DRIP CHAMBER WITH HYDROPHOBIC INTERIOR SURFACE

TECHNICAL FIELD

[0001] The present disclosure relates to a drip chamber, for an infusion tube, with an interior surface having a hydrophobic surface, in particular, a hydrophobic surface with optical properties enabling optical imaging through the hydrophobic surface.

BACKGROUND

[0002] Figure 5 is a pictorial representation of prior art drip chamber **200** with spurious droplets **202** clinging to interior surface **204** of the drip chamber. For purposes of illustration, Figure 5 is presented as a line drawing. During operation of drip chamber **200**, when fluids are flowing through the drip chamber, droplets of fluid, such as droplets **202**, form on the interior surface of the drip chamber due to splashing of the fluid, or by evaporation of the fluid from the reservoir at the bottom of the drip chamber and subsequent condensation of the fluid on the interior surface. Droplets **202** can cause substantial problems with respect to imaging the drip chamber, for example, imaging drop **206** pendant from drip tube **208**. For example, the droplets can cause errors in the measurement of the size of drop **206**. Droplets such as droplets **202** in other portions of the drip tube, for example in the vicinity of a meniscus, can cause similar problems, such as errors in measuring a position/level of the meniscus.

SUMMARY

[0003] According to aspects illustrated herein, there is provided a drip chamber for an infusion tube, including: a first end including a drip tube; a second end including an exit port; and a wall connecting the first and second ends and including an interior surface with a hydrophobic portion. The drip chamber includes a space enclosed by the interior surface and the first and second ends. The hydrophobic portion of the interior surface repels liquid contacting the hydrophobic portion. The hydrophobic portion of the interior surface enables light to refract through the hydrophobic portion and the wall in the same manner as is the case when the hydrophobic portion is not present on the interior surface.

[0004] According to aspects illustrated herein, there is provided a method of fabricating a drip chamber for an infusion tube, including: forming a first end including a drip tube; forming a second end including an exit port; forming a wall connecting the first and second ends and including an interior surface; forming a hydrophobic portion on the interior surface; and enclosing a space with the interior surface and the first and second ends. The hydrophobic portion of the interior surface repels liquid contacting the hydrophobic portion. The hydrophobic portion of the interior surface enables light to refract through the hydrophobic portion and the wall in the same manner as is the case when the hydrophobic portion is not present on the interior surface.

[0005] According to aspects illustrated herein, there is provided an optical imaging system for an infusion tube, including: a drip chamber with: a first portion with a drip tube; a second portion with an exit port; a third portion located between the first and second portions; and a wall connecting the first and second ends and including an interior surface with a portion having a hydrophobic portion of the interior surface aligned with at least one of the first or third portions in a direction orthogonal to a longitudinal axis for the drip chamber passing through the first and second ends. The system includes: at least one light source for emitting light; and an optics system including at least one lens for receiving and transmitting the light transmitted through the hydrophobic portion of the interior surface and the at least one of the first or third portions, and an image sensor for receiving the transmitted light from the at least one lens and generating and transmitting data characterizing the transmitted light from the at least one lens. The system includes a memory element configured to store computer readable instructions and at least one specially programmed processor configured to execute the computer readable instructions to generate, using the data, at least one image of the at least one of the first or third portions. The hydrophobic portion of the interior surface repels liquid contacting the hydrophobic portion of the interior surface. The hydrophobic portion of the interior surface enables the light to pass through the hydrophobic portion of the interior surface without scattering.

[0006] According to aspects illustrated herein, there is provided a method of imaging an infusion tube having a drip chamber including a first portion with a drip tube, a second portion with an exit port, a third portion located between the first and second portions, and a wall connecting the first and second ends and including an interior surface

with a portion having a hydrophobic portion of the interior surface aligned with at least one of the first or third portions in a direction orthogonal to a longitudinal axis for the drip chamber passing through the first and second ends, the method includes: repelling liquid contacting the hydrophobic portion of the interior surface; emitting, using at least at least one light source, light; transmitting the light through the hydrophobic portion of the interior surface and at least one of the first or third portions without scattering the light; receiving, using at least one lens, the light transmitted through the hydrophobic portion of the interior surface and at least one of the first or third portions; transmitting, through the at least one lens, the light transmitted through the hydrophobic portion of the interior surface and the at least one of the first or third portions; receiving, using an image sensor, the transmitted light from the at least one lens; generating and transmitting, using the image sensor, data characterizing the transmitted light from the at least one lens; storing computer readable instructions in a memory element; and executing the computer readable instructions, using at least one specially programmed processor and the data, to generate at least one image of the at least one of the first or third portions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Various embodiments are disclosed, by way of example only, with reference to the accompanying schematic drawings in which corresponding reference symbols indicate corresponding parts, in which:

