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Beebe et al.

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(54) **ONE-STEP SAMPLE EXTRACTION CASSETTE AND METHOD FOR POINT-OF-CARE MOLECULAR TESTING**

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B01L 3/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B01L 3/5029*** (2013.01); *B01L 2200/0636* (2013.01); *B01L 2200/141* (2013.01); *B01L 2200/16* (2013.01); *B01L 2300/069* (2013.01); *B01L 2300/0829* (2013.01); *B01L 2300/161* (2013.01)

(58) **Field of Classification Search**
CPC combination set(s) only.
See application file for complete search history.

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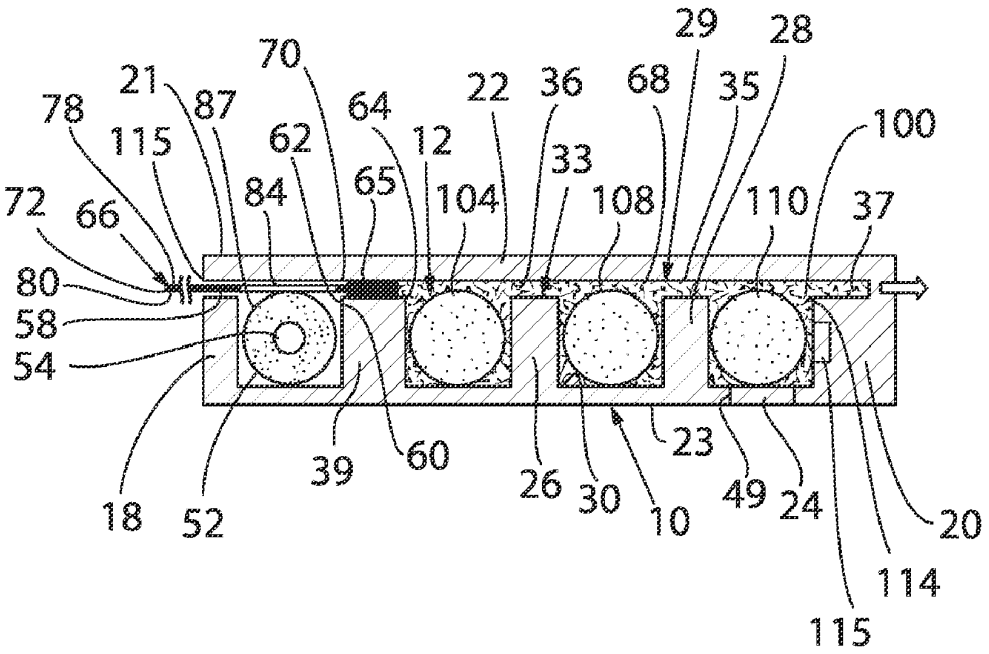
(57) **ABSTRACT**

A sample extraction cassette and method are provided to test for a target in a sample. The sample is obtained on a swab. The swab is inserted into a chamber in a case and into contact with a contact portion of a membrane. The contact portion of the membrane is axially moved into sequential communication with a wash fluid and a reaction fluid. The reaction fluid reacts with the target to provide a visual display corresponding to the presence of the target.

13 Claims, 6 Drawing Sheets



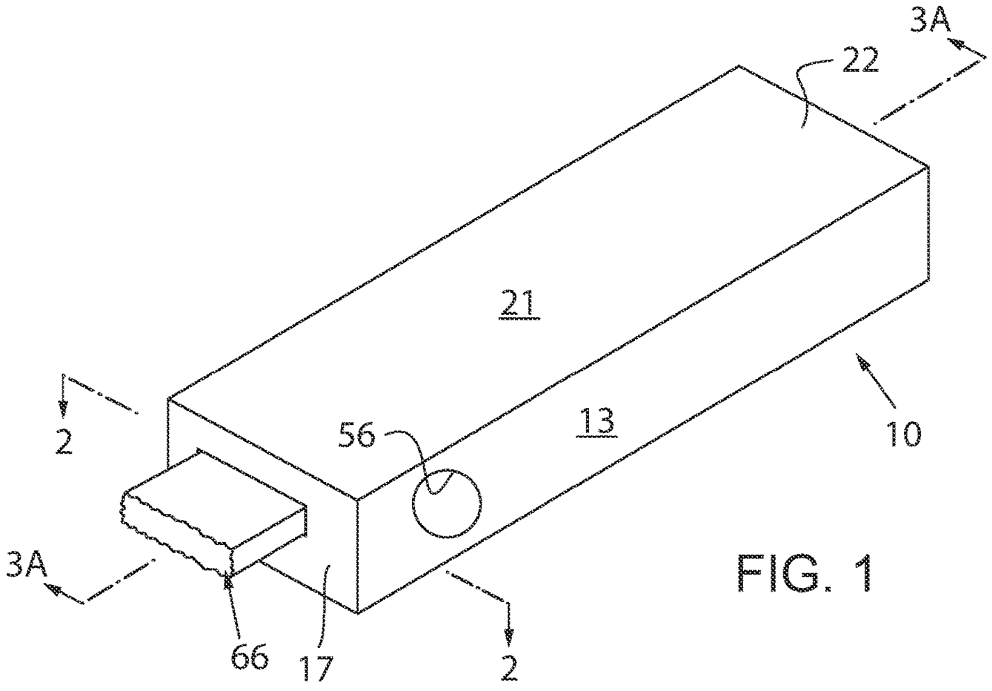

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FIG. 1

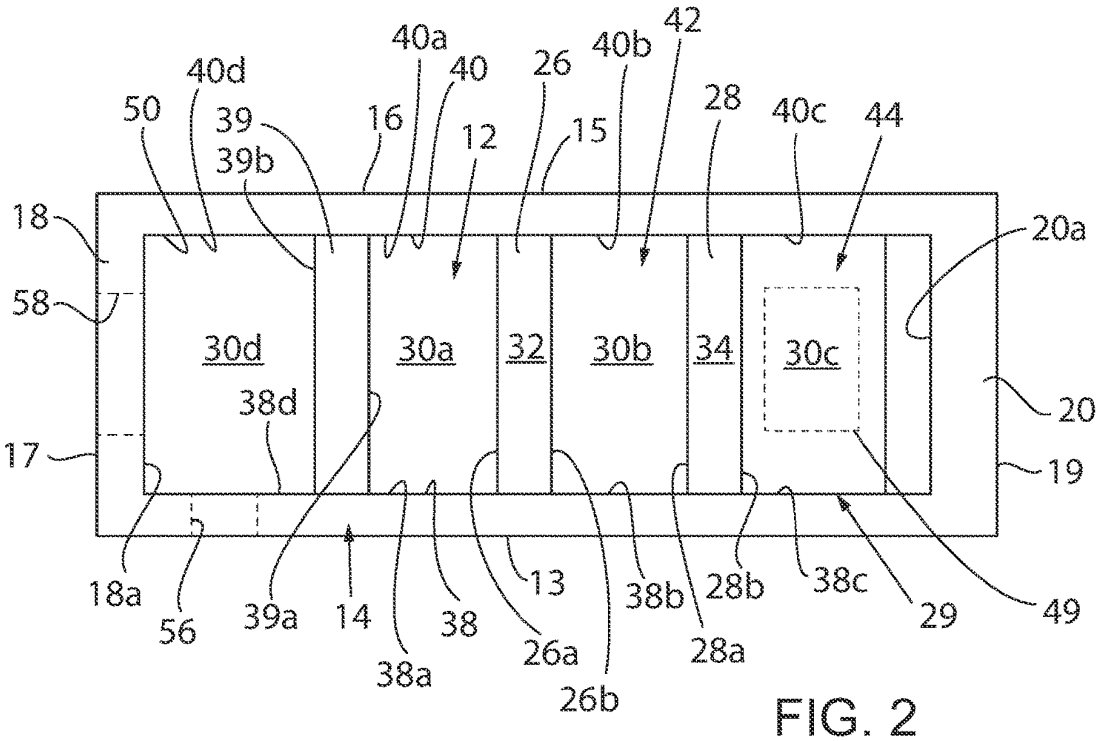
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FIG. 2

