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LYNN et al.

(54) **LIQUID CRYSTAL-INFUSED SLIPPERY ANTI-FOULING SURFACES**

(71) Applicant: **Wisconsin Alumni Research Foundation**, Madison, WI (US)

(72) Inventors: **David LYNN**, Middleton, WI (US); **Harshit AGARWAL**, Madison, WI (US)

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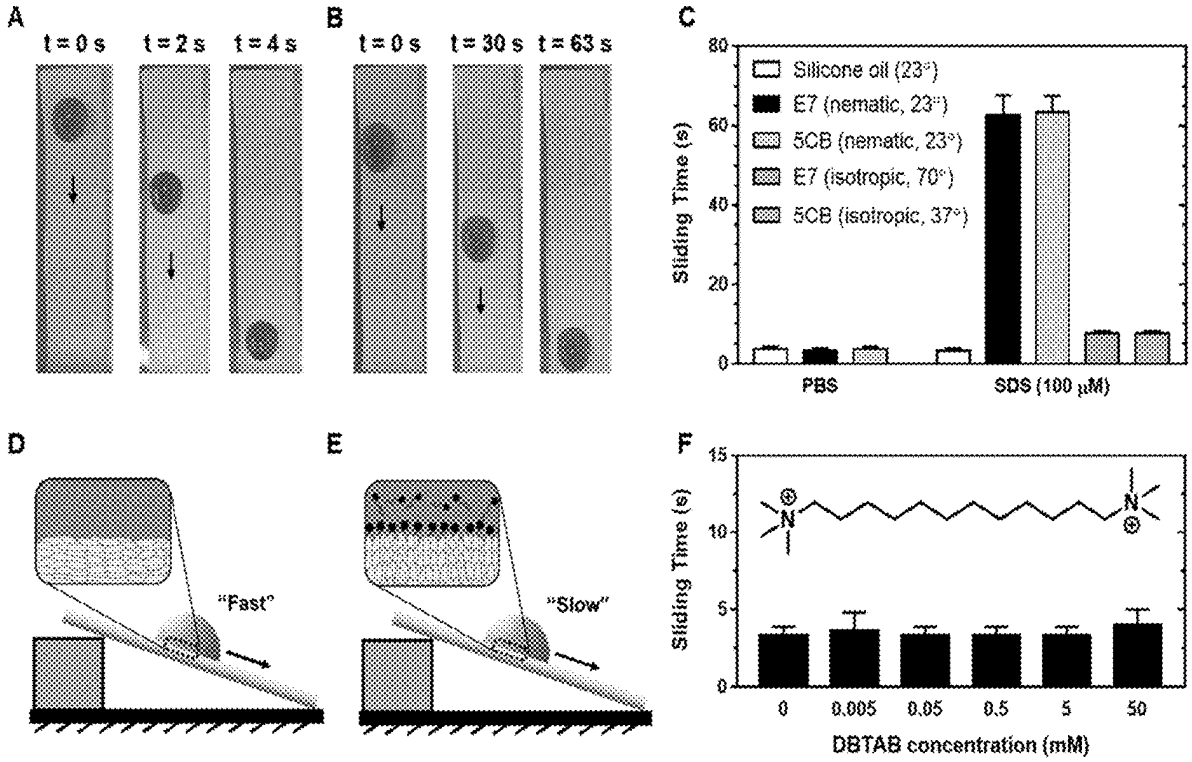
G01N 19/00	(2006.01)

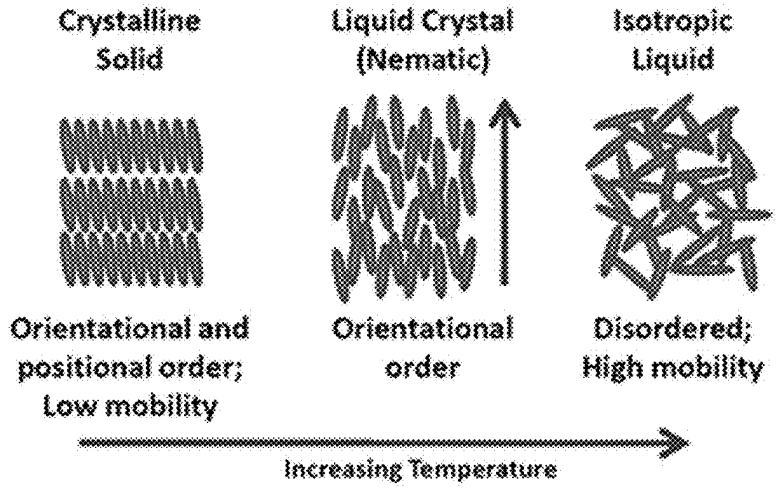
(52) **U.S. Cl.**

CPC ***C09D 5/16*** (2013.01); ***C12Q 1/02*** (2013.01); ***C09D 5/00*** (2013.01); ***C12Q 1/18*** (2013.01); ***C10M 109/00*** (2013.01); ***G01N 19/00*** (2013.01); *C10N 2050/08* (2013.01)

(57) **ABSTRACT**

The present invention provides liquid crystal (LC)-infused materials and methods for detecting compounds or impurities in liquid samples using such materials. These slippery materials comprise a lubricating liquid, preferably a thermotropic liquid crystal, and a solid substrate able to immobilize or host the lubricating liquid. The portion of the substrate coated by the lubricating fluid forms a slippery surface able to allow droplets of various materials to slide off the slippery surface in a manner dependent on the chemical composition of the droplet, which can be used to detect the presence of analytes, impurities and other molecules within the droplet.





E7

4-cyano-4'-*n*-pentyl-biphenly (5CB)

4-cyano-4'-*n*-heptyl-biphenyl (7CB)

4-cyano-4'-*n*-oxyoctyl-biphenyl (8OCB)

4-cyano-4''-*n*-pentyl-terphenyl (5CT)