Figure 1 is a schematic representation of an optical imaging system including a drip chamber with a hydrophobic portion of the interior surface;

Figure 2 is a cross-section view generally along line 2-2 in Figure 1;

Figure 3 is a cross-section view generally along line 3-3 in Figure 1;

Figure 4 is a picture illustrating example periodic structure for a hydrophobic portion of the interior surface; and,

Figure 5 is a pictorial representation of a prior art drip chamber with spurious droplets clinging to an interior surface of the drip chamber.

DETAILED DESCRIPTION

[0008] At the outset, it should be appreciated that like drawing numbers on different drawing views identify identical, or functionally similar, structural elements of the

disclosure. It is to be understood that the disclosure as claimed is not limited to the disclosed aspects.

[0009] Furthermore, it is understood that this disclosure is not limited to the particular methodology, materials and modifications described and as such may, of course, vary. It is also understood that the terminology used herein is for the purpose of describing particular aspects only, and is not intended to limit the scope of the present disclosure.

[0010] Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this disclosure belongs. It should be understood that any methods, devices or materials similar or equivalent to those described herein can be used in the practice or testing of the disclosure.

[0011] Figure 1 is a schematic representation of optical imaging system **100** including drip chamber **102** with a hydrophobic portion of the interior surface.

[0012] Figure 2 is a cross-section of drip chamber **102** generally along line 2-2 in Figure 1.

[0013] Figure 3 is a cross-section of drip chamber **102** generally along line 3-3 in Figure 1. The following should be viewed in light of Figures 1-3. Drip chamber **102** for infusion tube **104** includes end **106** with drip tube **108** and end **110** including exit port **112**. Drip chamber **102** includes wall **114** connecting ends **106** and **110**. Wall **114** includes interior surface **116** having at least one hydrophobic portion **118**. It should be understood that Figures 2 and 3 are not scale drawings and that the thickness of portion **118** in Figures 2 and 3 is exaggerated for purposes of illustration. Wall **114** includes space **122** enclosed by interior surface **116** and ends **106** and **110**. Hydrophobic portion **118** repels liquid **124** in drip chamber **102**. Hydrophobic portion **118** is optically clear and enables light to refract through hydrophobic portion **118** and wall **114** in the same manner as is the case when the hydrophobic portion **118** is not present on interior surface **116**, as further described below. Stated otherwise, hydrophobic portion **118** enables direct mapping of light **126A** and **126B**, passing through portion **118**, from a point, such as pendant drop **128** on drip tube **108**, within drip chamber **102**, to a point on an image (described below) of the point in drip chamber **102**. That is, hydrophobic portion **118** enables points illuminated in drip chamber **102** by the emitted light to be accurately imaged using light transmitted through

hydrophobic portion **118**. In an example embodiment, infusion tube **104** includes output tube **130**.

[0014] In an example embodiment, hydrophobic portion **118** is aligned with portion **132** of drip chamber **102**, including end **106**, in direction **R** orthogonal to longitudinal axis **LA** for drip chamber **102**. Axis **LA** passes through ends **106** and **110**. Portion **132** is sized to include drop **128** pendant from end **134** of drip tube **108**. Thus, hydrophobic portion **118** enables accurate optical imaging of pendant drop **128** by preventing the droplets described above from forming on portion **118**, while enabling undistorted light transmission. Optical imaging of drop(s) **128** can be used to control flow of liquid **124** through drip chamber **102** or can be used to detect alarm conditions, such as an empty bag alarm for bag **136** supplying liquid **124** to drip chamber **102**.