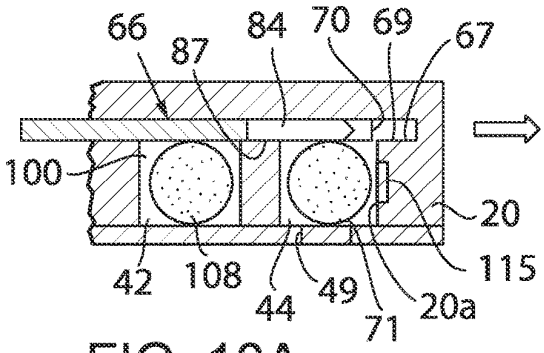

FIG. 10A

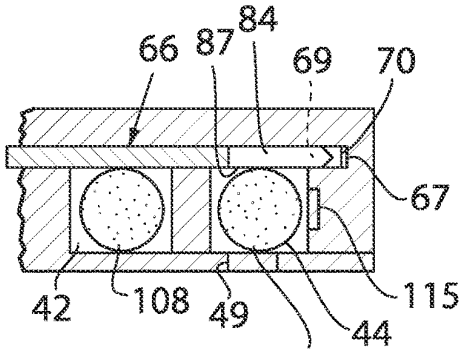

FIG. 10B

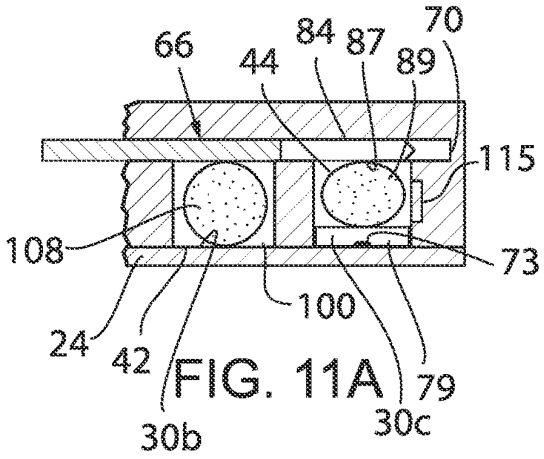

FIG. 11A

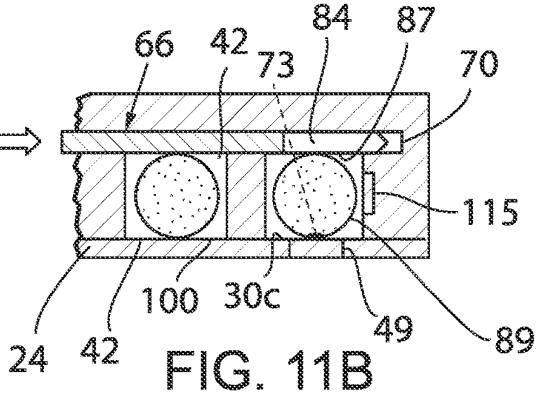

FIG. 11B

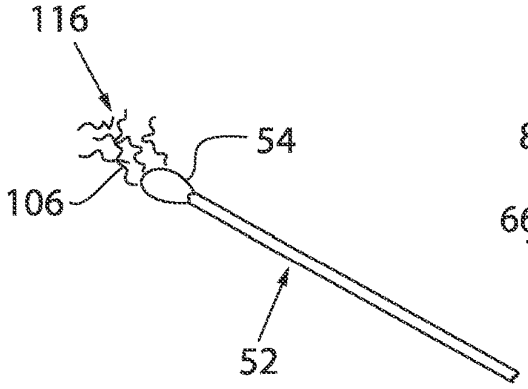

FIG. 2A

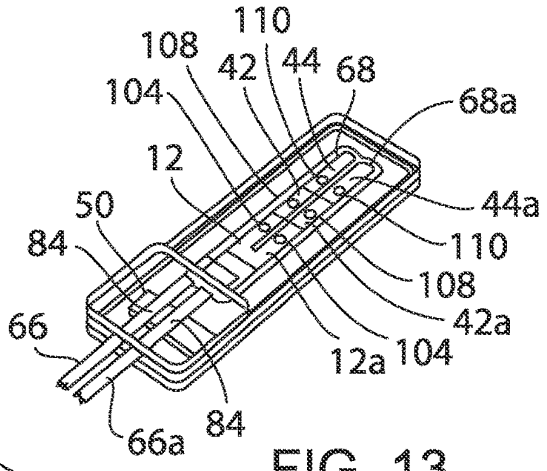

FIG. 13

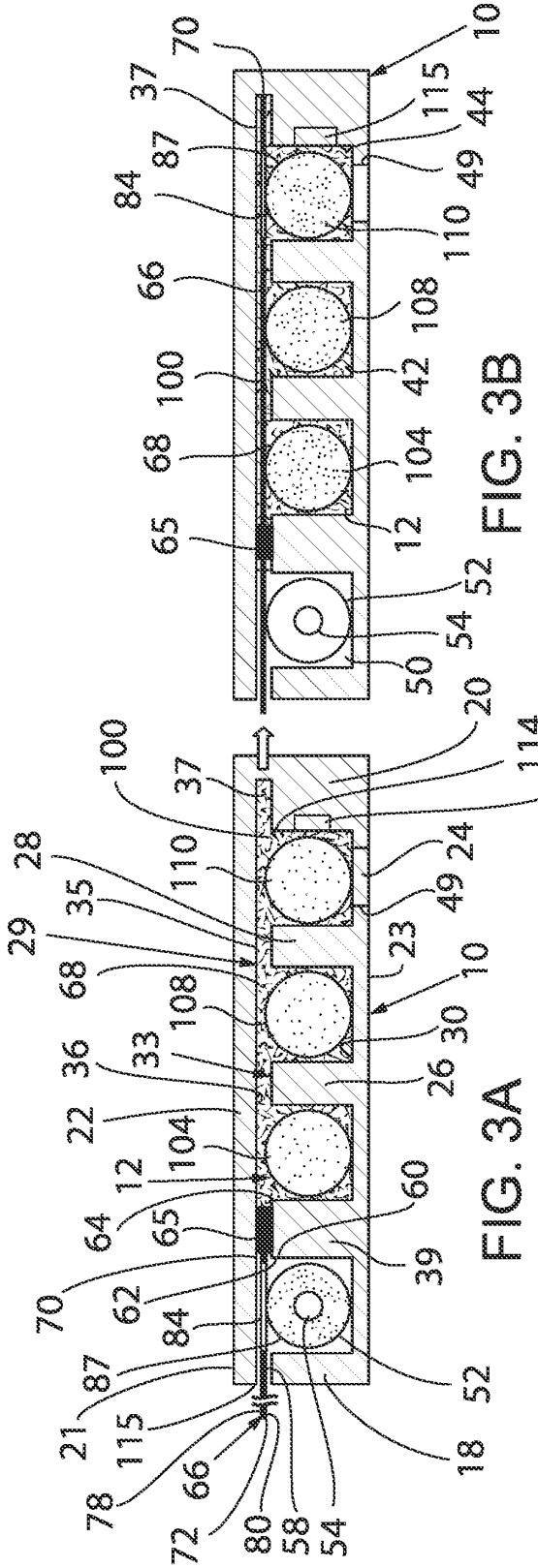

FIG. 3A

FIG. 3B

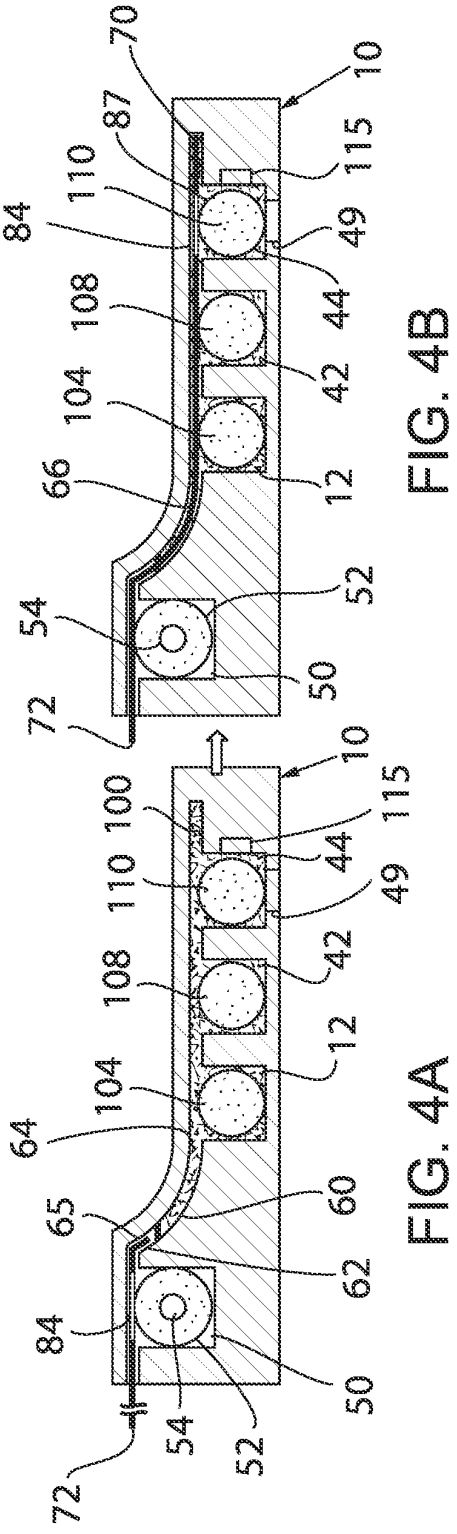

FIG. 4B

FIG. 4A

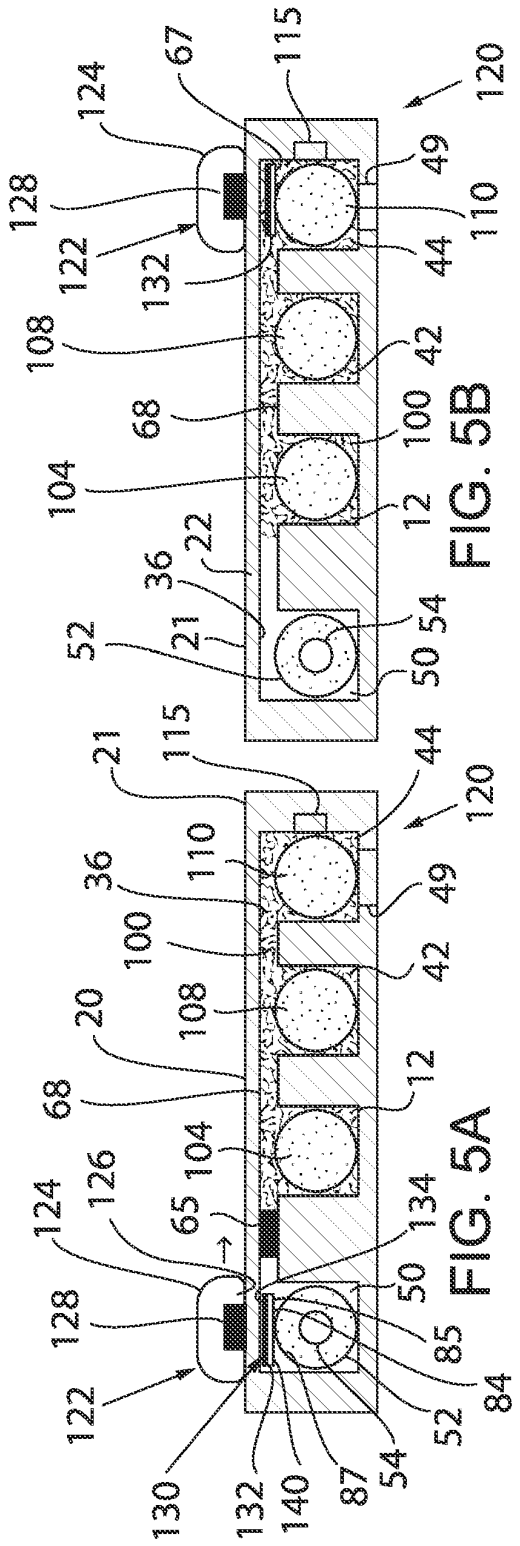
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FIG. 5B
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FIG. 5A

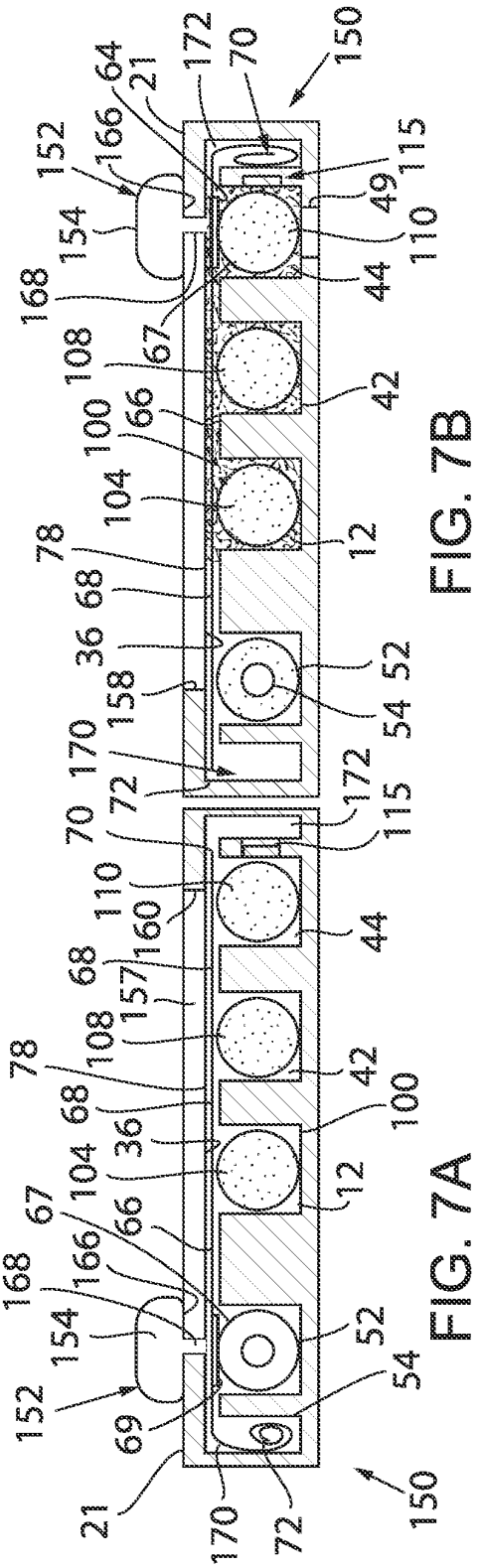
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FIG. 7B
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FIG. 7A