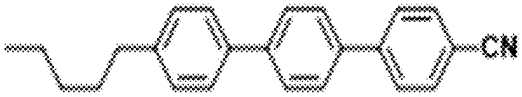


Figure 1

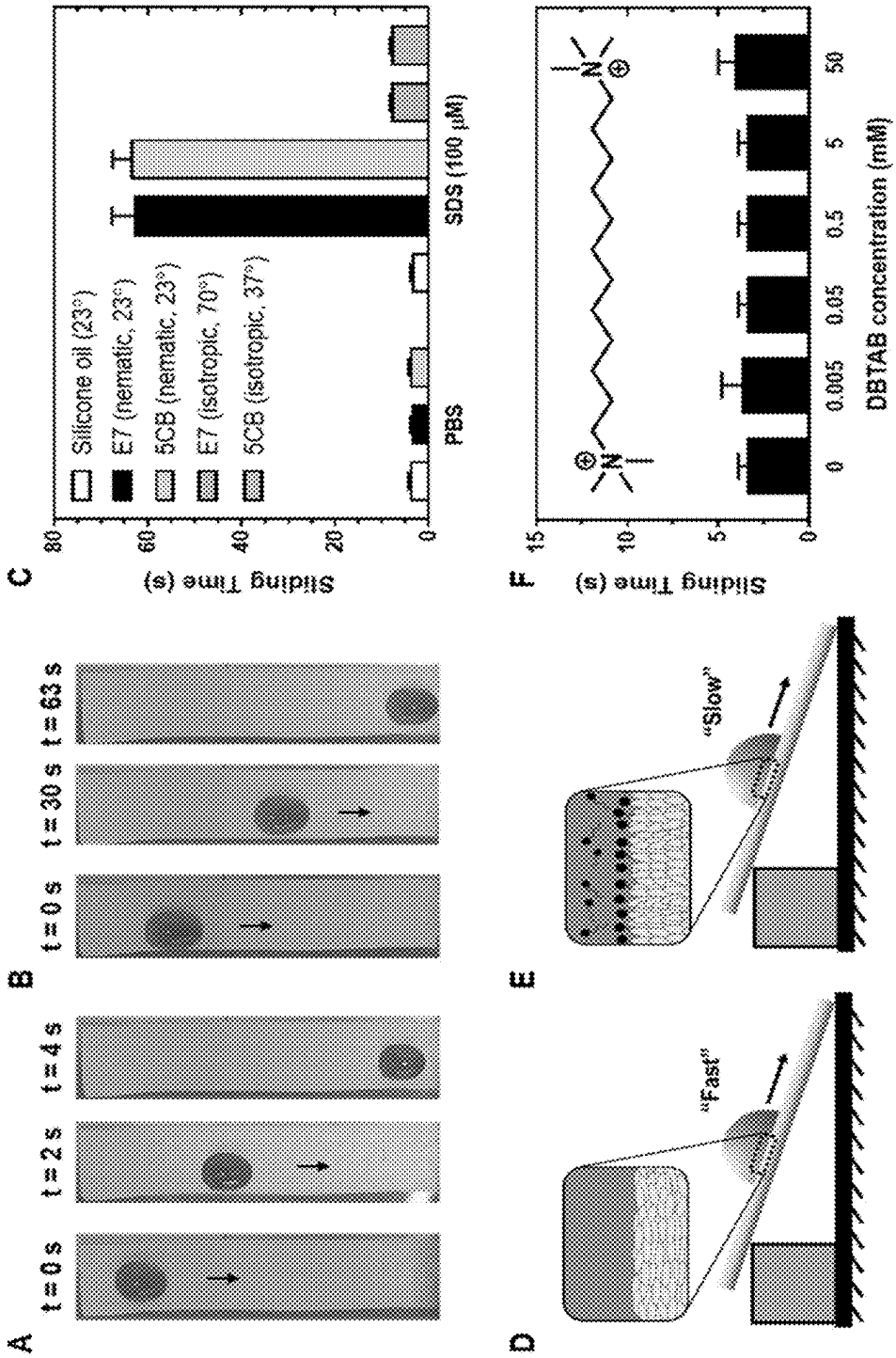

A
t = 0 s
t = 2 s
t = 4 s
B
t = 0 s
t = 30 s
t = 63 s
C
Sliding Time (s)
Silicone oil (23°)
E7 (nematic, 23°)
5CB (nematic, 23°)
E7 (isotropic, 70°)
5CB (isotropic, 37°)
PBS
SDS (100 μM)
D
"Fast"
E
"Slow"
F
Sliding Time (s)
DBTAB concentration (mM)

Figure 2

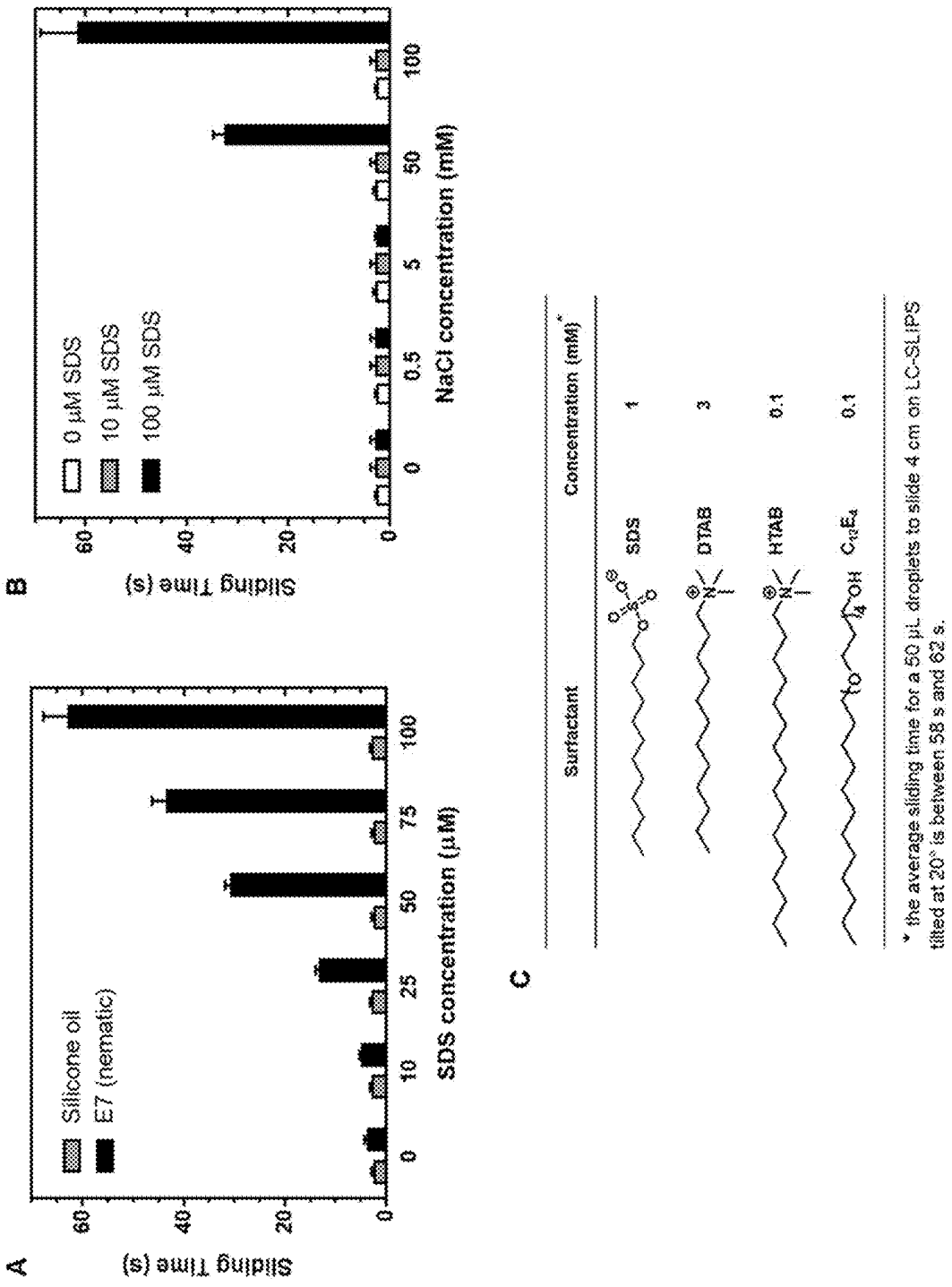

A
Sliding Time (s)
Silicone oil
E7 (nematic)
SDS concentration (μM)
B
Sliding Time (s)
0 μM SDS
10 μM SDS
100 μM SDS
NaCl concentration (mM)
C
Surfactant
Concentration (mM)*
SDS
1
DTAB
3
HTAB
0.1
$C_{12}E_4$
0.1
* the average sliding time for a 50 μL droplets to slide 4 cm on LC-SLIPS tilted at 20° is between 58 s and 62 s.

