) such impact extrusion processes, material removal processes can be used to define recessed features of a jet-pump body. For example, the various channels and through-holes can be machined (as by  
10 milling, drilling), chemically removed (e.g, by an etching process) and/or ablated (as by laser machining).

Some embodiments can be formed using an injection molding process, as by a plastic injection molding process and/or a metal injection molding process. The various components (including the jet-pump body 1) can be formed using composite  
15 construction techniques, such as for example a lamination process.

A stamping process is but one example of yet another process that can be used to form at least some components of slide-dryers, e.g., a bottom cap 26.

In view of the many possible embodiments to which the principles of the disclosed innovations can be applied, it should be recognized that the above-  
20 described embodiments are only preferred examples and should not be taken as limiting the scope of what is claimed. Rather, the scope of what is claimed is set forth in the following claims. We therefore claim as our invention all that comes within the scope and spirit of these claims.

We claim:

1. A microscope-slide dryer, comprising:
  - a jet-pump body having a first side defining a flow channel and an exhaust
  - 5 port, and a second side defining a vacuum channel, an exhaust region and a heat-transfer surface, wherein the exhaust port fluidly couples the flow channel and the exhaust region; and
  - a top member adjoining the first side.
- 10 2. The microscope-slide dryer of claim 1, further comprising:
  - a bottom member adjacent to and at least partially spaced from the second side to at least partially define an exhaust plenum fluidly coupled with the exhaust region.
- 15 3. The microscope-slide dryer of claim 1, further comprising a heater configured to heat a microscope slide positioned adjacent the second side.
4. The microscope-slide dryer of claim 3, wherein the heater comprises one or more of the following:
  - 20 an electrically resistive heater positioned adjacent to the jet pump body;
  - an electrical connector for supplying the jet-pump body with an electrical current for resistively heating the jet-pump body directly, wherein the jet-pump body comprises an electrically conductive material;
  - a fluid connector for coupling the flow channel to a heated stream of gas;
  - 25 a member extending into the flow channel; and
  - a thermally conductive member for conducting heat into the slide.
5. The microscope-slide dryer of claim 4, wherein the thermally conductive member comprises one or more of at least a portion of the jet-pump body and a thermally
- 30 conductive interface material for enhancing thermal contact between adjacent surfaces.

6. The microscope-slide dryer of claim 1, wherein the vacuum channel comprises a floor side and the heat transfer surface comprises a plurality of heat transfer surfaces, wherein one or more of the plurality of heat transfer surfaces are spaced  
5 from the floor side.
7. The microscope-slide dryer of claim 1, wherein the jet-pump body defines a vacuum orifice configured to fluidly couple the flow channel and the vacuum channel.  
10
8. The microscope-slide dryer of claim 7, wherein the body is configured such that a flow of gas through the flow channel induces a first pressure adjacent the vacuum orifice and exhausts adjacent the at least one exhaust region in an exhaust stream.
- 15 9. The microscope-slide dryer of claim 8, further comprising a bottom member adjacent to and at least partially spaced from the first side to at least partially define an exhaust plenum fluidly coupled with the exhaust port.
10. The microscope-slide dryer of claim 9, wherein the first pressure is less than an  
20 exhaust pressure of the exhaust stream.
11. The microscope-slide dryer of claim 10, wherein the body is configured such that a difference between the first pressure and the exhaust pressure applied across a microscope slide positioned adjacent the first side applies a force to the microscope  
25 slide in excess of a weight of the microscope slide.
12. The microscope-slide dryer of claim 11, further comprising a heater for heating the microscope slide.
- 30 13. The microscope-slide dryer of claim 12, wherein the gas comprises one or more of air and dry nitrogen.

14. The microscope-slide dryer of claim 2, wherein the bottom member comprises a duct member.

- 5 15. A method for drying a microscope slide, the method comprising:  
passing a flow of gas through a flow channel defined by a first side of a jet-pump body and fluidly coupled with a first region at least partially defined by a second side of the jet-pump body, thereby inducing a low pressure in the first region;  
10 placing a microscope slide in a drying position adjacent the first region;  
directing a portion of the flow of gas over the microscope slide; and  
heating the microscope slide.