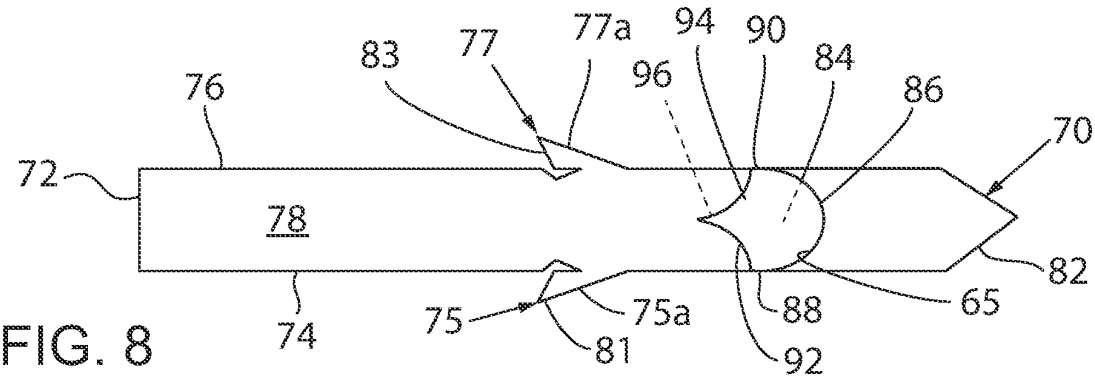

FIG. 8

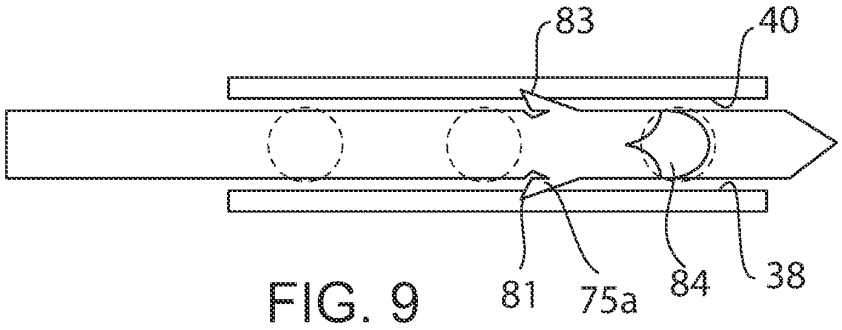

FIG. 9

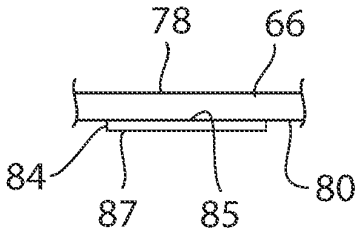

FIG. 8A

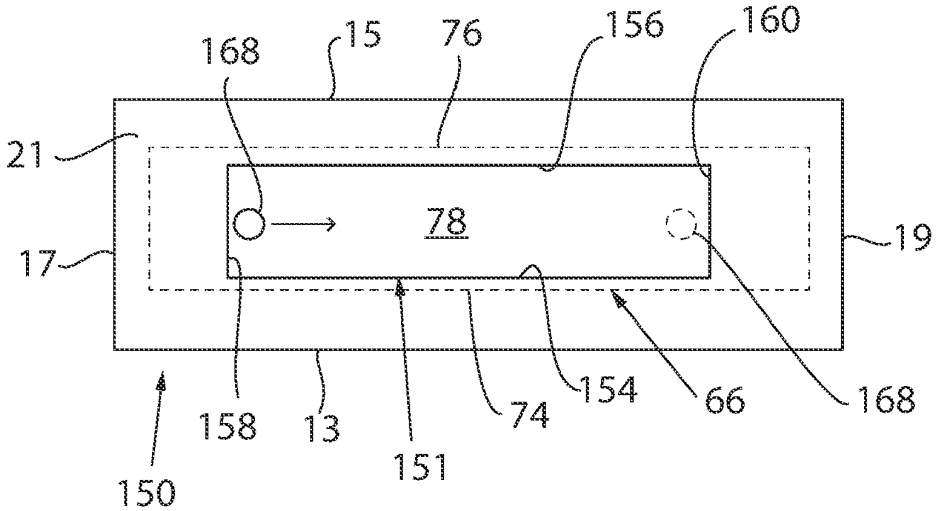

FIG. 6

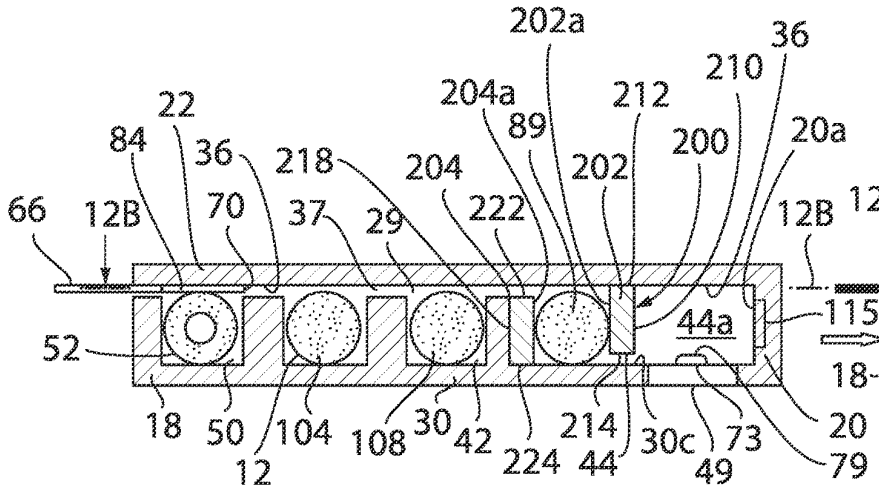

FIG. 12A

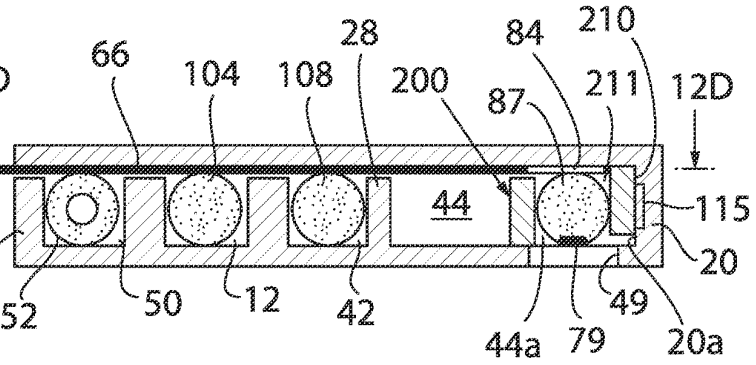

FIG. 12C

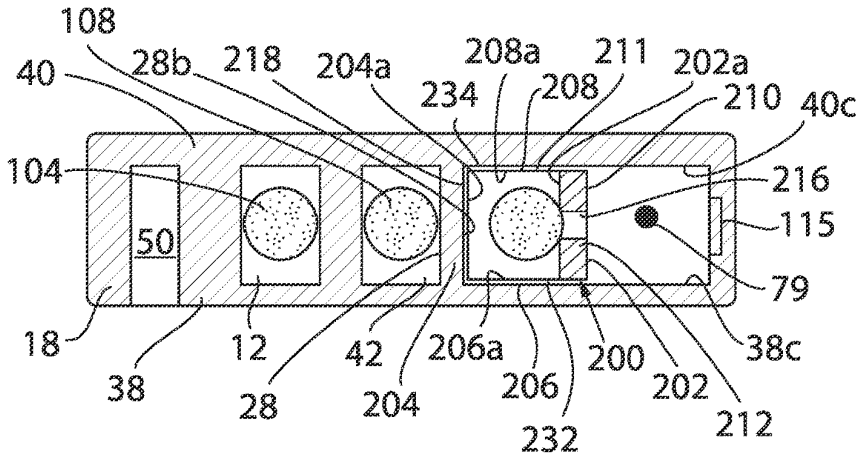

FIG. 12B

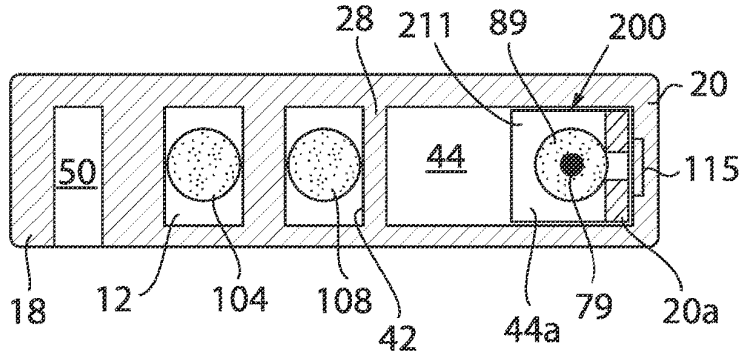

FIG. 12D

ONE-STEP SAMPLE EXTRACTION CASSETTE AND METHOD FOR POINT-OF-CARE MOLECULAR TESTING

GOVERNMENT GRANT

This invention was made with government support under CA247479, TR002373 and OD011106 awarded by the National Institutes of Health. The government has certain rights in the invention.

FIELD OF THE INVENTION

This invention relates generally to diagnostic testing, and in particular, to a one-step sample extraction cassette and method for point-of-care molecular testing for a target in a sample provided on a swab.

BACKGROUND AND SUMMARY OF THE INVENTION

As testing laboratories attempt to scale up existing protocols for SARS-CoV-2 testing, a number of shortcomings have emerged. These shortcomings include supply chain problems (e.g. lack of available RNA extraction kits and specialized equipment), the cost, time and/or effort required for the current test protocols and the relatively low throughput of nonautomated systems. Supply chain issues may be reduced, but not eliminated, as companies ramp up their production. However, the cost, time and/or effort required for the current test protocols and the throughput challenges are inherent in current testing methods. Hence, despite best efforts, it is clear that test availability and throughput do not meet current demands.

The current gold standard method for COVID-19 testing is a multi-step protocol involving RNA extraction using column-based or magnetic bead-based methods, followed by RT-qPCR-based detection of the extracted RNA. Unless automated platforms are employed, this extraction process is lengthy and laborious involving 1) mixing the sample with lysis/binding buffer and vortexing; 2) column-based or magnetic-bead-based capture of the viral RNA; 3) multiple washes (generally two to three washes) involving centrifugation or magnetic separation for each wash; 4) elution of viral RNA; 5) aspirating the eluted RNA and pipetting it into a PCR plate loaded with RT-qPCR master mix; and 6) placing the PCR plate in a specialized fluorescent qPCR instrument to run thermocycling and data capture. This process usually takes 3-4 hours and is hard to scale because: 1) the RNA extraction process is time consuming due to the multiple pipetting and centrifugation/magnetic separation steps for washing; and 2) the RT-qPCR process itself takes approximately one (1) hour with continuous "real-time" fluorescence measurements at each cycle. Since most machines are designed to handle one plate at a time, the turnaround time is significantly limited.

In view of the foregoing, real-world sample-to-result turnaround time for COVID-19 tests is at least 1 to 2 days. The substantial turnaround time for real-world COVID-19 tests greatly diminishes the value of conducting a PCR test in many scenarios. Moreover, large-scale, centralized community sample collection sites themselves pose a potential risk for infectious disease exposure, as subjects need to remove face coverings to perform nasal swabs or saliva collection.