Figure 3

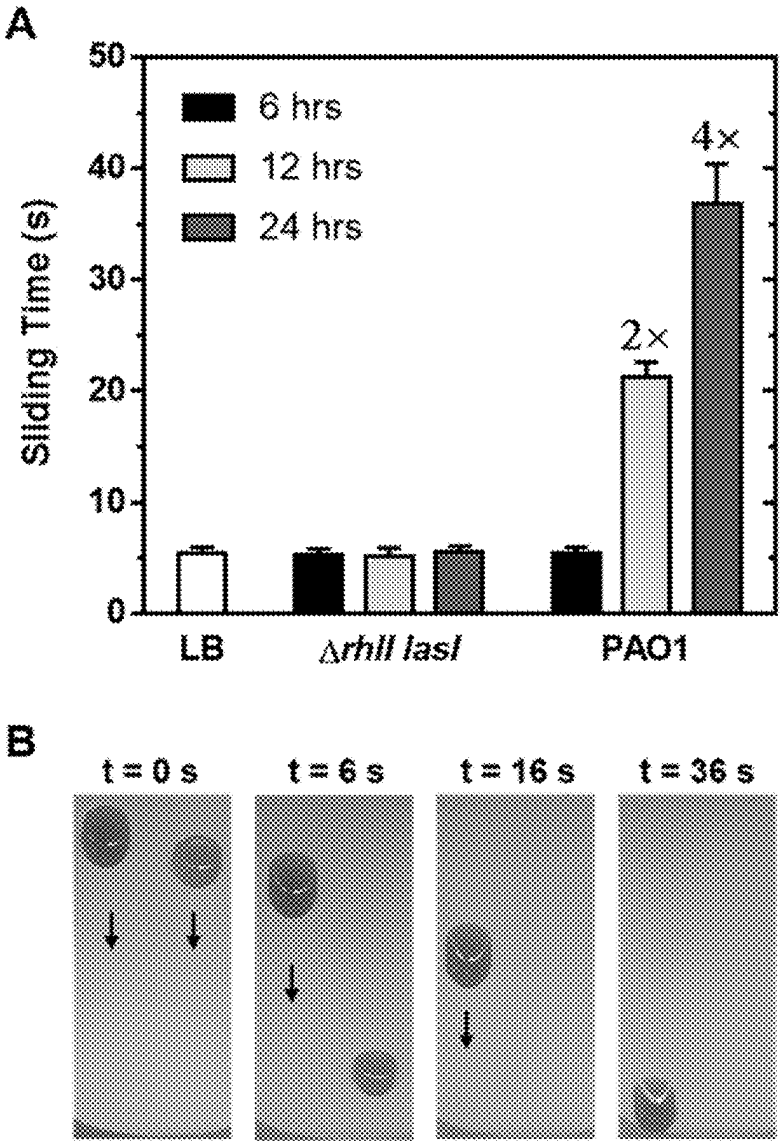

A
Sliding Time (s)
50
40
30
20
10
0
6 hrs
12 hrs
24 hrs
2×
4×
LB
ΔrhlI lasI
PAO1
B
t = 0 s
t = 6 s
t = 16 s
t = 36 s

Figure 4

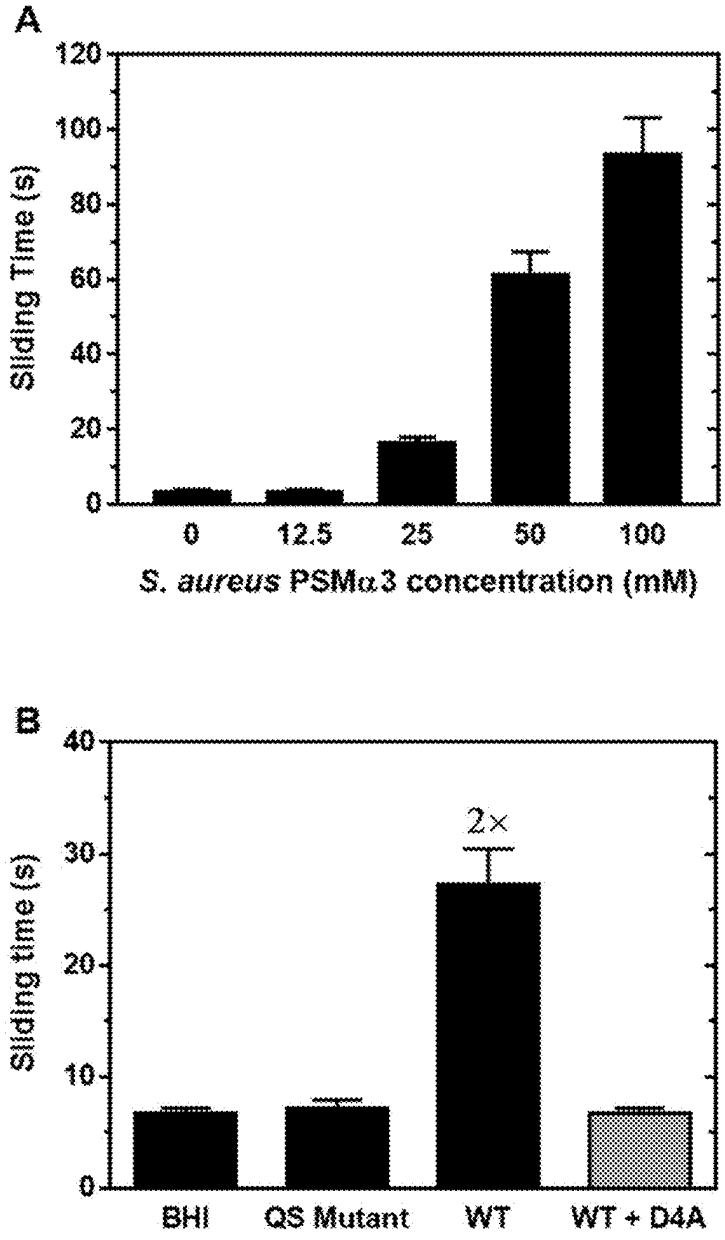

A
Sliding Time (s)
120
100
80
60
40
20
0
0
12.5
25
50
100
S. aureus PSMα3 concentration (mM)
B
Sliding time (s)
40
30
20
10
0
2×
BHI
QS Mutant
WT
WT + D4A

Figure 5

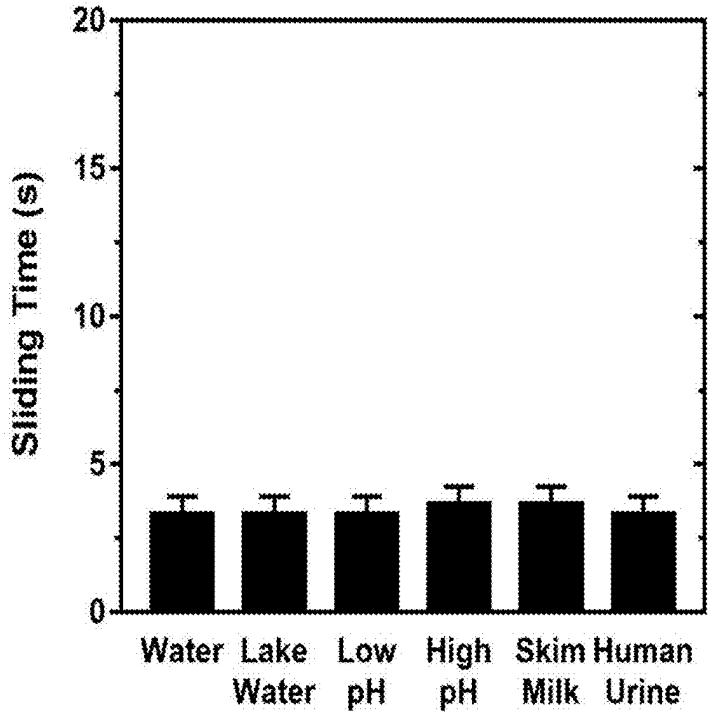

Sliding Time (s)
20
15
10
5
0
Water
Lake Water
Low pH
High pH
Skim Milk
Human Urine