[0015] In an example embodiment, hydrophobic portion **118** is aligned with portion **138** of drip chamber **102**, between ends **106** and **110**, in direction **R**. In an example embodiment, portion **138** is located to include meniscus **140** for liquid **124** in drip chamber **102**. Thus, hydrophobic portion **118** enables accurate optical imaging of meniscus **140** by preventing the droplets described above from forming on portion **118**, while enabling undistorted light transmission. Optical imaging of meniscus **140** can be used to determine a level of liquid **124** in chamber **102**, which can be used to control flow of liquid **124** through drip chamber **102**. In an example embodiment, hydrophobic portion **118** covers both portions **132** and **138**. In an example embodiment, hydrophobic portion **118** covers more than portions **132** and **138**. In an example embodiment, hydrophobic portion **118** covers the entirety of surface **116** between ends **106** or **110**.

[0016] In an example embodiment, a contact angle for liquid **124** in contact with hydrophobic portion **118** is between 90 and 180 degrees. As is understood in the art, the contact angle is an angle, measured through liquid, such as liquid **124**, where a liquid interface contacts a hydrophobic material, such as hydrophobic portion **118**. The angle range described above enables robust repelling of liquid from portion **118**.

[0017] Figure 4 is a picture illustrating example periodic structure for hydrophobic portion **118**. In an example embodiment, hydrophobic portion **118** includes a plurality of periodic structures. In an example embodiment, hydrophobic portion **118** includes a plurality of structures in a non-periodic configuration.

[0018] In an example embodiment, hydrophobic portion **118** is formed of a same piece of material forming wall **114**, that is, hydrophobic portion **118** is integral to material forming wall **114**. For example, interior surface **116** is operated upon in some fashion to create hydrophobic portion **118**. As an example, interior surface **116** can be molded using injection molding, injection-compression molding, compression molding, or embossing, to form hydrophobic portion **118**. Hydrophobic portion **118** can be formed by modifying surface **116** with surface modification technologies such as plasma.

[0019] In an example embodiment, hydrophobic portion **118** is formed of a material **141**, separate from material **143** forming wall **114**. Material **141** is adhered to material **143**. Material **141** can include a polymer, such as, but not limited to acrylic, polystyrene, polycarbonate, vinyl or a mixture of polymers.

[0020] In an example embodiment, hydrophobic portion **118** is a coating free of microstructure, such as wax, polytetrafluoroethylene, or water repellent glass powder, applied to surface **116**.

[0021] In an example embodiment, the material forming hydrophobic portion **118** is fluorinated to improve hydrophobic properties.

[0022] In addition to the desirable optical clarity characteristics noted above, in an example embodiment, hydrophobic portion **118** reflects less than one percent of light incident upon hydrophobic portion **118**. Thus, the vast majority of light incident upon hydrophobic portion **118** is transmitted through wall **114**, enabling high resolution and accurate imagery, and virtually eliminating fresnel reflectance or glare.

[0023] In an example embodiment, hydrophobic portion **118** repels: inorganic liquid such as water; organic liquid such as alcohols, proteins, and oils; a solution of an inorganic liquid with a dissolved organic substance; a solution of an inorganic liquid with a dissolved inorganic substance; a solution of an organic liquid with a dissolved organic substance; and, a solution of an organic liquid with a dissolved inorganic substance.

[0024] The following provides further exemplary detail regarding hydrophobic portion **118**. Hydrophobic portion **118** can be a one-dimensional or a two-dimensional array of microstructure. Hydrophobic portion **118** can have random or stochastic structure. The depth of hydrophobic portion **118** can be between 50nm and 500nm. The pitch of an array of hydrophobic microstructure for hydrophobic portion **118** can be between 50nam and 500nm.

[0025] In an example embodiment, when hydrophobic portion **118** is microstructured, the microstructure can have a cross-sectional profile that is substantially triangular, partially elliptical, parabolic, or hair-like with an indeterminate profile. In an example embodiment, surface **116** is transparent to light **126A** and **126B**, but is tinted for visual differentiation by the naked eye. In an example embodiment, the microstructure is oriented substantially orthogonal to wall **114**. In an example, the microstructure is oriented at an acute angle with respect to wall **114**, for example, angled toward end **106** or toward end **110.**