16. The method of claim 15, wherein the portion of the flow comprises a portion of  
15 an exhaust stream.

17. The method of claim 15, wherein the jet-pump body defines a vacuum orifice fluidly coupling the first region and the flow channel.

20 18. The method of claim 15, wherein an average static pressure of the portion of the flow is greater than an average total pressure of the first region.

19. The method of claim 18, wherein the average total pressure is substantially identical to the low pressure.

25 20. The method of claim 15, wherein the act of heating the microscope slide comprises heating the flow of gas.

21. The method of claim 20, wherein the act of heating the flow of gas comprises  
30 heating the jet-pump body.

22. The method of claim 15, wherein the act of heating the microscope slide comprises heating the jet-pump body.

23. The method of claim 22, wherein the act of heating the jet-pump body  
5 comprises passing an electrical current through at least a portion of the jet-pump body.

24. A jet-pump body, comprising:

10 a first side having one or more recessed regions defining an inlet for receiving a pressurized gas, a primary flow region, a flow channel fluidly coupling the inlet and the primary flow region and extending therebetween, a backflow branch extending from the flow channel, and at least one exhaust manifold downstream of and fluidly coupled with the primary flow region;

15 a second side comprising one or more heat transfer surfaces and defining one or more recessed vacuum-channel regions extending about the one or more heat transfer surfaces;

a vacuum port extending through the jet-pump body and fluidly coupling the backflow branch and at least one of the vacuum-channel regions; and

20 an exhaust port extending through the jet-pump body and fluidly coupling the exhaust manifold with a region adjacent the second side.

25. The jet-pump body of claim 24, further comprising one or more elongate members extending into the primary flow region.

26. The jet-pump body of claim 24, wherein the jet-pump body is substantially a unitary body.

27. The jet-pump body of claim 25, wherein the jet-pump body and the one or more elongate members comprise a substantially unitary construction.

30

28. The jet-pump body of claim 25, wherein a bulk average thermal conductivity of the jet-pump body is at least about 100 W/m-k.