Figure 8

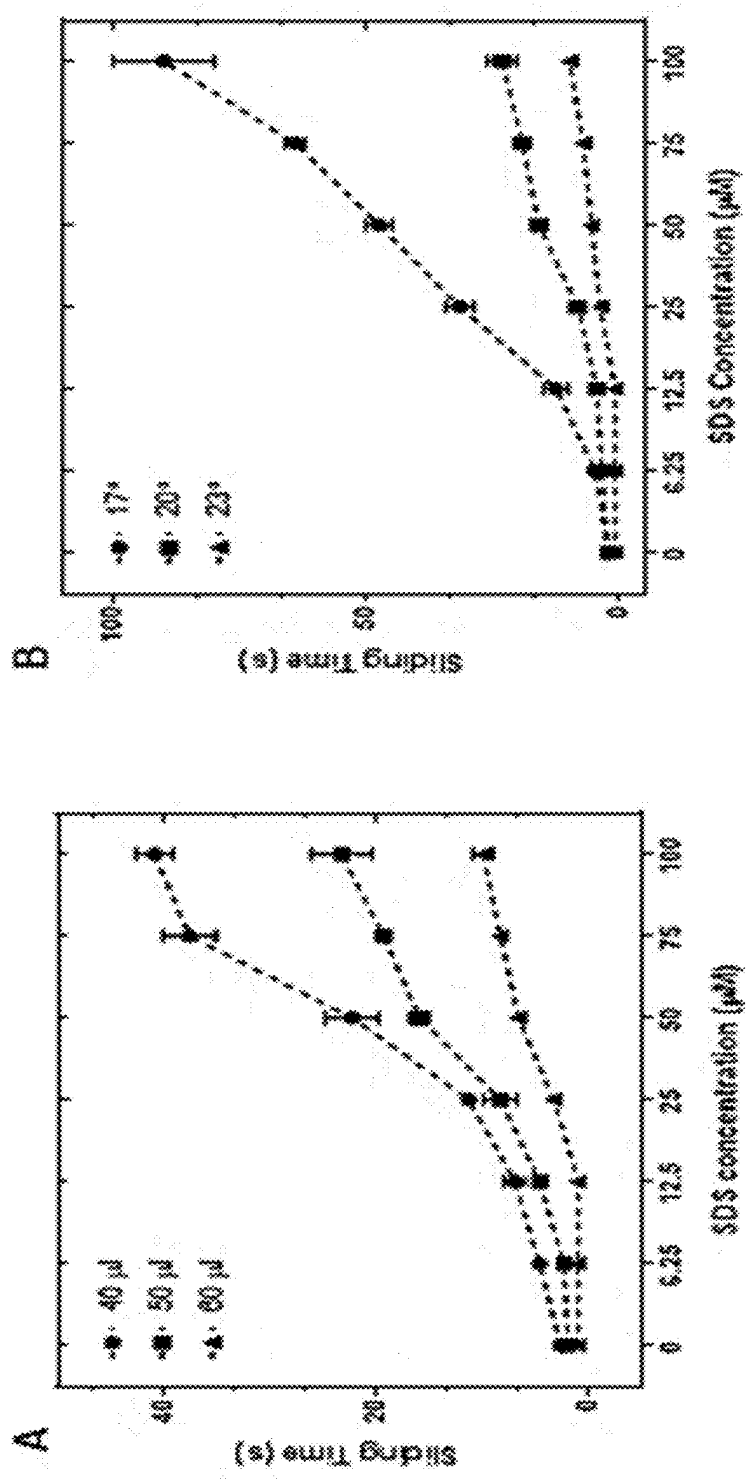

B
Sliding Time (s)
100
50
0
17°
20°
23°
0
6.25
12.5
25
50
75
100
SDS Concentration (μM)
A
Sliding Time (s)
40
20
0
40 μl
50 μl
60 μl
0
6.25
12.5
25
50
75
100
SDS concentration (μM)