One way to greatly reduce assay turnaround time is to perform rapid, individualized, standalone tests on site (point of care—POC). However, due to technical, logistical, and monetary challenges, standard RT-qPCR based molecular tests are challenging to deploy in a POC setting. These challenges include: 1) a requirement for precision liquid handling operations; 2) complex instrumentation; 3) use of toxic reagents; 4) strict biosafety requirements; and 5) skilled personnel to perform the tests. Although there has been recent progress in deploying rapid COVID-19 antigen tests (lateral flow immunoassay tests), the sensitivity and specificity of rapid antigen tests still lag significantly behind molecular tests and often require additional verification using PCR. In addition, POC molecular (RNA) tests are relatively costly, complex, bulky, and of very limited availability

Therefore, it is a primary object and feature of the present invention to provide a one-step sample extraction cassette for point-of-care molecular testing.

It is a further object and feature of the present invention to provide a one-step sample extraction cassette for point-of-care molecular testing which reduces the cost, effort, complexity and reagent consumption associated with prior devices/methods, while decreasing the turnaround time over these prior devices/methods.

It is a still further object and feature of the present invention to provide a one-step sample extraction cassette for point-of-care molecular testing which is simple and inexpensive as compared with prior devices/methods.

In accordance with the present invention, a sample extraction cassette is provided for point-of-care molecular testing for a target in a sample provided on a swab. The cassette includes a case having a chamber configured for receiving the swab; a wash zone configured for receiving a wash fluid therein; and a reaction zone configured for receiving a reaction fluid therein. The reaction fluid reacts with the target. A membrane having a contact portion is slidably receivable into case. The membrane is moveable between a transfer position, a wash position and a reaction position. In the transfer position, the contact portion of the membrane communicates with the sample provided on the swab when the swab is received in the chamber such that at least a portion of the sample is transferred to the contact portion. In the wash position, the contact portion of the membrane communicates with the wash zone. In the reaction position, the contact portion of the membrane communicates with the reaction zone.

The wash zone is defined by a wash well in the case. The wash well is adapted for receiving the wash fluid therein. The reaction zone is defined by a reaction well in the case. The reaction well is adapted for receiving the reaction fluid therein. Oil is receiveable in the wash well and the reaction well. The oil fluidially isolates the wash fluid from the reaction fluid when the wash fluid is received in the wash well and the reaction fluid is received in the reaction well.

The case is defined by a plurality of surfaces. The plurality of surfaces are hydrophobic. The contact portion of the membrane is defined by a hydrophilic adsorbent pad. The membrane extends along an axis and has a terminal leading end. The hydrophilic adsorbent pad is spaced from the terminal leading end of the membrane. The hydrophilic adsorbent pad includes a generally arcuate leading edge having first and second ends. A trailing edge is defined by a first portion extending from the first end of the leading edge and a second portion extending from the second end of the leading edge. The first and second portions of the trailing edge converge as the first and second portions of the trailing edge extend from a corresponding first and second ends of the leading edge.

A slide is slidably connected to the case and operatively connected to the membrane. The sliding of the slide relative to the case moves the membrane between the transfer position, the wash position and the reaction position. A dried reagent may be provided in communication with the reaction zone. The reaction fluid is defined by a mixture of the dried reagent and an aqueous solution. A barrier material may be provided about the dried reagent to prevent contamination thereof. The barrier material is solid at first temperature and melts at a second, higher temperature.

The membrane includes first and second sides and a lower surface interconnecting the first and second sides. First and second barbs extend from corresponding first and second sides. The first and second barbs allow for slideable movement of the membrane in a first direction and prevents slideable movement of the membrane in a second, opposite direction.

In accordance with a further aspect of the present invention, a sample extraction cassette is provided to test for a target in a sample provided on a swab. The cassette includes a case having a chamber configured for receiving the swab, a wash zone configured for receiving a wash fluid therein, and a reaction zone configured for receiving a reaction fluid therein. The reaction fluid reacts with the target. A membrane is slideable in a first direction within the case. The membrane has a contact portion which sequentially communicates with the swab, the wash zone and the reaction zone as the membrane is axially slid in the case in the first direction.

An oil is receiveable in the wash zone and the reaction zone. The oil fluidially isolates the wash fluid from the reaction fluid when the wash fluid is received in the wash zone and the reaction fluid is received in the reaction zone. The case is defined by a plurality of surfaces. The plurality of surfaces are hydrophobic. The contact portion of the membrane is defined by a hydrophilic adsorbent pad. The membrane extends along an axis and has a terminal leading end. The hydrophilic adsorbent pad defines the terminal leading end of the membrane. The hydrophilic adsorbent pad includes a generally arcuate leading edge having first and second ends. A trailing edge is defined by a first portion extending from the first end of the leading edge and a second portion extending from the second end of the leading edge. The first and second portions of the trailing edge converge as the first and second portions of the trailing edge extend from a corresponding first and second ends of the leading edge.

A slide may be slidably connected to the case and operatively connected to the membrane. Sliding of the slide relative to the case moves the membrane in the first direction. A dried reagent may be provided in communication with the reaction zone. The reaction fluid is defined by a mixture of the dried reagent and an aqueous solution. A barrier material extends about the dried reagent to prevent contamination thereof. The barrier material is solid at first temperature and melts at a second, higher temperature.

The membrane includes first and second sides interconnected by a lower surface. First and second barbs extend from corresponding first and second sides. The first and second barbs allow for slideable movement of the membrane in the first direction and prevent slideable movement of the membrane in a second, opposite direction. The lower surface of the membrane includes the contact portion.

In accordance with a still further aspect of the present invention, a method of point-of-care molecular testing for a target in a sample is provided. The method includes the steps obtaining the sample on a swab and inserting the swab into a chamber in a case into contact with a contact portion of a membrane. The contact portion of the membrane is axially moved into sequential communication with a wash fluid and a reaction fluid. The reaction fluid reacts with the target.

Oil may be deposited within the case to fluidially isolate the wash fluid from the reaction fluid. The case is defined by a plurality of surfaces. The plurality of surfaces being hydrophobic. The contact portion of the membrane is defined by a hydrophilic adsorbent pad. The membrane extends along an axis and has a terminal leading end. The hydrophilic adsorbent pad spaced from the terminal leading end of the membrane. The hydrophilic adsorbent pad includes a generally arcuate leading edge having first and second ends. A trailing edge is defined by a first portion extending from the first end of the leading edge and a second portion extending from the second end of the leading edge. The first and second portions of the trailing edge converge as the first and second portions of the trailing edge extend from a corresponding first and second ends of the leading edge.

A slide operatively connected to the membrane to move the membrane into sequential communication with the wash fluid and the reaction fluid. Prior to axially moving the contact portion of the membrane into communication the reaction fluid, a reagent may be dried within the case. A barrier material is deposited on the dried reagent to isolate the dried reagent from an external environment. An aqueous droplet is deposited on the barrier material. The barrier material is exposed to an elevated temperature to allow aqueous droplet to mix with the dried reagent to form the reaction fluid. Alternatively, prior to axially moving the contact portion of the membrane into communication the reaction fluid, an aqueous droplet may be deposited adjacent the dried reagent. When the contact portion of the membrane is moved axially, the contact portion of the membrane brings the aqueous droplet into contact with the dried reagent to allow the aqueous droplet to mix with the dried reagent to form the reaction fluid. The contact portion of the membrane axially moves in a first direction and prevented from axially movement in a second direction opposite to the first direction. Alternatively, prior to axially moving the contact portion of the membrane into communication the reaction fluid, an aqueous droplet may be deposited adjacent the dried reagent. The aqueous droplet may be moved into contact with the dried reagent to allow the aqueous droplet to mix with the dried reagent to form the reaction fluid.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings furnished herewith illustrate a preferred methodology of the present invention in which the above advantages and features are clearly disclosed as well as others which will be readily understood from the following description of the illustrated embodiment.

In the drawings:

FIG. **1** is an isometric view of a one-step sample extraction cassette in accordance with the present invention;

FIG. **2** is a cross sectional view of the one-step sample extraction cassette of the present invention taken along line **2-2** of FIG. **1**;

FIG. **2A** is an isometric view of an anterior nares swab for use with the one-step sample extraction cassette of the present invention;

FIG. **3A** is a cross sectional view of the one-step sample extraction cassette of the present invention in an initial configuration taken along line **3A-3A** of FIG. **1**;

FIG. **3**B is a cross sectional view, similar to FIG. **3**A, of the one-step sample extraction cassette of the present invention in a reaction configuration;

FIG. **4**A is a cross sectional view, similar to FIG. **3**A, showing an alternate configuration of the one-step sample extraction cassette of the present invention in an initial configuration;

FIG. **4**B is a cross sectional view, similar to FIG. **3**B, showing the one-step sample extraction cassette of FIG. **4**A in a reaction configuration;

FIG. **5**A is a cross sectional view, similar to FIG. **3**A, showing an further alternate configuration of the one-step sample extraction cassette of the present invention in an initial configuration;

FIG. **5**B is a cross sectional view, similar to FIG. **3**B, showing the one-step sample extraction cassette of FIG. **5**A in a reaction configuration;

FIG. **6** is a top plan view, with portions broken away, showing a still further alternate configuration of the one-step sample extraction cassette of the present invention;

FIG. **7**A is a cross sectional view, similar to FIG. **3**A, showing the one-step sample extraction cassette of FIG. **6** in an initial configuration;

FIG. **7**B is a cross sectional view, similar to FIG. **3**B, showing the one-step sample extraction cassette of FIG. **7**A in a reaction configuration;

FIG. **8** is a top plan view of a membrane for the one-step sample extraction cassette of the present invention;

FIG. **8**A is an enlarged, side elevational view showing a portion of an alternate configuration of the membrane of FIG. **8**;

FIG. **9** is a top plan view of the membrane of FIG. **8** received in a pathway of the one-step sample extraction cassette of the present invention;

FIG. **10**A is a cross sectional view depicting an alternate methodology for point-of-care molecular testing for a target in a sample showing a membrane of the one-step sample extraction cassette of the present invention in a first position;

FIG. **10**B is a cross sectional view, similar to FIG. **10**A, showing the membrane of the one-step sample extraction cassette of the present invention in a second position;

FIG. **11**A is a cross sectional view depicting a further, alternate methodology for point-of-care molecular testing for a target in a sample showing a membrane of the one-step sample extraction cassette of the present invention in a first position;

FIG. **11**B is a cross sectional view, similar to FIG. **11**A, showing the membrane of the one-step sample extraction cassette of the present invention in a second position;

FIG. **12**A is a cross sectional view depicting a further, alternate methodology for point-of-care molecular testing for a target in a sample showing a membrane of the one-step sample extraction cassette of the present invention in a first position;

FIG. **12**B is a cross sectional view, similar to FIG. **11**A, showing the membrane of the one-step sample extraction cassette of the present invention in a second position;

FIG. **12**C is a is a cross sectional, similar to FIG. **12**A showing a membrane of the one-step sample extraction cassette of the present invention in the second position;

FIG. **12**D a cross sectional view of the one-step sample extraction cassette of the present invention taken along line **12**D-**12**D of FIG. **12**C; and

FIG. **13** is an isometric view of a still further an alternate configuration of an alternate configuration of the one-step sample extraction cassette of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to FIG. **1**, an extraction cassette in accordance with the present invention, is generally designated by the reference numeral **10**. It is contemplated to fabricate cassette **10** out of a heat-resistant plastic material (e.g., polycarbonate or polycarbonate resin thermoplastic), which allows for a wide temperature working range for both cold chain transport and isothermal amplification, as hereinafter described. It is noted that polycarbonate has a working temperature ranging from –40° Celsius ("C") to 115-130° C.