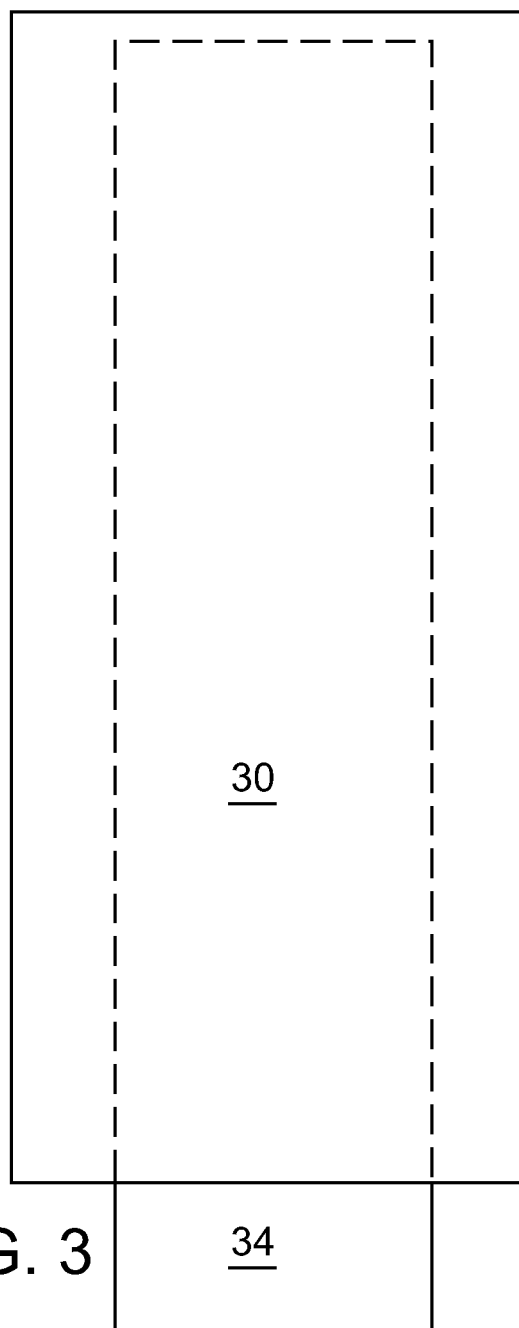
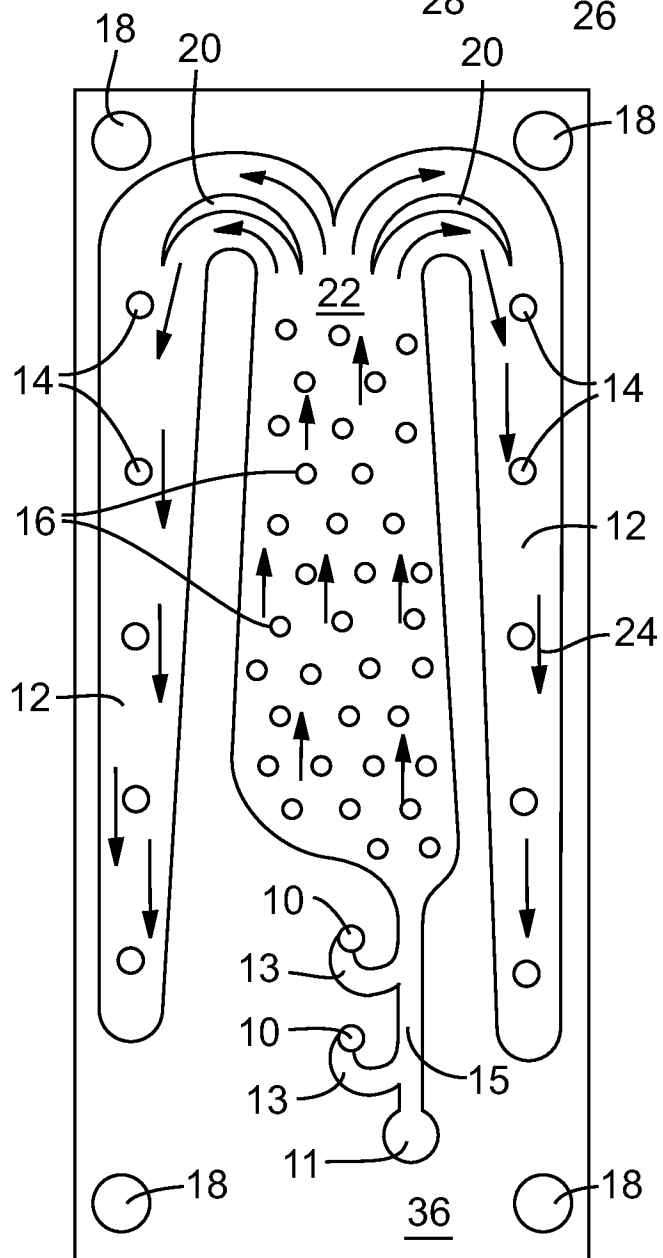
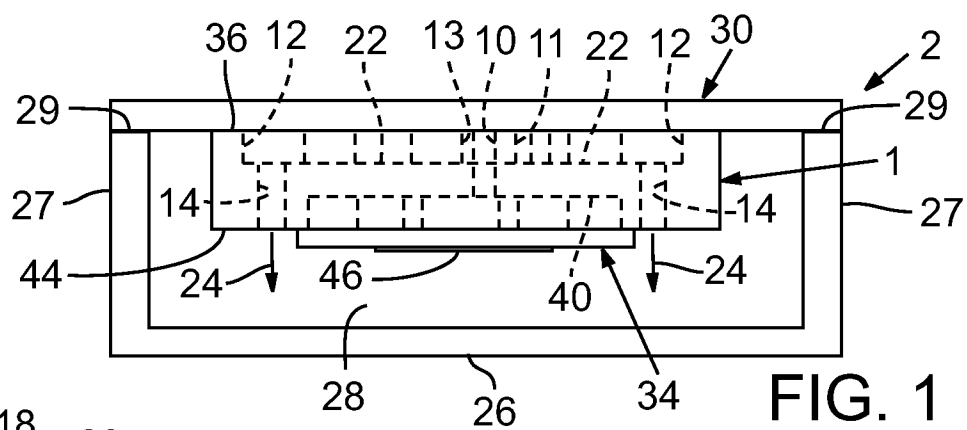
29. The jet-pump body of claim 28, wherein the bulk average thermal conductivity  
5 is at least about 200 W/m-k.