Figure 9

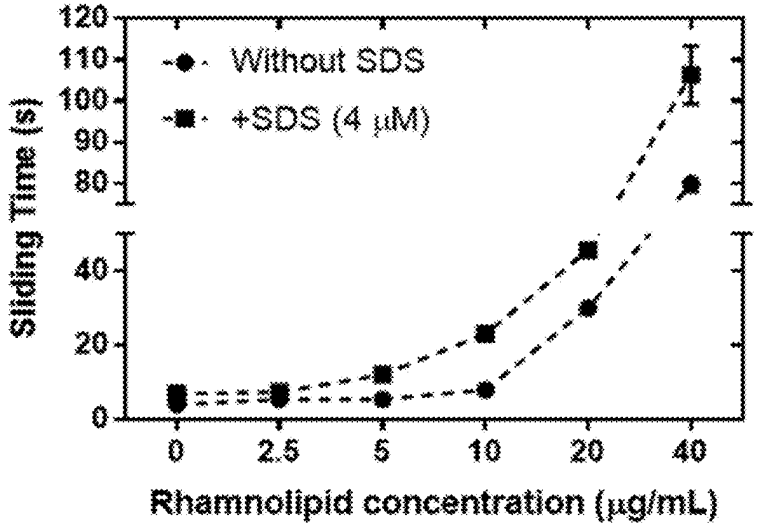


Figure 11

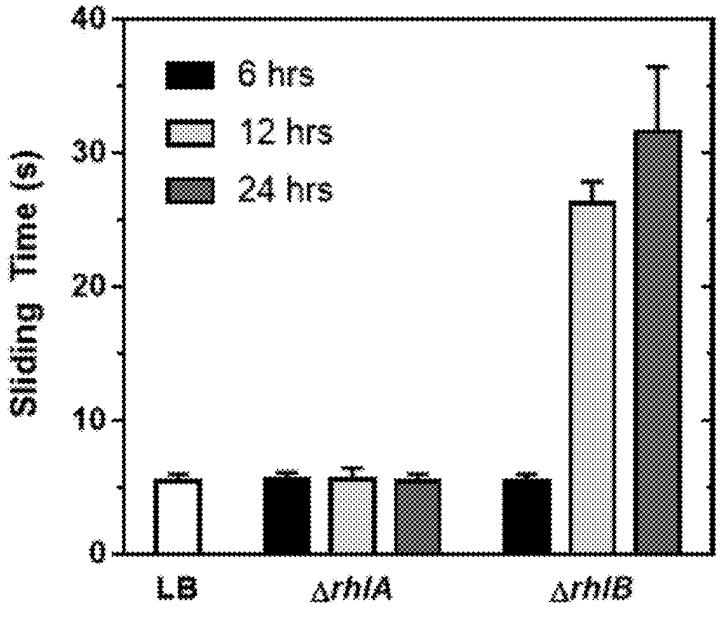


Figure 12

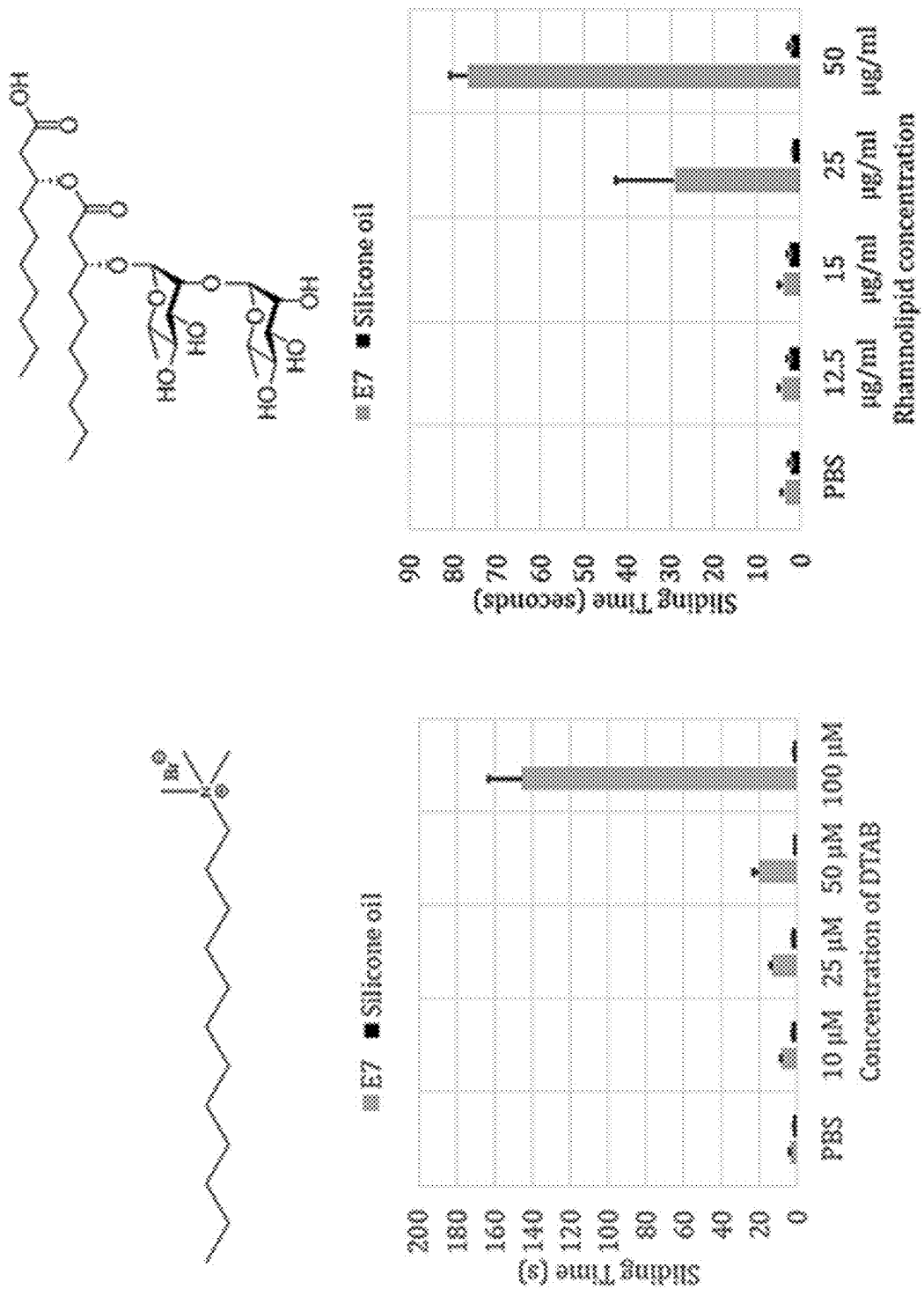

Sliding Time (seconds)
0
10
20
30
40
50
60
70
80
90
E7
Silicone oil
PBS
12.5 μg/ml
15 μg/ml
25 μg/ml
50 μg/ml