In the depicted configuration, cassette **10** extends along an axis and is defined by first and second sidewalls **14** and **16**, respectively, first and second end walls **18** and **20**, respectively, upper wall **22** and bottom wall **24**. First and second sidewalls **14** and **16**, respectively, includes first and second outer side surfaces **13** and **15**, respectively, and first and second end walls **18** and **20**, respectively, include first and second outer end surfaces **17** and **19**, respectively. Upper wall **22** includes an upper surface **21** and bottom wall **24** includes a lower surface **23**. It can be understood that cassette **10** may have other external configurations without deviating from the scope of the present invention

Cassette **10** further includes a plurality of wells formed within interior chamber **29** thereof. More specifically, interior chamber **29** is defined by inner surfaces **38** and **40** of first and second sidewalls **14** and **16**, respectively; first chamber end wall **39** and first end wall **20**; lower surface **36** of upper wall **22**; and upper surface **30** of bottom wall **24**. First and second well walls **26** and **28**, respectively, project from upper surface **30** of bottom wall **24** and terminate at corresponding upper end surfaces **32** and **34**, respectively. Upper end surfaces **32** and **34** of first and second well walls **26** and **28**, respectively, lie in a generally common plane which is parallel to and are spaced from lower surface **36** of upper wall **22** by passages **33** and **35**, respectively. Passage **37** is provided in second chamber end wall **20** and is axially aligned with passages **33** and **35**, for reasons hereinafter described.

First wash well **12** is defined by leading surface **39***a* of first chamber end wall **39**, trailing surface **26***a* of first well wall **26**, first well portion **30***a* of upper surface **30** of bottom wall **24**, first portion **38***a* of inner surface **38** of first sidewall **14**, and first portion **40***a* of inner surface **40** of second sidewall **16**. Second wash well **42** is defined by leading surface **26***b* of first well wall **26**, trailing surface **28***a* of second well wall **28**, second well portion **30***b* of upper surface **30** of bottom wall **24**, second portion **38***b* of inner surface **38** of first sidewall **14**, and second portion **40***b* of inner surface **40** of second sidewall **16**. Reaction well **44** is defined by leading surface **28***b* of second well wall **28**, trailing surface **20***a* of second end wall **20**, third well portion **30***c* of upper surface **30** of bottom wall **24**, third portion **38***c* of inner surface **38** of first sidewall **14**, and third portion **40***c* of inner surface **40** of second sidewall **16**. It is contemplated to provide a transparent window **49** in cassette **10**, for example in bottom wall **24**, to allow for optical measurement/interrogation of the interior of reaction well **44**, for reasons hereinafter described.

Cartridge **10** further includes swab chamber **50** adapted for receiving an end **52** of a conventional, sample collection swab **54**, FIG. **2**A. Swab chamber **50** is defined by leading surface **18***a* of first end wall **18**, trailing surface **39***b* of first chamber end wall **39**, swab chamber portion **30***d* of upper surface **30** of bottom wall **24**, fourth portion **38***d* of inner surface **38** of first sidewall **14**, and fourth portion **40***d* of inner surface **40** of second sidewall **16**. Opening **56** extends

through first sidewall **14** so as to allow access to swab chamber **50**. In the depicted embodiment, opening **56** has a generally circular configuration. However, other configurations of opening **56** are possible without deviating from the scope of the present invention.

First end wall **18** includes a passage **58** extending therethrough having an output end communicating with swab chamber **50**. Similarly, first chamber end wall **39** has a passage **60** extending therethrough in axial alignment with passage **58**. Input end **62** of passage **60** communicates with swab chamber **50** and output end **64** of passage **60** communicates with axially aligned with passages **33**, **35** and **37**, as heretofore described. Further, it is intended for passages **58**, **60**, **33**, **35** and **37** to collectively define a pathway **68** having sufficient dimension to accommodate slidable receipt of membrane **66**, as hereinafter described.

As best seen in FIGS. **3**A and **8**, membrane **66** is defined by a leading end **70** and trailing end **72**, first and second generally parallel sides **74** and **76**, respectively, and upper and lower surfaces **78** and **80**, respectively. It is intended for membrane **66** to be fabricated from a flexible material having sufficient rigidity to be slid through pathway **68**. In addition, membrane **66** is fabricated from hydrophobic material or coated by a hydrophobic material, for reasons hereinafter described. Further, it contemplated for the leading end **70** of membrane **66** to define leading edge **82** which facilitate the sliding of membrane **66** through pathway **68** in a first direction, as hereinafter described; to pierce puncturable seal **65**; and to prevent membrane **66** from becoming hung up within cartridge **10** during a sliding operation.

Barbs **75** and **77** are provided on corresponding sides **74** and **76**, respectively, of membrane **66**. Barbs **75** and **77** are moveable between an extended position when barbs **75** and **77** are urged away from sides **74** and **76**, respectively, and a retracted position wherein barbs **75** and **77** are adjacent corresponding sides **74** and **76**, respectively, thereof. It can be understood that as membrane **66** is slid in a first direction along pathway **68**, leading edges **75***a* and **77***a* of barbs **75** and **77**, respectively, are engageable with inner surfaces **38** and **40** of first and second sidewalls **14** and **16**, respectively, thereby urging barbs **75** and **77** urged toward their retracted position and allowing membrane **66** to continue sliding in the first direction, FIG. **9**. In contrast, when one attempts to slide membrane **66** along pathway **68** in a second direction, opposite to the first direction, tips **81** and **83** of leading edges **75***a* and **77***a* of barbs **75** and **77**, respectively, engage inner surfaces **38** and **40** of first and second sidewalls **14** and **16**, respectively, and prevent membrane **66** from sliding in the second direction.

Adsorbent pad, generally designated by the reference numeral **84**, may be formed in membrane **66** or affixed to lower surface **80** of membrane **66** at a location. Adsorbent pad **84** includes an upper surface **85** and a lower surface **87**. By way of example, adsorbent pad **84** may be secured within aperture **65** extending through membrane **66**. Alternatively, upper surface **85** of adsorbent pad **84** may be affixed lower surface **80** of membrane **66**, FIG. **8**A. It is intended for adsorbent pad **84** to be fabricated from a material or treated with a material that will bind to a target, such as an analyte of interest, as hereinafter described.

Adsorbent pad **84** has a generally arcuate leading edge **86** having a first end **88** adjacent first side **74** of membrane **66** and a second end **90** adjacent second side **76** of membrane **66**. First and second trailing edges **92** and **94**, respectively, of adsorbent pad **84** extend rearwardly from corresponding first and second end **88** and **90**, respectively, away from leading edge **82** of membrane **66** and intersect each other at intersection **96**. First and second trailing edges **92** and **94**, respectively, have generally concave configurations such that adsorbent pad **84** has a generally teardrop-shape.

In order to load cassette **10**, interior chamber **29**, including first and second wash wells **12** and **42**, respectively, reaction well **44**, and passages **33**, **35** and **37**, is filled with a selected fluid, such as oil **100**. It is noted that oil **100** flows through first and second wash wells **12** and **42**, respectively, reaction well **44**, and passages **33**, **35** and **37** via capillary action owing to the hydrophobic nature of the surfaces, i.e. an oleophilic version of capillary action.

With each of the plurality of first and second wash wells **12** and **42**, respectively, reaction well **44**, and passages **33**, **35** and **37** filled with oil **100**, a pipet may be used to deliver drop **104** of a first aqueous solution, e.g., water, into first wash well **12**. It is intended for the first aqueous solution to wash away unbound analyte from adsorbent pad **84**, as hereinafter described, with the minimal loss of any targets **106** bound to adsorbent pad **84**. It is contemplated for the first aqueous solution of drop **104** and oil **100** to have a first interfacial tension. Similarly, the first aqueous solution of drop **104** and the surfaces of cassette **10** defining interior chamber **29** have a second interfacial tension. The second interfacial tension is greater than or equal to the first interfacial tension, thereby giving rise to liquid repellency between drop **104** and the surfaces defining interior chamber **29** of cassette **10**. It is noted that drop **104** has a diameter greater than the dimension of passage **33** and greater than the dimension of output end **64** of passage **60** such that drop **104** is retained in first wash well **12**.

Similarity, a pipet may be used to deliver drop **108** of a second aqueous solution, e.g., ethanol, into second wash well **12**. The second aqueous solution may be the same or different from the first aqueous solution. It is intended for the second aqueous solution to wash away any unbound analyte from adsorbent pad **84**, as hereinafter described, with the minimal loss of any targets **106** bound to adsorbent pad **84**. It is contemplated for the aqueous solution of drop **108** to have a third interfacial tension. The second interfacial tension is greater than or equal to the third interfacial tension, thereby giving rise to liquid repellency between drop **108** and the surfaces defining interior chamber **29** of cassette **10**. It is noted that drop **108** has a diameter greater than the dimension of passage **35** and greater than the dimension of passage **37** such that drop **108** is retained in second wash well **42**.

A pipet may be used to deliver drop **110** of a reaction solution into reaction cavity **44**. It is contemplated for a parameter of the reaction solution drop to change in response to the presence of target **106**, thereby allowing detection of target **106** from a collected sample. For example, if drop **110** of the reaction solution includes an isothermal nucleic acid amplification reagent, a change in color, fluorescence intensity, absorbance, or precipitation of drop **110** will occur in response to the presence of target **106**. To facilitate understanding of the present invention, a colorimetric loop-mediated isothermal amplification (LAMP) solution is used as an exemplary reaction solution in cassette **10** and methodology of the present invention. However, it can be appreciated that drop **110** may be formed from other reaction solutions, including those that do not require the heating of drop **110** hereinafter described, without deviating from the scope of the present invention.

As is known, the LAMP solution provides a visible indicator (e.g. a color change) in response to the presence of the desired target, e.g., target **106**, after incubation. More specifically, drop **110** of the LAMP solution is provided in

reaction cavity **44**, e.g. by a pipet or similar tool delivering drop **110** directly into oil **100**. It is contemplated for the reaction solution of drop **110** to have a fourth interfacial tension wherein the second interfacial tension is greater than or equal to the fourth interfacial tension, thereby giving rise to liquid repellency between drop **110** and the surfaces defining interior chamber **29** of cassette **10**. It is noted that drop **110** has a diameter greater than the dimension of passage **35** and greater than the dimension of input end **114** of passage **37** is provided in second chamber end wall **20** such that drop **110** is retained in reaction well **44**.

It can be understood that oil **100** in interior chamber **29**: 1) prevents evaporation of drops **104**, **108** and **110**; 2) provides a barrier to prevent contamination of drops **104**, **108** and **110** from the external environment; 3) prevents the LAMP solution from leaking from cassette **10** thereby contaminating the external environment; and 4) makes long-term storage of cassette **10** possible by physically constraining the individual aqueous solutions in first well **12**, second well **42** and reaction well **44**.

Further, with interior chamber **29** of cassette **10** filled as heretofore described, it is contemplated for oil **100** to be allowed to solidify therein so as to prevent oil **100** from flowing into swab chamber **50** through passage **60** during transport. Alternatively, a puncturable seal **65** may be provided in passage **60** to isolate swab chamber **60** from first wash well **12**. Referring to FIGS. **4**A-**4**B, in a still further alternative, it is contemplated for passage **60** to have a generally concave configuration wherein input end **62** of passage **60** lies in a first plane and output end **64** of passage **60** lies in a second plane vertically spaced from the first plane so us to discourage the flow of oil **100** upward from first wash well **12** to swab chamber **50**. Of course, puncturable seal **65** may be provided in passage **60** in such a configuration to fluidically isolate swab chamber **50** from first wash well **12**.