30. The jet-pump body of claim 29, wherein the bulk average thermal conductivity is at least about 400 W/m-k.

10 31. The jet-pump body of claim 24, further comprising a heater configured to heat a microscope slide positioned adjacent one or more of the one or more heat transfer surfaces.

32. The jet-pump body of claim 31, wherein the heater comprises one or more of  
15 the following:

- an electrically resistive heater positioned adjacent to the jet pump body;
- an electrical connector for supplying the jet-pump body with an electrical current for resistively heating the jet-pump body directly, wherein the jet-pump body comprises an electrically conductive material;
- 20 a fluid connector for coupling the flow channel to a heated stream of gas;
- a member extending into the flow channel; and
- a thermally conductive member for conducting heat into the slide.



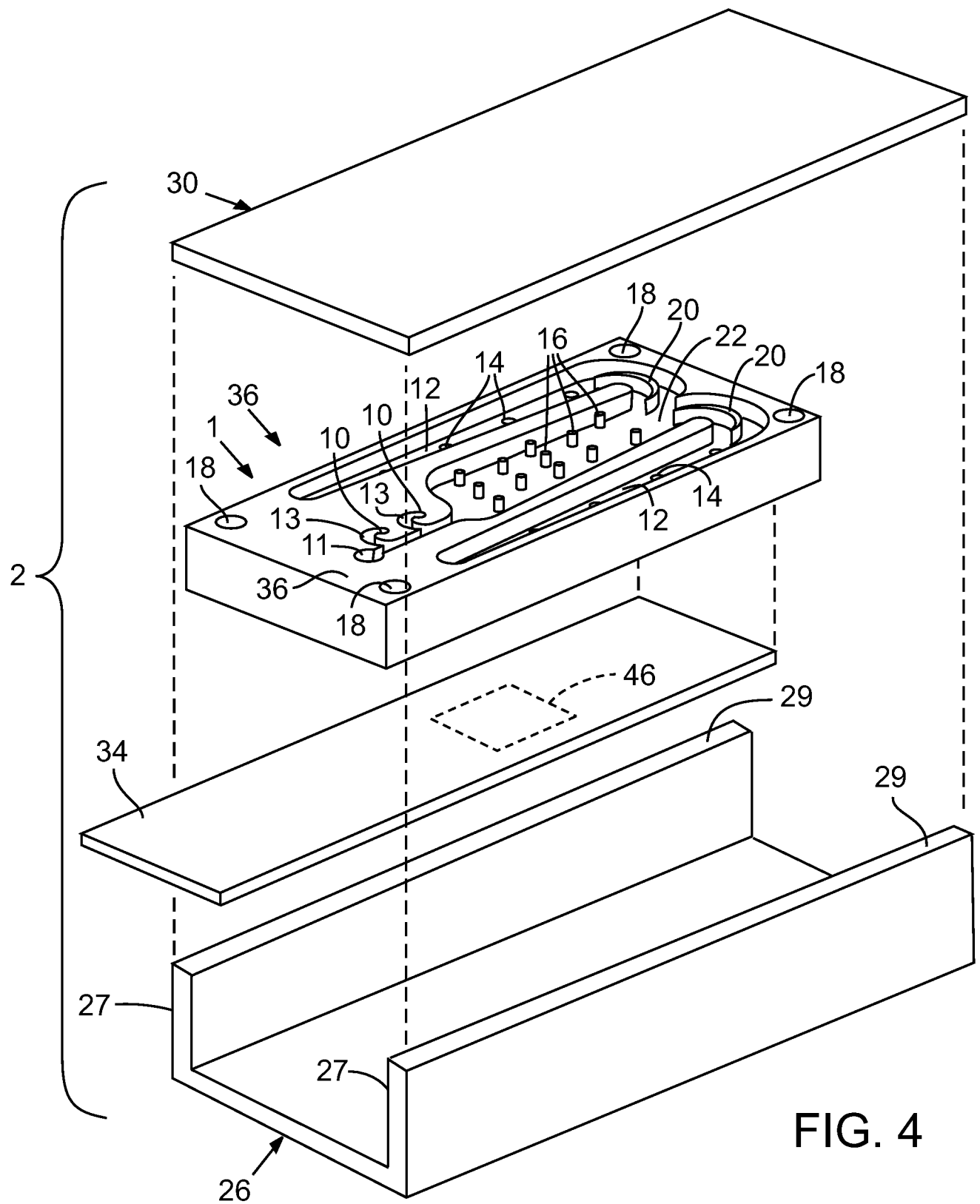
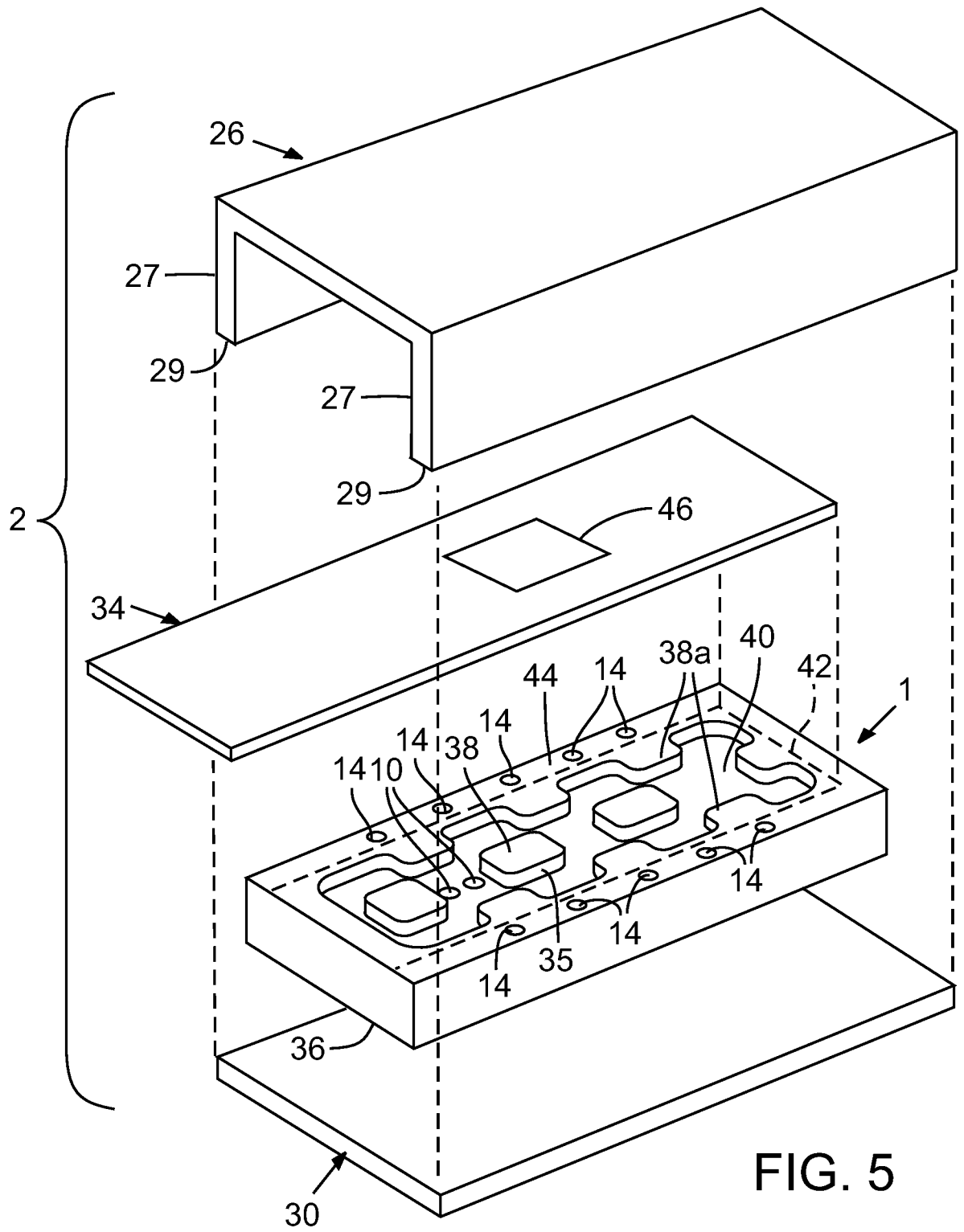