Rhamnolipid concentration
Sliding Time (s)
0
20
40
60
80
100
120
140
160
180
200
E7
Silicone oil
PBS
10 μM
25 μM
50 μM
100 μM
Concentration of DTAB

Figure 13

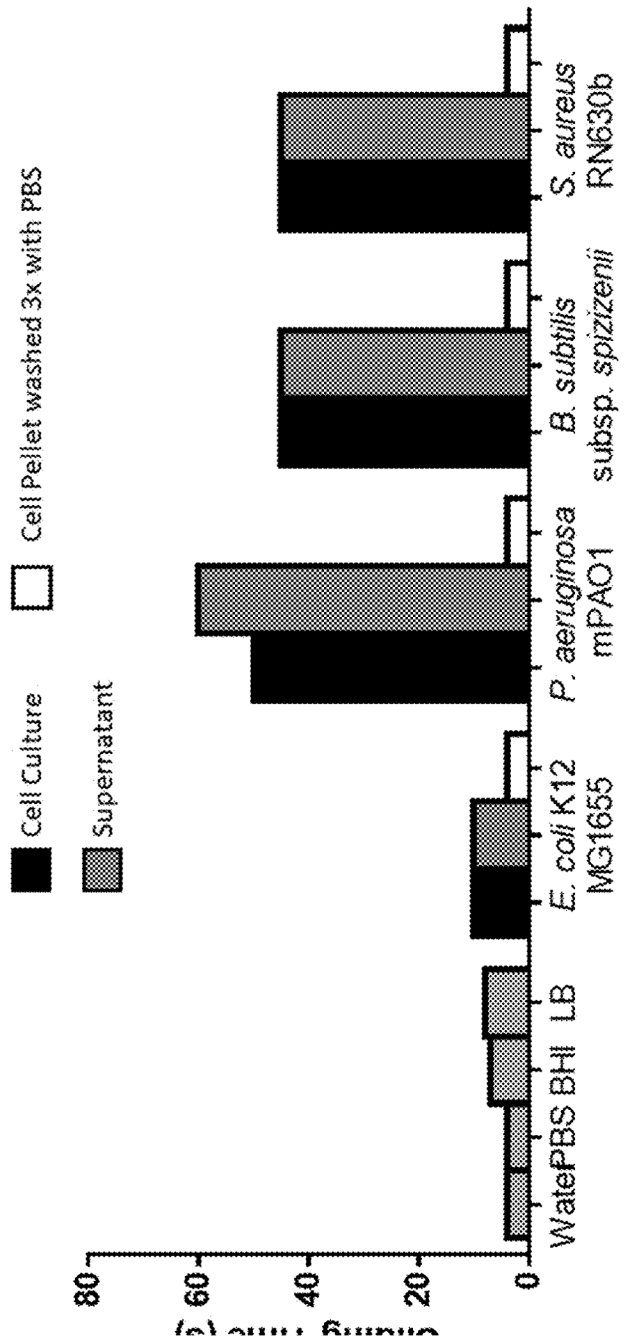
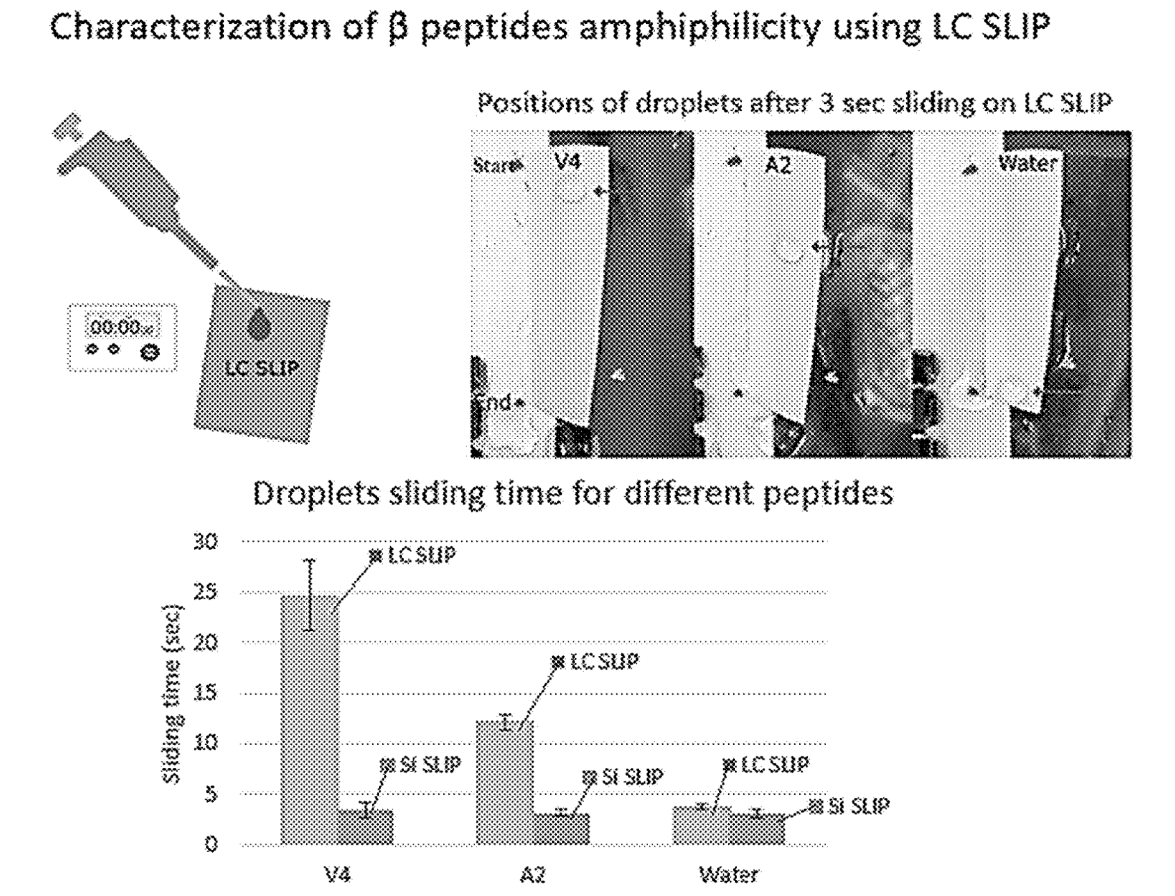
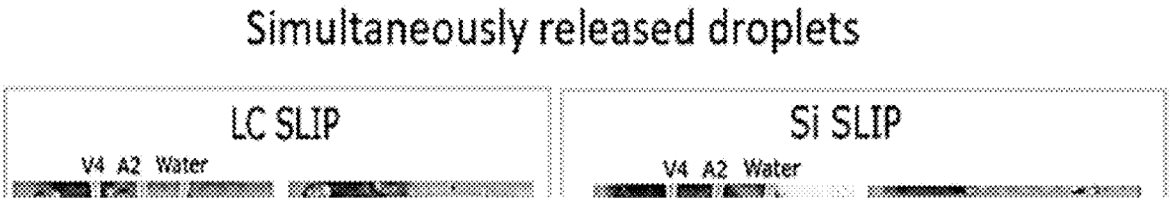