[0026] As shown in Figure 1, optical imaging system **100** can be used with infusion tube **104** including drip chamber **102**. In an example embodiment, system **100** includes at least one light source **142**, for example sources **142A** and **142B** for emitting light **126A** and **126B**, respectively, and system **100** includes optics system **144**. System **144** includes at least one lens **148**, for example, lenses **148A** and **148B**, and at least one image sensor **150**, for example, sensors **150A** and **150B**. Lenses **148A** and **148B** are for receiving and transmitting light **126A** and **126B** transmitted through hydrophobic portion **118** of the interior surface and portions **132** and **138**, respectively. Sensors **150A** and **150B** receive the transmitted light **126A** and **126B** from lenses **148A** and **148B**, respectively, and generate and transmit data **152A** and **152B** characterizing transmitted light **126A** and **126B** from lenses **148A** and **148B**, respectively. System **100** includes at least one specially programmed processor **156** configured to generate images **158A** and **158B** of portions **132** and **138**, respectively. System **100** includes memory element **160** configured to store computer executable instructions **162**. Processor **156** is configured to execute instructions **162** to generate images **158A** and **158B**. Note that system can include only light source **142A**, lens **148A**, and sensor **150A**, and not light source **142B**, lens **148B**, and sensor **150B**, or light source **142B**, lens **148B**, and sensor **150B** and not light source **142A**, lens **148A**, and sensor **150A**.

[0027] As noted above, image **158A** can include pendant drop **128** and image **158A** can be used to control flow through infusion tube **102** or to monitor for alarm conditions. As noted above, image **158B** can include meniscus **140** and image **158B** can be used to monitor the level of meniscus **140** in drip chamber **102**.

[0028] Advantageously, hydrophobic portion **118** enables more accurate and precise images **158A** and **158B** by eliminating spurious droplets, noted above, clinging to

interior surface **116**, while enabling undistorted or diffused light transmission. For example, a rendering of pendant drop **128** in image **158A** is not cluttered or obscured by spurious droplets clinging to surface **116** in portion **130**, while at the same time benefiting from diffused transmission of the light used to form image **158A**. For example, the boundary of meniscus **140** is not obscured or distorted by spurious droplets clinging to surface **116** in portion **138** between meniscus **140** and portion **130**, while at the same time benefiting from diffused transmission of the light used to form image **158B**.

[0029] It will be appreciated that various of the above-disclosed and other features and functions, or alternatives thereof, may be desirably combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

CLAIMS

1. A drip chamber for an infusion tube, comprising:

a first end including a drip tube;

a second end including an exit port;

a wall:

connecting the first and second ends; and,

including an interior surface with a hydrophobic portion; and,

a space enclosed by the interior surface and the first and second ends, wherein:

the hydrophobic portion of the interior surface repels liquid contacting the hydrophobic portion; and,

the hydrophobic portion of the interior surface enables light to refract through the hydrophobic portion and the wall in the same manner as is the case when the hydrophobic portion is not present on the interior surface.

2. The drip chamber of claim 1, wherein the hydrophobic portion of the interior surface enables direct mapping of the light passing through the hydrophobic portion of the interior surface from a point within the drip chamber to a point on an image of the point in the drip chamber.

3. The drip chamber of claim 1, wherein the hydrophobic portion of the interior surface is aligned with the end of the drip tube in a direction orthogonal to a longitudinal axis for the drip chamber passing through the first and second ends of the drip chamber.

4. The drip chamber of claim 1, wherein when the drip chamber includes fluid disposed in the drip chamber, the hydrophobic portion of the interior surface is aligned with a meniscus for the fluid in a direction orthogonal to a longitudinal axis for the drip chamber passing through the first and second ends of the drip chamber.

5. The drip chamber of claim 1, wherein:

a contact angle for a liquid in contact with the hydrophobic portion of the interior surface is between 90 and 180 degrees; and,

the contact angle is an angle, measured through the liquid, where a liquid interface contacts the hydrophobic portion of the interior surface.

6. The drip chamber of claim 1, wherein the hydrophobic portion of the interior surface includes a first plurality of periodic structures.

7. The drip chamber of claim 1, wherein the hydrophobic portion of the interior surface includes a first plurality of structures in a non-periodic configuration.

8. The drip chamber of claim 1, wherein the hydrophobic portion is formed of a same piece of material forming the interior surface of the wall.