FIG. 4



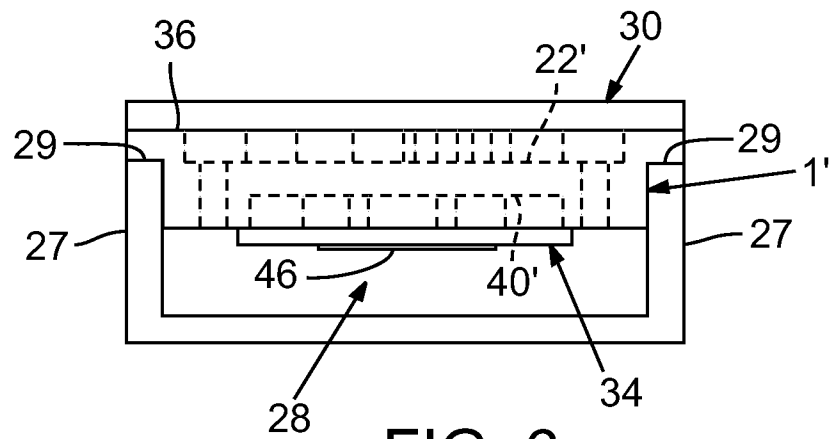


FIG. 6

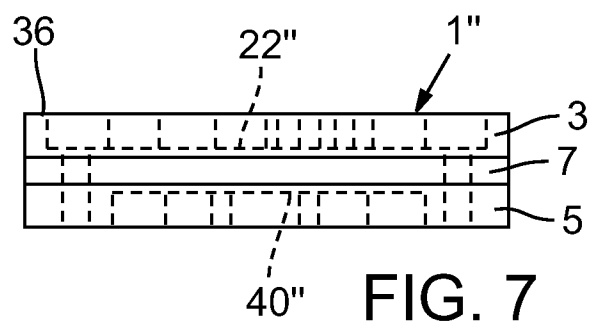


FIG. 7

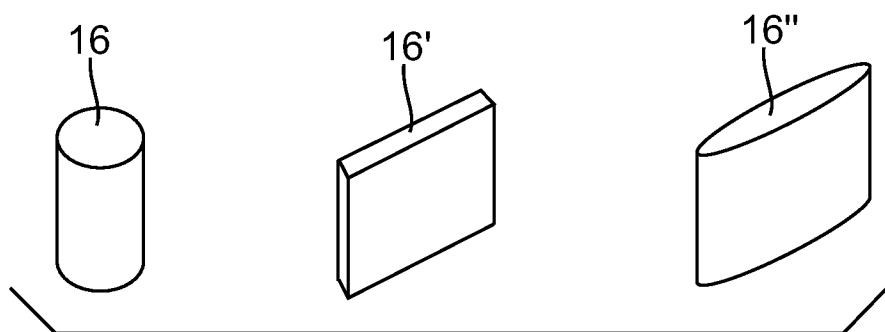


FIG. 8

**A. CLASSIFICATION OF SUBJECT MATTER****G02B 21/34(2006.01)i, G01N 1/28(2006.01)i**

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)

G02B 21/34; A47L 15/48; B01L 3/00; B01L 9/00; B67D 5/06; C12M 1/00; F04D 19/04; G01N 1/31

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

(Chinese Patents and application for patent)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) &amp; Keywords: "microscope", "slide", "dry", "jet pump"

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages      | Relevant to claim No. |
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Further documents are listed in the continuation of Box C.



See patent family annex.

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

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"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

"&amp;" document member of the same patent family

Date of the actual completion of the international search

28 MAY 2010 (28.05.2010)

Date of mailing of the international search report

**28 MAY 2010 (28.05.2010)**

Name and mailing address of the ISA/KR

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Facsimile No. 82-42-472-7140

Authorized officer

LEE Chang Ho

Telephone No. 82-42-481-8435



**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2009/066637**

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Information on patent family members

International application No.

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None