Cell Culture
Supernatant
Cell Pellet washed 3x with PBS
80
60
40
20
0
Water
PBS
BHI
LB
E. coli K12 MG1655
P. aeruginosa mPAO1
B. subtilis subsp. spizizenii
S. aureus RN630b

Figure 14


Characterization of β peptides amphiphilicity using LC SLIP
00:00
LC SLIP
Positions of droplets after 3 sec sliding on LC SLIP
Start
V4
A2
Water
End
Droplets sliding time for different peptides
Sliding time (sec)
30
25
20
15
10
5
0
LC SLIP
Si SLIP
LC SLIP
Si SLIP
LC SLIP
Si SLIP
V4
A2
Water


Simultaneously released droplets
LC SLIP
V4 A2 Water
Si SLIP
V4 A2 Water

Use of LC SLIP for characterizing peptide secondary structures

Peptides with same sequence but different α/β motifs

Peptide 59 ααaβ

Gly	β3hLeu	Phe	Lys	Ile	β3hIle	Lys	Lys	Ile	β3hAla	Lys	Ser	Phe

Peptide 56 ααβ

Gly	Leu	β3hPhe	Lys	Ile	β3hIle	Lys	Lys	β3hIle	Ala	Lys	β3hSer	Phe

Peptide 38 ααβααaβ

Gly	β3hLeu	Phe	Lys	Ile	β3hIle	Lys	Lys	β3hIle	Ala	Lys	Ser	β3hPhe

Peptide 52 αβαβααβ

Gly	β3hLeu	Phe	β3hLys	Ile	Ile	β3hLys	Lys	β3hIle	Ala	β3hLys	Ser	Phe

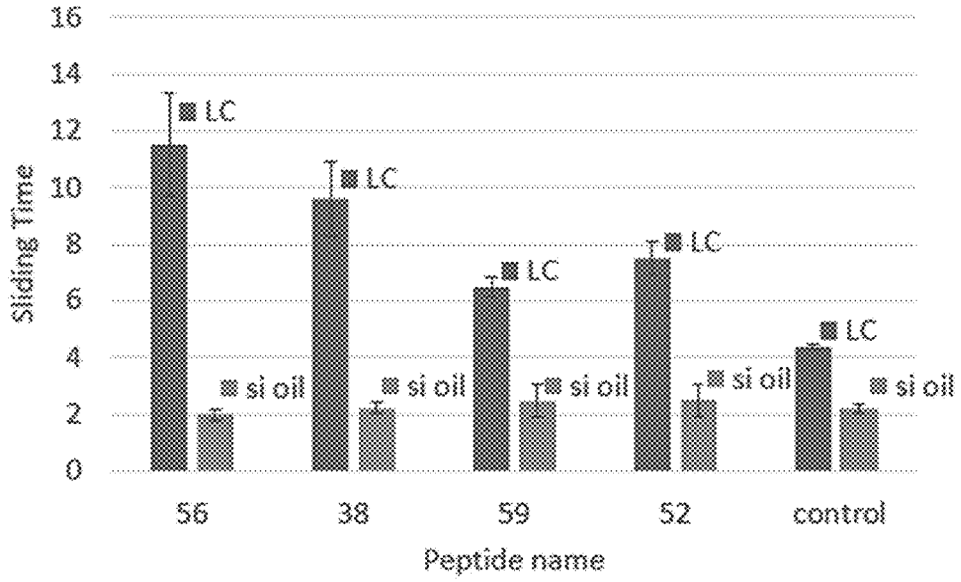


Figure 17

Use of LC SLIP for monitoring enzymatic activity

Peptide 59

αααβ

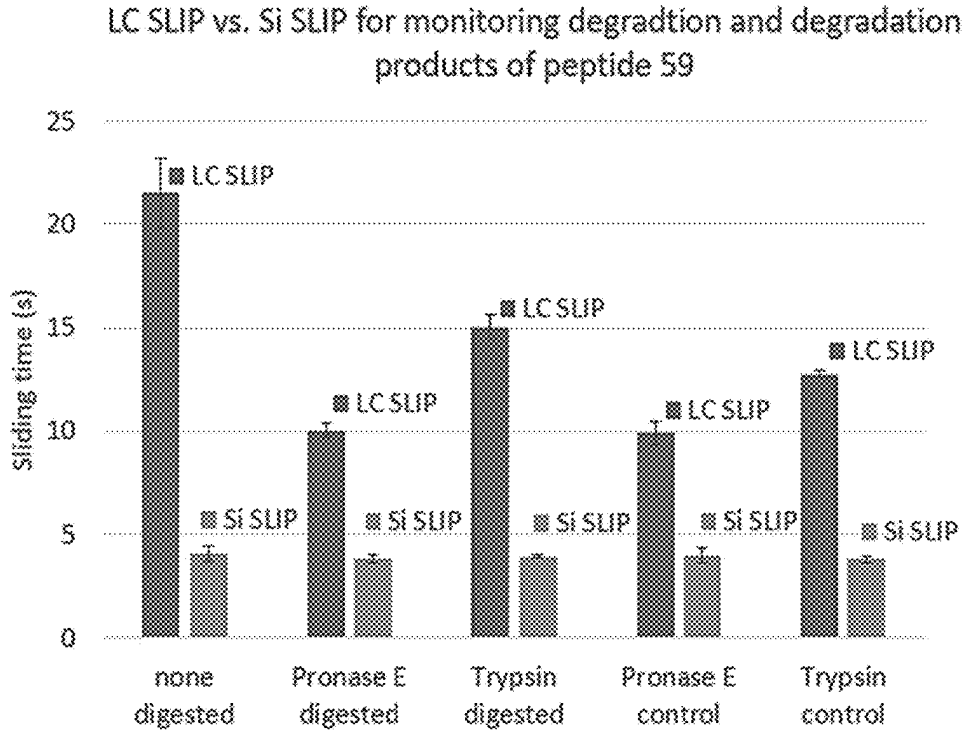


Figure 18

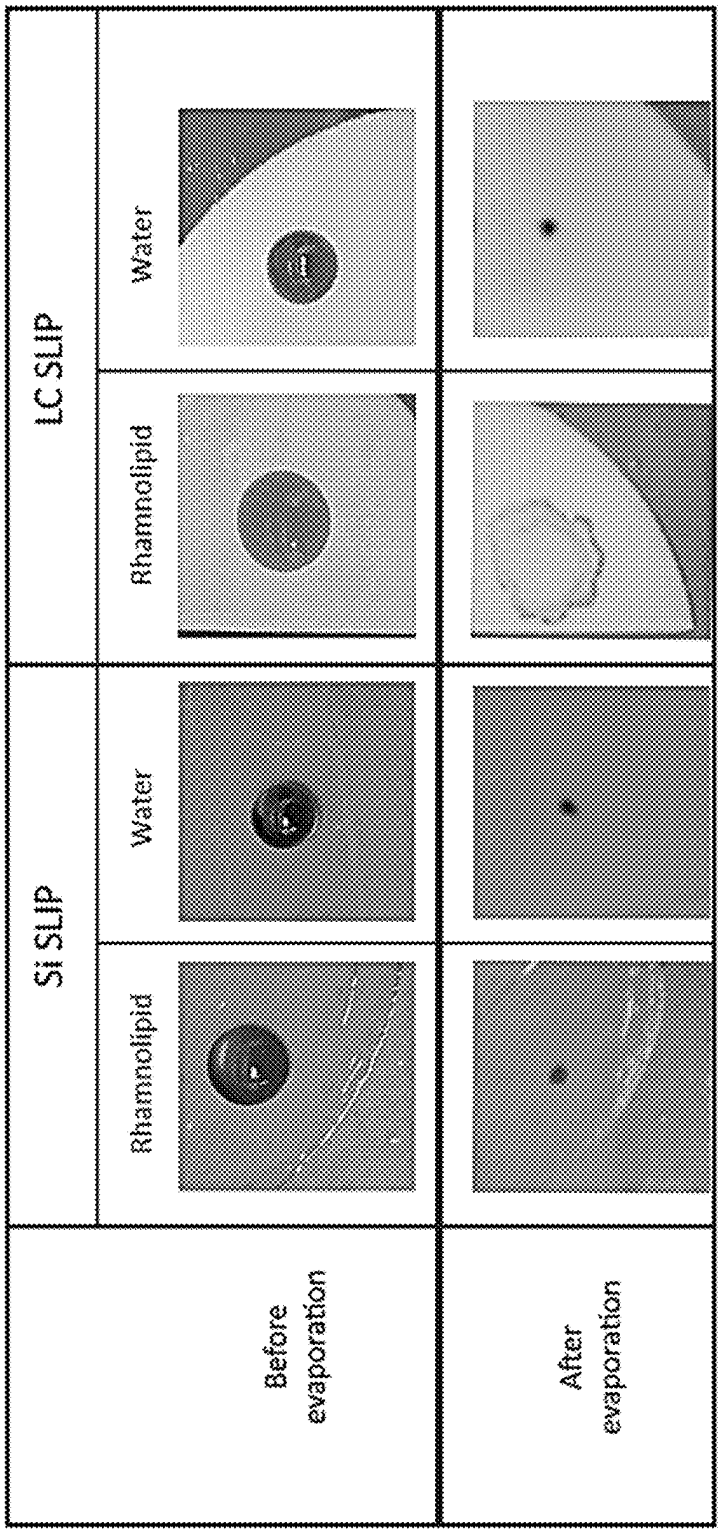
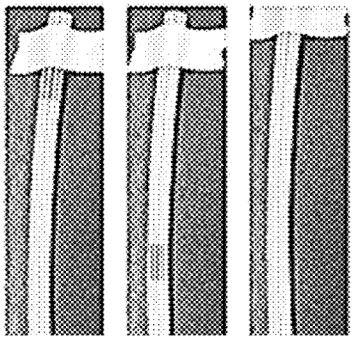

Droplets evaporation as an alternative analyzing method of LC SLIP
Si SLIP
LC SLIP
Rhamnolipid
Water
Rhamnolipid
Water
Before evaporation
After evaporation

Figure 19

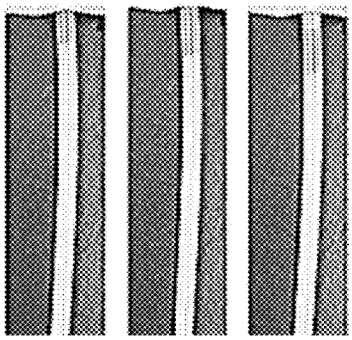
- **Tubing**
  - Material: Polyethylene
  - Inner Diameter: 5 mm
  - Length: 15 cm

- **Sliding Test Conditions**
  - Droplet: DI Water w/food coloring
  - Droplet Volume: 50 µL
  - Angle: 25 °