9. The drip chamber of claim 1, wherein:

the hydrophobic portion is formed of a first material, separate from a second material forming the interior surface of the wall; and,

the first material is adhered to the second material.

10. The drip chamber of claim 1, wherein the hydrophobic portion of the interior surface reflects less than one tenth of one percent of light incident upon the hydrophobic portion of the interior surface.

11. The drip chamber of claim 1, wherein the hydrophobic portion of the interior surface repels:

a first inorganic liquid including water;

a first organic liquid including alcohols, proteins, or oils;

a solution of a second inorganic liquid with a dissolved first inorganic substance;

a solution of a third inorganic liquid with a dissolved first organic substance;

a solution of a second organic liquid with a dissolved second inorganic substance;

or,

a solution of a third organic liquid with a dissolved second organic substance.

12. A method of fabricating a drip chamber for an infusion tube, comprising:

forming a first end including a drip tube;

forming a second end including an exit port;

forming a wall connecting the first and second ends and including an interior surface with a hydrophobic portion; and;

enclosing a space with the interior surface and the first and second ends, wherein:

the hydrophobic portion of the interior surface repels liquid contacting the hydrophobic portion; and,

the hydrophobic portion of the interior surface enables light to refract through the hydrophobic portion and the wall in the same manner as is the case when the hydrophobic portion is not present on the interior surface.

13. The method of claim 12, wherein the hydrophobic portion of the interior surface enables direct mapping of the light passing through the hydrophobic portion of the interior surface from a point within the drip chamber to a point on an image of the point in the drip chamber.

14. The method of claim 12, wherein the hydrophobic portion of the interior surface is aligned with the end of the drip tube in a direction orthogonal to a longitudinal axis for the drip chamber passing through the first and second ends of the drip chamber.

15. An optical imaging system for an infusion tube, comprising:

a drip chamber including:

a first portion with a drip tube;

a second portion with an exit port;

a third portion located between the first and second portions; and,

a wall:

connecting the first and second ends; and,

including an interior surface with a hydrophobic portion aligned with at least one of the first or third portions in a direction orthogonal to a longitudinal axis for the drip chamber passing through the first and second ends;

at least one light source for emitting light;

an optics system including:

at least one lens for receiving and transmitting the light transmitted through the hydrophobic portion of the interior surface and the at least one of the first or third portions; and,

an image sensor for:

receiving the transmitted light from the at least one lens; and,

generating and transmitting data characterizing the transmitted light from the at least one lens;

a memory element configured to store computer readable instructions; and,

at least one specially programmed processor configured to execute the computer readable instructions to generate, using the data, at least one image of the at least one of the first or third portions, wherein:

the hydrophobic portion of the interior surface repels liquid contacting the hydrophobic portion of the interior surface; and,

the hydrophobic portion of the interior surface enables the light to pass through the hydrophobic portion of the interior surface without scattering.

16. The optical imaging system of claim 15, wherein the hydrophobic portion of the interior surface enables direct mapping of the light from respective points within the first or third portions to respective points on the at least one image.

17. A method of imaging an infusion tube having a drip chamber including a first portion with a drip tube, a second portion with an exit port, a third portion located between the first and second portions, and a wall connecting the first and second ends and including an interior surface with a hydrophobic portion aligned with at least one of the first or third portions in a direction orthogonal to a longitudinal axis for the drip chamber passing through the first and second ends, comprising:

repelling liquid contacting the hydrophobic portion of the interior surface;

emitting, using at least at least one light source, light;

transmitting the light through the hydrophobic portion of the interior surface and at least one of the first or third portions without scattering the light;

receiving, using at least one lens, the light transmitted through the hydrophobic portion of the interior surface and the at least one of first or third portions;

transmitting, through the at least one lens, the light transmitted through the hydrophobic portion of the interior surface and the at least one of the first or third portions;

receiving, using an image sensor, the transmitted light from the at least one lens;

generating and transmitting, using the image sensor, data characterizing the transmitted light from the at least one lens;

storing computer readable instructions in a memory element; and,

executing the computer readable instructions, using at least one specially programmed processor and the data, to generate at least one image of the at least one of the first or third portions.

18. The method of claim 17, further comprising:

directly mapping, using the at least one specially programmed processor, the light from respective points within the at least one of the first or third portions to respective points on the at least one image.