Referring to FIGS. **3**A-**3**B and **4**A-**4**B, in operation, leading end **70** of membrane **66** is inserted into input end **117** of passage **58** and urged axially in a first direction to an initial position such that: 1) leading end **70** of membrane **66** extends through passage **58** and swab chamber **50** into input end **62** of passage **60**; and 2) lower surface **87** of adsorbent pad **84** communicates with swab chamber **50**. To test for the presence of target **106**, end **52** of swab **54** can be used for collection of other clinical and/or environmental samples. For example, end **52** of swab **54** may be inserted into one or both nostrils of the individual and rotated therein while pressed against the inside of the nostril to transfer as much nasal discharge onto end **52** of swab **54**, hereinafter referred to swab sample **116**. Swab **54** is removed from the nostril[s]. End **52** of swab **54** is inserted through opening **56** in first sidewall **14** of cassette **10** and into swab chamber **50**. End **52** of swab **54** is pressed against lower surface **87** of adsorbent pad **84** and rotated so as to transfer swab sample **116** onto adsorbent pad **84**.

Once swab sample **116** is transferred onto adsorbent pad **84**, membrane **66** is urged axially in the first direction further into cassette **10** to a first wash position. More specifically, membrane **66** is urged into cassette **10** along pathway **68** such that: 1) leading end **70** of membrane **66** pierces puncturable seal **65** in passage **60**, if present, and passes through passage **60**, out of output end **64** thereof, through first wash well **12** and passage **33**, and into second wash well **42**; and 2) adsorbent pad **84** communicates with first wash well **12**. With adsorbent pad **84** communicating with first wash well **12**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **104** in first wash well **12** such that the first aqueous solution washes away any unbound analyte on adsorbent pad **84** with minimal loss of any targets **106** bound to adsorbent pad **84**.

After the first aqueous solution washes away any unbound analyte on adsorbent pad **84**, membrane **66** is urged axially in the first direction further into cassette **10** to a second wash position. More specifically, membrane **66** is urged into cassette **10** along pathway **68** such that: 1) leading end **70** of membrane **66** passes through second wash well **42**, through passage **35** and into reaction well **44**; and 2) adsorbent pad **84** communicates with second wash well **42**. The "teardrop" shape of adsorbent pad **84**, as heretofore described, facilitates the breakoff of adsorbent pad **84** from drop **104** in first wash well **12** so as to minimize, and preferably prevent, the dragging of the first aqueous solution into drop **108** of the second aqueous solution in second wash well **42**. With adsorbent pad **84** communicating with second wash well **42**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **108** in second wash well **42** such that the second aqueous solution washes away any unbound analyte from adsorbent pad **84** with minimal loss of any targets **106** bound to adsorbent pad **84**.

After the second aqueous solution washes away any unbound analyte on adsorbent pad **84**, membrane **66** is urged axially in the first direction further into cassette **10** to a third, reaction position. More specifically, membrane **66** is urged into cassette **10** along pathway **68** such that: 1) leading end **70** of membrane **66** passes through reaction well **44**, through input of passage **37** in second end wall **20**, and into passage **37**; and 2) adsorbent pad **84** is received within reaction well **44**. As previously noted, the "teardrop" shape of adsorbent pad **84** facilitates the breakoff of adsorbent pad **84** from drop **108** in second wash well **42** so as to minimize, and preferably prevent, the dragging of the second aqueous solution into drop **110** of the reaction solution in reaction well **44**. With adsorbent pad **84** received within reaction well **44**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **110** in reaction well **44**.

With lower surface **87** of adsorbent pad **84** communicating with drop **110** in reaction well **44**, cassette **10** is inserted device into a temperature-controlled heater for a predetermined period of time for amplification. After a predetermined time period, a user may determine the presence of target in **106** in swab sample **116** via a visual inspection of cassette **10** (e.g., through window **49**) or by means of a fluorescence reader. Alternatively, it is contemplated to provide an on-device heater **115** powered by USB power or battery may be integrated into cassette **10** for performing the isothermal amplification.

Referring to FIGS. **5**A-**5**B, an alternate configuration of the cassette of the present invention is generally designated by the reference numeral **120**. Cassette **120** is identical in structure to cassette **10**, except as hereinafter provided. As such, the previous description of cassette **10** is understood to describe cassette **120** as if fully described herein.

In cassette **120**, passage **58** through first end wall **18** and passage **37** in second end wall **20** are eliminated. Slider **122** is provided to move adsorbent pad **84** between the first wash position, the second wash position, and the reaction position. Slider **122** is defined by handle portion **124** having a generally flat lower surface **126** configured to form a slidable interface with upper surface **21** of upper wall **22** of cartridge **120**. Magnet **128** is embedded in lower surface **126** of handle portion **124**, for reasons hereinafter described.

Slider **122** further includes a membrane-support portion **130** receivable within cartridge **120**. Membrane-support portion **130** includes a magnetic layer **132** magnetically

attracted to magnet **128** embedded in lower surface **126** of handle portion **124**. Magnetic layer **132** has a generally flat upper surface **134** configured to slidably engage lower surface **36** of upper wall **22** for movement along pathway **68**. Membrane **66** fixed to lower surface **140** of magnetic layer **132**. In the depicted embodiment, it is contemplated for membrane **66** to take the form of adsorbent pad **84** wherein upper surface **85** of adsorbent pad **84** is affixed to lower surface **140** of magnetic layer **132**. As noted above, adsorbent pad **84** has a generally teardrop-shape configuration.

In operation, membrane-support portion **130** of slider **122** is positioned within swab chamber **50** in an initial position and handle portion **124** is positioned on upper surface **21** of upper wall **22** of cartridge **120** such that the magnetic force generated by magnet **128** embedded in lower surface **126** of handle portion **124** retains membrane-support portion **130** in the initial position, FIG. **5**A. With membrane-support portion **130** in the initial position, lower surface **87** of adsorbent pad **84** communicates with swab chamber **50**. To test an individual for the presence of target **106**, end **52** of swab **54** is inserted into one or both of the nostrils of the individual and rotated therein while pressed against the inside of the nostril to transfer as much nasal discharge onto end **52** of swab **54**, hereinafter referred to swab sample **116**. Swab **54** is removed from the nostril[s]. End **52** of swab **54** is inserted through opening **56** in first sidewall **14** of cassette **10** and into swab chamber **50**. End **52** of swab **54** is pressed against lower surface **87** of adsorbent pad **84** and rotated so as to transfer swab sample **116** onto adsorbent pad **84**.

Once swab sample **116** is transferred onto adsorbent pad **84**, handle portion **124** of slider **122** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **120** such that magnet **128**, embedded in lower surface **126** of handle portion **124**, draws magnetic layer **132** of membrane-support portion **130** therewith and causes membrane-support portion **130** to slide through passage **60** along pathway **68** along lower surface **36** of upper wall **22** to a first wash position wherein adsorbent pad **84** communicates with first wash well **12**. If present in passage **60**, membrane-support portion **130** pierces puncturable seal **65**, thereby allowing membrane-support portion **130** to slide therepast. With adsorbent pad **84** communicating with first wash well **12**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **104** in first wash well **12** such that the first aqueous solution washes away any unbound analyte on adsorbent pad **84** with minimal loss of any targets **106** bound to adsorbent pad **84**.

After the first aqueous solution washes away any unbound analyte on adsorbent pad **84**, handle portion **124** of slider **122** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **120** such that magnet **128**, embedded in lower surface **126** of handle portion **124**, draws magnetic layer **132** of membrane-support portion **130** therewith and causes membrane-support portion **130** to slide in pathway **68** along lower surface **36** of upper wall **22** to a second wash position wherein adsorbent pad **84** communicates with second wash well **42**. The "teardrop" shape of adsorbent pad **84**, as heretofore described, facilitates the breakoff of adsorbent pad **84** from drop **104** in first wash well **12** so as to minimize, and preferably prevent, the dragging of the first aqueous solution into drop **108** of the second aqueous solution in second wash well **42**. With adsorbent pad **84** communicating with first wash well **12**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **104** in first wash well **12** such that the first aqueous solution washes away any unbound analyte on adsorbent pad **84** with minimal loss of any targets **106** bound to adsorbent pad **84**. With adsorbent pad **84** communicating with second wash well **42**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **108** in second wash well **42** such that the second aqueous solution washes away any unbound analyte from adsorbent pad **84** with minimal loss of any targets **106** bound to adsorbent pad **84**.

After the second aqueous solution washes away any unbound analyte on adsorbent pad **84**, handle portion **124** of slider **122** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **120** such that magnet **128**, embedded in lower surface **126** of handle portion **124**, draws magnetic layer **132** of membrane-support portion **130** therewith and causes membrane-support portion **130** to slide in pathway **68** along lower surface **36** of upper wall **22** to a third, reaction position wherein adsorbent pad **84** is received within reaction well **44**. As previously noted, the "teardrop" shape of adsorbent pad **84** facilitates the breakoff of adsorbent pad **84** from drop **108** in second wash well **42** so as to minimize, and preferably prevent, the dragging of the second aqueous solution into drop **110** of the reaction solution in reaction well **44**. With adsorbent pad **84** received within reaction well **44**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **110** in reaction well **44**, FIG. **5**B. With lower surface **87** of adsorbent pad **84** communicating with drop **110** in reaction well **44**, the reaction solution of drop **110** in cassette **10** is heated, either by insertion of cassette **10** into a temperature-controlled heater or by use of on-device heater **115** for a predetermined period of time for isothermal amplification. After the predetermined time period, a user may determine the presence of target in **106** in swab sample **116** via a visual inspection of cassette **10** (e.g., through window **49**) or by means of a fluorescence reader.

Referring to FIGS. **6** and **7**A-**7**B, a still further configuration of the cassette of the present invention is generally designated by the reference numeral **150**. Cassette **150** is identical in structure to cassette **120**, except as hereinafter provided. As such, the previous description of cassette **120** is understood to describe cassette **150** as if fully described herein.

Cassette **150** includes an input storage compartment **170** formed in first end wall **18** which communicates with pathway **68** and an output storage compartment **172** in second end wall **20** which also communicates with pathway **68**. Input storage compartment **170** is configured to receive the trailing end **72** of membrane **66** and output storage compartment **172** is configured to receive leading end **70** of membrane **66**.

Cassette **150** further includes a slot **151** formed in upper wall **22** thereof. Slot **151** is defined by first and second sidewalls **154** and **156**, respectively, lying in corresponding generally parallel planes and first and second end walls **158** and **160**, respectively, lying in corresponding generally parallel planes perpendicular to first and second sidewalls **154** and **156**, respectively. Slot **151** is intended to guide the slidable movement of slider **152** in order to move adsorbent pad **84** between the first wash position, the second wash position, and the reaction position. More specifically, slider **152** is defined by handle portion **154** having a generally flat lower surface **166** configured to form a slidable interface with upper surface **21** of upper wall **22** of cartridge **150**. Support post **168** depends from lower surface **166** of handle portion **154** and is configured to pass through slot **151**, for reasons hereinafter described. Membrane **66** is interconnected to slider **152** such that upper surface **78** of membrane **66** slidably engages lower surface **36** of upper wall **22** for

movement along pathway **68**. Preferably, upper surface **78** forms a sealing relationship with lower surface **36** of upper wall **22** to isolate internal chamber from the external embodiment.

In operation, slider **152** is positioned on upper surface **21** of upper wall **22** of cartridge **150** in an initial position such that support post **168** engages end wall **158**, thereby aligning lower surface **87** of adsorbent pad **84** with swab chamber **50**, FIGS. **6** and **7**A. To test an individual for the presence of target **106**, end **52** of swab **54** is inserted into one or both of the nostrils of the individual and rotated therein while pressed against the inside the nostril to transfer as much nasal discharge onto end **52** of swab **54**, hereinafter referred to swab sample **116**. Swab **54** is removed from the nostril[s]. End **52** of swab **54** is inserted through opening **56** in first sidewall **14** of cassette **10** and into swab chamber **50**. End **52** of swab **54** is pressed against lower surface **87** of adsorbent pad **84** and rotated so as to transfer swab sample **116** onto adsorbent pad **84**.

Once swab sample **116** is transferred onto adsorbent pad **84**, handle portion **154** of slider **152** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **150** so as to draw membrane **66** along pathway **68** along lower surface **36** of upper wall **22** to a first wash position wherein adsorbent pad **84** communicates with first wash well **12**. It can be understood that first and second sidewalls **154** and **156**, respectively, act to guide slider **122**, and hence membrane **66**, as handle portion **154** of slider **152** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **150** by limiting lateral movement of slider **122** as support post **168** travels through slot **151**. In addition, it is intended for leading end **70** of membrane **66** to be received in output storage compartment **172** and for trailing end **72** of membrane **66** to be drawn from input storage compartment **170**. With adsorbent pad **84** communicating with first wash well **12**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **104** in first wash well **12** such that the first aqueous solution washes away any unbound analyte on adsorbent pad **84** with minimal loss of any targets **106** bound to adsorbent pad **84**.

After the first aqueous solution washes away any unbound analyte on adsorbent pad **84**, handle portion **154** of slider **152** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **150** so as to draw membrane **66** along pathway **68** along lower surface **36** of upper wall **22** to a second wash position, wherein adsorbent pad **84** communicates with second wash well **42**. Once again, first and second sidewalls **154** and **156**, respectively, act to guide slider **122**, and hence membrane **66**, as handle portion **154** of slider **152** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **150** by limiting lateral movement of slider **122** as support post **168** travels through slot **151**. As previously noted, the "teardrop" shape of adsorbent pad **84**, facilitates the breakoff of adsorbent pad **84** from drop **104** in first wash well **12** so as to minimize, and preferably prevent, the dragging of the first aqueous solution into drop **108** of the second aqueous solution in second wash well **42**. With adsorbent pad **84** communicating with second wash well **42**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **108** in second wash well **42** such that the second aqueous solution washes away any unbound analyte from adsorbent pad **84** with minimal loss of any targets **106** bound to adsorbent pad **84**.

After the second aqueous solution washes away any unbound analyte on adsorbent pad **84**, handle portion **154** of slider **152** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **150** so as to draw membrane **66** along pathway **68** along lower surface **36** of upper wall **22** to a reaction position, wherein support post **168** engages end wall **158** and adsorbent pad **84** communicates with reaction well **44**. Once again, first and second sidewalls **154** and **156**, respectively, act to guide slider **122**, and hence membrane **66**, as handle portion **154** of slider **152** is slid in the first direction along upper surface **21** of upper wall **22** of cartridge **150** by limiting lateral movement of slider **122** as support post **168** travels through slot **151**. Again, the "teardrop" shape of adsorbent pad **84** facilitates the breakoff of adsorbent pad **84** from drop **108** in second wash well **42** so as to minimize, and preferably prevent, the dragging of the second aqueous solution into drop **110** of the reaction solution in reaction well **44**. With adsorbent pad **84** received within reaction well **44**, it is intended for lower surface **87** of adsorbent pad **84** to communicate with drop **110** in reaction well **44**.

With lower surface **87** of adsorbent pad **84** communicating with drop **110** in reaction well **44**, the reaction solution of drop **110** in cassette **10** is heated, either by insertion of cassette **10** into a temperature-controlled heater or by use of on-device heater **115** for a predetermined period of time for isothermal amplification. After the predetermined time period, a user may determine the presence of target in **106** in swab sample **116** via a visual inspection of cassette **10** (e.g., through window **49**) or by means of an optical reader.

Referring to FIGS. **10**A-**10**B and **11**A-**11**B, alternate methodologies are depicted for loading cassettes **10**, **120** and **150** by providing for the volume-free addition of a reagent to reaction well **44**. As is known, LAMP solutions have limited stability in liquid form (>0° C.). Although, cassette **10** loaded with drop **110** of a LAMP solution may be successfully stored at temperatures less than −20° C., such a requirement may limit the convenience and distribution of the cassette **10**. As such, it is contemplated to utilize a dried (desiccated or lyophilized) LAMP solution that may be reconstituted before or during effectuating the methodology of the present invention. Dried LAMP solutions are stable for approximately one (1) month at room temperature and up to twenty-four (24) months at 4° C.

Referring to FIGS. **10**A-**10**B, in the first alternative methodology, ledge **67** is provided in trailing surface **20***a* of second end wall **20** so as to communicate with reaction well **44** and with passage **37** in second end wall **20**. With interior chamber **29** dry and free of fluids, a reagent **69** of interest in a LAMP solution is deposited onto ledge **67**. Reagent **69** is allowed to dry (such as by desiccation and/or lyophilization) and physically adsorb onto the surface defining ledge **67**. Once reagent **69** is dried on ledge **67**, interior chamber **29** is filled with a selected fluid, such as oil **100**, as heretofore described. Similarly, drops **104** and **108** are provided in first and second wash wells **12** and **42**, respectively, as heretofore described. However, instead of providing a drop **110** of LAMP/reaction solution in reaction well **44**, it is contemplated for the pipet to deliver drop **71** of water/buffer into reaction cavity **44**.

Once loaded, a corresponding cassette **10**, **120** or **150** may be used as heretofore described. By way of example, a description of the operation of cassette **10** is hereinafter after provided. However, such description is understood to describe operation of cassettes **120** and **150** as if fully described herein. More specifically, after swab sample **116** is transferred onto adsorbent pad **84**, membrane **66** is urged axially in the first direction from the initial position, further into cassette **10**, to the first and second wash positions. Thereafter, after the second aqueous solution washes away any unbound analytes on adsorbent pad **84**, membrane **66** is

urged axially in the first direction further into cassette **10** to a third, reaction position wherein membrane **66** is urged into cassette **10** along pathway **68** such that adsorbent pad **84** is positioned in passage **37**, as heretofore described, to communicate with drop **71**. Thereafter, adsorbent pad **84** is moved axially in a first direction along pathway **68** toward ledge **67** so as to drag drop **71** therewith and form a liquid bridge between drop **71** and dried reagent **69** on ledge **67**. With dried reagent **69** in communication with drop **71**, dried reagent **69** reconstitutes and forms the aqueous reaction solution.

With lower surface **87** of adsorbent pad **84** now in communication with the reconstituted reaction solution, cassette **10** is heated, either by insertion of cassette **10** into a temperature-controlled heater or by use of on-device heater **115**, for a predetermined period of time for isothermal amplification. After the predetermined time period, a user may determine the presence of target in **106** in swab sample **116** via a visual inspection of cassette **10** (e.g., through window **49**) or by means of an optical reader.

Referring to FIGS. **11**A-**11**B, in the second alternative methodology, with interior chamber **29** dry and free of fluids, a reagent **73** of interest in a LAMP solution is deposited on third well portion **30***c* of upper surface **30** of bottom wall **24**. The LAMP solution is allowed to dry (such as by desiccation and/or lyophilization) and physically adsorb onto third well portion **30***c* of upper surface **30** of bottom wall **24**. Once reagent **73** is dried on third well portion **30***c* of upper surface **30** of bottom wall **24**, a barrier material (such as wax) **79** is deposited over dried reagent **73** and allowed to harden. It is intended for barrier material **79** to be a solid at room temperature, but melt at higher temperatures. After barrier material **79** hardens, interior chamber **29** is filled with a selected fluid, such as oil **100**, as heretofore described. Similarly, drops **104** and **108** are provided in first and second wash wells **12** and **42**, respectively, as heretofore described. In addition, it is contemplated for the pipet to deliver drop **89** of a water or buffer solution into reaction cavity **44**. It is intended for barrier material **79** to have a density that is lower than the density of drop **89** when barrier material **79** is in a liquid form.

Once loaded, a corresponding cassette **10**, **120** or **150** may be used as heretofore described. By way of example, a description of the operation of cassette **10** is hereinafter provided. However, such description is understood to describe operation of cassettes **120** and **150** as if fully described herein. After swab sample **116** is transferred onto adsorbent pad **84**, membrane **66** is urged axially in the first direction from the initial position, further into cassette **10**, to the first and second wash positions as heretofore described. Thereafter, after the second aqueous solution washes away any unbound analyte on adsorbent pad **84**, membrane **66** is urged axially in the first direction further into cassette **10** to a third, reaction position wherein adsorbent pad **84** is positioned in passage **37**, as heretofore described, and communicate with drop **89**.

With lower surface **87** of adsorbent pad **84** now in communication with the drop **89**, cassette **10** is heated, either by insertion of cassette **10** into a temperature-controlled heater or by use of on-device heater **115**, for a predetermined period of time such that barrier material melts, thereby enabling drop **89** to come into contact with dried reagent **73**. With dried reagent **73** in communication with drop **89**, dried reagent **73** reconstitutes and forms the aqueous reaction solution. Thereafter, cassette **10** is heated in the temperature-controlled heater or by use of on-device heater **115**, for a predetermined period of time, for isothermal amplification. After the predetermined time period, a user may determine the presence of target in **106** in swab sample **116** via a visual inspection of cassette **10** (e.g., through window **49**) or by means of an optical reader.

Referring to FIGS. **12**A-**12**D, in the third alternative methodology, movable wall structure, generally designated by the reference numeral **200**, is provided in reaction well **44** of a corresponding cassette **10**, **120** or **150**. More specifically, wall structure **200** includes leading wall **202** and a generally parallel trailing wall **204** interconnected and spaced by first and second side walls **206** and **208**, respectively. First and second side walls **206** and **208**, respectively, are generally parallel to each other and perpendicular to leading wall **202** and trailing wall **204**. Inner surfaces **202***a*, **204***a*, **206***a* and **208***a* of leading wall **202**, trailing wall **204**, first side wall **206** and second side wall **208**, respectively, define sub-chamber **211**.

Leading wall **202** includes leading surface **210** directed toward trailing surface **20***a* of second end wall **20**. Inner surface **202***a* of leading wall **202** and leading surface **210** of leading wall **202** are interconnected by upper edge **212** and lower edge **214**. It is contemplated for upper edge **212** to include notch **216** formed therein, for reasons hereinafter described. Trailing wall **204** includes trailing surface **218** directed toward leading surface **28***b* of second well wall **28**. Inner surface **204***a* of trailing wall **204** and trailing surface **220** of trailing wall **204** are interconnected by upper edge **222** and lower edge **224**. It is contemplated for upper edge **222** of trailing wall **222** to lie in a plane parallel to and spaced from upper edge **212** of leading wall **202**. Similarly, it is contemplated for lower edge **224** of trailing wall **204** to lie in a plane parallel to and spaced from lower edge **214** of leading wall **202**.

In operation, wall structure **200** is positioned in a first position in reaction well **44** such that: trailing surface **218** of trailing wall **204** adjacent to or abutting leading surface **28***b* of second well wall **28**; leading surface **210** is spaced from trailing surface **20***a* of second end wall **20** so as to define reagent portion **44***a* of reaction chamber **44**; lower edge **224** of trailing wall **204** engages and forms a slidable interface with third portion **30***c* of upper surface **30** of bottom wall **24**; upper edge **222** of trailing wall **204** is spaced from lower surface **36** of upper wall **22** so as to partially define passage **37**; lower edge **214** of leading wall **204** is spaced from third portion **30***c* of upper surface **30** of bottom wall **24**; upper edge **212** of leading wall **204** engages and forms a slidable interface with lower surface **36** of upper wall **22**; notch **216** in upper edge **212** of leading wall **202** is axially aligned with passage **37**; and outer surfaces **230** and **232** of first side wall **206** and second side wall **208**, respectively, engage and form slidable interfaces with corresponding third portions **38***c* and **40***c* of inner surfaces **38** and **40** of first and second sidewalls **14** and **16**, respectively.

With interior chamber **29** dry and free of fluids, a reagent **73** of interest in a LAMP solution is deposited on third well portion **30***c* of upper surface **30** of bottom wall **24** such that reagent **73** communicates with reagent portion **44***a* of reagent well **44**. The LAMP solution is allowed to dry (such as by desiccation and/or lyophilization) and physically adsorb onto third well portion **30***c* of upper surface **30** of bottom wall **24**. Once reagent **73** is dried on third well portion **30***c* of upper surface **30** of bottom wall **24**, interior chamber **29** is filled with a selected fluid, such as oil **100**, as heretofore described. Optionally, a barrier material (such as wax) **79** may be deposited over dried reagent **73** and allowed to harden. It is intended for barrier material **79** to be a solid at room temperature, but melt at higher temperatures. In

such an arrangement, after barrier material **79** hardens, interior chamber **29** is filled with a selected fluid, such as oil **100**, as heretofore described. Thereafter, drops **104** and **108** are provided in first and second wash wells **12** and **42**, respectively, as heretofore described. In addition, it is contemplated for the pipet to deliver drop **89** of a water or buffer solution into sub-chamber **211** defined within wall structure **200**. It is intended for barrier material **79** to have a density that is lower than the density of drop **89** when barrier material **79** is in a liquid form.

Once loaded, a corresponding cassette **10**, **120** or **150** may be used as heretofore described. By way of example, a description of the operation of cassette **10** is hereinafter provided. However, such description is understood to describe operation of cassettes **120** and **150** as if fully described herein. After swab sample **116** is transferred onto adsorbent pad **84**, membrane **66** is urged axially in the first direction from the initial position, further into cassette **10**, to the first and second wash positions as heretofore described. Thereafter, after the second aqueous solution washes away any unbound analyte on adsorbent pad **84**, membrane **66** is urged axially in the first direction further into cassette **10** such that leading end **70** of membrane **66** is received within and becomes seated in notch **216** in upper edge **212** of leading wall **202** of wall structure **200** and such that adsorbent pad **84** communicates with drop **89** in sub-chamber **211** defined by wall structure **200**. As such, as membrane **66** is urged axially in the first direction further into cassette **10**, membrane **66** causes wall structure **200** to slide in the first direction toward trailing surface **20***a* of second end wall **20**. The spacing between lower edge **214** of leading wall **204** and third portion **30***c* of upper surface **30** of bottom wall **24** allows for leading wall **204** to pass over barrier material **79** is deposited over dried reagent **73** thereon. Membrane **66** is urged axially in the first direction until wall structure **200** is in second position wherein sub-chamber **211** within wall structure **200** is coincident with reaction portion **44***a* of reaction chamber **44**.

With wall structure **200** in the second position and adsorbent pad **84** in communication with drop **89**, dried reagent **73** communicates with drop **89** and reconstitutes to form the aqueous reaction solution. Alternatively, if barrier material **79** has been deposited on dried reagent **73**, cassette **10** may be heated, either by insertion of cassette **10** into a temperature-controlled heater or by use of on-device heater **115**, for a predetermined period of time such that barrier material **79** melts, thereby enabling drop **89** to come into contact with dried reagent **73** and form the aqueous reaction solution, as heretofore described. Once dried reagent **73** reconstitutes to form the aqueous reaction solution, cassette **10** is heated in the temperature-controlled heater or by use of on-device heater **115**, for a predetermined period of time, for amplification. After the predetermined time period, a user may determine the presence of target in **106** in swab sample **116** via a visual inspection of cassette **10** (e.g., through window **49**) or by means of an optical reader.

Referring to FIG. **13**, it can be understood that cassettes **10**, **120** and **150** may be modified to allow for multiplexing, e.g. allowing for multiple detection targets or inclusion of an internal assay control. For example, cassettes **10**, **120** and **150** may be provided with a pathway **68***a* parallel to pathway **68** and communicating with corresponding with first wash well **12***a*, second wash well **42***a*, and reaction well **44***a*, which are identical in structure and adjacent to corresponding first wash well **12**, second wash well **42***a*, and reaction well **44***a*. Similarly, a membrane **66***a*, identical in structure to membrane **66**, is provided to travel in a first direction along pathway **68***a*.

In operation, end **52** of swab **54** is inserted through opening **56** in first sidewall **14** of a corresponding cassette **10**, **120** or **150** and into swab chamber **50**. End **52** of swab **54** is pressed against lower surface **87** of adsorbent pad **84** of membrane **66** and against lower surface **87** of adsorbent pad **84** of membrane **66***a*. Swab **54** is rotated so as to transfer swab samples **116** onto adsorbent pads **84** of corresponding membranes **66** and **66***a*. After swab samples **116** are transferred onto adsorbent pads **84**, membranes **66** and **66***a* are urged axially in the first direction from their initial position to the third reaction position, as heretofore described.

With lower surfaces **87** of adsorbent pads **84** of membranes **66** and **66***a* in communication with corresponding drops **110** in reactions wells **44** and **44***a*, the cassette **10**, **120** or **150** is heated, either by insertion of cassette **10**, **120** and **150** into a temperature-controlled heater or by use of on-device heater **115** for a predetermined period of time for isothermal amplification. After the predetermined time period, a user may determine the presence of target in **106** in swab samples **116** via a visual inspection of cassette **10**, **120** or **150** or by means of an optical reader.

Various modes of carrying out the invention are contemplated as being within the scope of the following claims particularly pointing out and distinctly claiming the subject matter that is regarded as the invention.

We claim:

1. A sample extraction cassette for point-of-care molecular testing for a target in a sample provided on a swab, comprising:

a case having:

a chamber configured for receiving the swab;

a wash zone configured for receiving a wash fluid therein;

a reaction zone configured for receiving a reaction fluid therein, the reaction fluid reacting with the target; and

a membrane having a contact portion and being slidably moveable in case;

wherein when the swab is received in the chamber of the case, the membrane is moveable between:

a transfer position wherein the contact portion of the membrane communicates with the sample provided on the swab such that at least a portion of the sample is transferred to the contact portion;

a wash position wherein the contact portion of the membrane is out of contact with the swab and communicates with the wash zone; and

a reaction position wherein the contact portion of the membrane is out of contact with the swab and communicates with the reaction zone.

2. The sample extraction cassette of claim **1** wherein the wash zone is defined by a wash well in the case, the wash well adapted for receiving the wash fluid therein.

3. The sample extraction cassette of claim **2** wherein the reaction zone is defined by a reaction well in the case, the reaction well adapted for receiving the reaction fluid therein.

4. The sample extraction cassette of claim **3** further comprising an oil receiveable in the wash well and the reaction well, the oil fluidially isolating the wash fluid from the reaction fluid when the wash fluid is received in the wash well and the reaction fluid is received in the reaction well.

5. The sample extraction cassette of claim **1** wherein the case is defined by a plurality of surfaces, the plurality of surfaces being hydrophobic.

6. The sample extraction cassette of claim 1 wherein the contact portion of the membrane is defined by a hydrophilic adsorbent pad.

7. The sample extraction cassette of claim 6 wherein the membrane extends along an axis and has a leading end, the hydrophilic adsorbent pad being spaced from the leading end of the membrane.

8. The sample extraction cassette of claim 1 further comprising a dried reagent in communication with the reaction zone, wherein the reaction fluid is defined by a mixture of the dried reagent and an aqueous solution.

9. The sample extraction cassette of claim 8 further comprising a barrier material positioned over the dried reagent to prevent contamination thereof.

10. A sample extraction cassette for point-of-care molecular testing for a target in a sample provided on a swab, comprising:

a case having:

a chamber configured for receiving the swab;

a wash zone configured for receiving a wash fluid therein;

a reaction zone configured for receiving a reaction fluid therein, the reaction fluid reacting with the target; and

a membrane having a contact portion, the membrane slidably receivable into the case and being moveable between:

a transfer position wherein the contact portion of the membrane communicates with the sample provided on the swab when the swab is received in the chamber such that at least a portion of the sample is transferred to the contact portion;

a wash position wherein the contact portion of the membrane communicates with the wash zone; and

a reaction position wherein the contact portion of the membrane communicates with the reaction zone;

wherein:

the contact portion of the membrane is defined by a hydrophilic adsorbent pad;

the membrane extends along an axis and has a leading end, the hydrophilic adsorbent pad being spaced from the leading end of the membrane; and

the hydrophilic adsorbent pad includes:

a generally arcuate leading edge having first and second ends; and

a trailing edge defined by a first portion extending from the first end of the leading edge and a second portion extending from the second end of the leading edge, the first and second portions of the trailing edge converging as the first and second portions of the trailing edge extend from a corresponding first and second ends of the leading edge.

11. A sample extraction cassette for point-of-care molecular testing for a target in a sample provided on a swab, comprising:

a case having:

a chamber configured for receiving the swab;

a wash zone configured for receiving a wash fluid therein; and

a reaction zone configured for receiving a reaction fluid therein, the reaction fluid reacting with the target;

a membrane having a contact portion, the membrane slidably receivable into the case and being moveable between:

a transfer position wherein the contact portion of the membrane communicates with the sample provided on the swab when the swab is received in the chamber such that at least a portion of the sample is transferred to the contact portion;

a wash position wherein the contact portion of the membrane communicates with the wash zone; and

a reaction position wherein the contact portion of the membrane communicates with the reaction zone; and

a slider slidably connected to the case and operatively connected to the membrane, wherein sliding of the slider relative to the case moves the membrane between the transfer position, the wash position and the reaction position.

12. The sample extraction cassette of claim 9 wherein the barrier material is solid at first temperature and melts at a second, higher temperature.

13. A sample extraction cassette for point-of-care molecular testing for a target in a sample provided on a swab, comprising:

a case having:

a chamber configured for receiving the swab;

a wash zone configured for receiving a wash fluid therein;

a reaction zone configured for receiving a reaction fluid therein, the reaction fluid reacting with the target; and

a membrane having a contact portion, the membrane slidably receivable into the case and being moveable between:

a transfer position wherein the contact portion of the membrane communicates with the sample provided on the swab when the swab is received in the chamber such that at least a portion of the sample is transferred to the contact portion;

a wash position wherein the contact portion of the membrane communicates with the wash zone; and

a reaction position wherein the contact portion of the membrane communicates with the reaction zone;

wherein the membrane includes:

first and second sides and a lower surface interconnecting the first and second sides; and

first and second barbs extending from corresponding first and second sides;

wherein the first and second barbs allow slideable movement of the membrane in a first direction and prevents slideable movement of the membrane in a second, opposite direction.

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