LC-SLIPS Coated Tube



Uncoated Tube



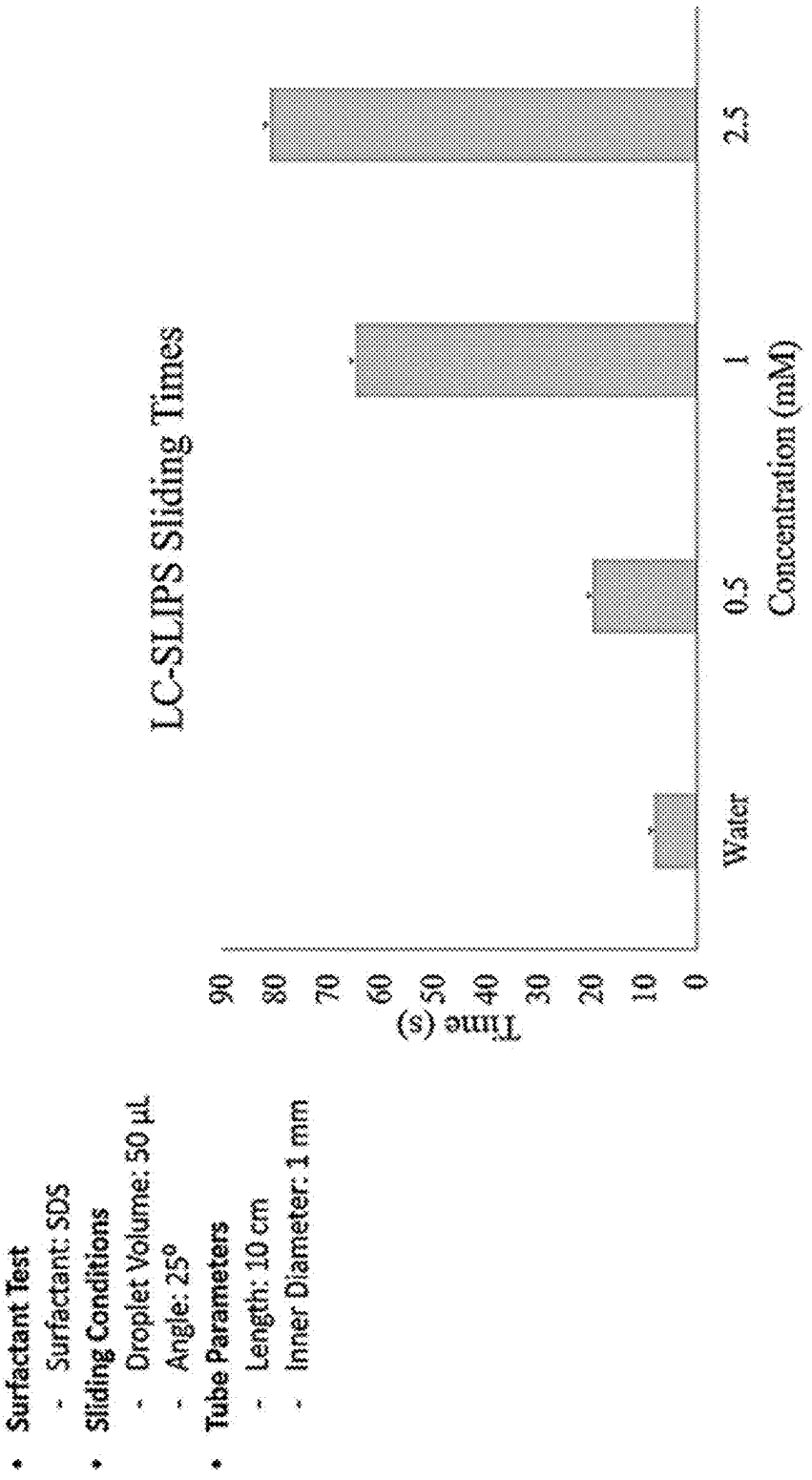

LC-SLIPS Sliding Times
Time (s)
0
10
20
30
40
50
60
70
80
90
Water
0.5
1
2.5
Concentration (mM)
• Surfactant Test
- Surfactant: SDS
• Sliding Conditions
- Droplet Volume: 50 µL
- Angle: 25°
• Tube Parameters
- Length: 10 cm
- Inner Diameter: 1 mm

Figure 21

- **Surfactant Test**
  - Surfactant: SDS
- **Sliding Conditions**
  - Droplet Volume: 50 µL
  - Angle: 25°
- **Tube Parameters**
  - Length: 10 cm
  - Inner Diameter: 1 mm

LIQUID CRYSTAL-INFUSED SLIPPERY ANTI-FOULING SURFACES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Patent Application No. 63/171,881, filed Apr. 7, 2021, which is incorporated by reference herein to the extent that there is no inconsistency with the present disclosure.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with government support under GM109403 awarded by the National Institutes of Health and under 1720415 awarded by the National Science Foundation. The government has certain rights in the invention.

BACKGROUND OF THE INVENTION

[0003] Slippery liquid-infused porous surfaces (SLIPS) and lubricant-impregnated surfaces (LIS) comprise a relatively new class of synthetic soft materials fabricated by the infusion of lubricating liquids into chemically compatible nanoporous, microporous, or topographically patterned surfaces (see Wong et al., Nature 2011, 477 (7365): 443-447; Manabe et al., ACS Applied Materials & Interfaces 2015, 7 (8): 4763-4771; Huang et al., ACS Macro Letters 2013, 2 (9): 826-829; and Lafuma et al., EPL (Europhysics Letters) 2011, 96 (5): 56001; Manna and Lynn, Advanced Materials 2015, 27 (19): 3007-3012). Provided that the chemical properties of the lubricant and the underlying surfaces are suitably matched, these materials present a 'slippery' layer of mobile fluid at the surface that can repel other immiscible fluids or substances with which they come in contact (Wong et al., Nature 2011, 477 (7365): 443-447; Preston et al., ACS Applied Materials & Interfaces 2017, 9 (48): 42383-42392; Schellenberger et al., Soft Matter 2015, 11 (38): 7617-7626; and Smith et al., Soft Matter 2013, 9 (6): 1772-1780).

[0004] For example, SLIPS and LIS can shed droplets of aqueous solutions at very low sliding angles (e.g., angles less than 5° from horizontal), endowing these materials with robust anti-icing, anti-frosting, and anti-fouling properties (see also Stamatopoulos et al., ACS Applied Materials & Interfaces 2017, 9 (11): 10233-10242; Dou et al., ACS Applied Materials & Interfaces 2014, 6 (10): 6998-7003; Subramanyam et al., Langmuir 2013, 29 (44): 13414-13418; Kim et al., ACS Nano 2012, 6 (8): 6569-6577; Ma et al., coatings, medical devices, and sensors. Attention to practical issues such as long-term stability can further expand the commercial utility of these materials. Integration of new design principles that impart new functions and behaviors while maintaining the slippery character could also open the door to exciting and entirely new applications of these antifouling materials.

[0006] Aizenberg and co-workers reported the first examples of SLIPS by infusing perfluorinated liquids into nanofibrous Teflon (polytetrafluoroethylene (PTFE)) membranes (Wong et al., Nature, 2011, 477: 443-447). Since that initial report, many groups have expanded on the range of lubricating liquids and underlying porous matrices that can be used to fabricate SLIPS, improve their chemical and physical stabilities in complex environments, and design multifunctional coatings with improved anti-fouling behaviors, some of which rely on multilayer films to create porous surfaces that are subsequently infused with liquids (see U.S. Pat. Nos. 10,487,217, 10,557,042, and 10,557,044; Li et al., ACS Applied Materials & Interfaces 2013, 5 (14): 6704-6711; Ware et al., ACS Applied Materials & Interfaces 2018, 10 (4): 4173-4182; Huang et al., Advanced Materials 2017, 29 (8): 1604641; Guo et al., Advanced Materials 2016, 28 (32): 6999-7007; Khalil et al., Applied Physics Letters 2014, 105 (4): 041604; Wang et al., ACS Applied Materials & Interfaces 2016, 8 (12): 8265-8271; Badv et al., ACS Nano 2018, 12 (11): 10890-10902; and Goudie et al., Scientific Reports 2017, 7 (1): 13623).

[0007] The multilayer films provided several advantages over previously reported methods, including the ability to fabricate SLIPS on complex surfaces and the development of means to tune, pattern, and manipulate the interfacial properties of the materials. However, there are some limitations to the multilayer-based approach, including manufacturability and scale-up. Providing substrates other than just multilayer films would have several benefits, including decreased complexity and cost as well as increased stability and manufacturability.

[0008] It is also recognized that the properties of the infused oil can have substantial impacts on both the stability of the mobile liquid layer (e.g., the degree to which the infused oil can be displaced by a contacting fluid) and the mobility of droplets of aqueous fluid (e.g., droplets of water slide more slowly on SLIPS fabricated using higher viscosity oils, and more rapidly on coatings infused with lower viscosity liquids) (see Peppou-Chapman et al., Chemical Society Reviews 2020, 49 (11): 3688-3715; Wexler et al., Physical Review Letters 2015, 114 (16): 168301; Howell et

10,557,042, and 10,557,044, and U.S. 2020/0325347). For placed on the substrate and the lubricating liquid differences

formed using the naked eye. Optionally, the liquid can be dyed or reacted with a compound containing a dye or fluorophore to improve visibility. In an embodiment, differences between the time and/or speed the sample liquid travels across the first surface area and the control sample or known standard of the sample liquid are observed using one

are to be detected, the droplets optionally comprise, or are suspected of comprising, amphiphilic or lipophilic small molecules or macromolecules, microorganisms selected from the group consisting of gram-negative bacteria, gram-positive bacteria, yeast, and combinations thereof, suspended particles, viruses, vesicles, polymers, proteins, or

ment, a first polymer layer of the bilayer comprises a [illegible] optionally functionalized polymer selected from the group

sliding down F7-infused SLIPS tilted at 20°. (Panel C) Plot angle (20°) and (B) different tilt angles (17°, 20°, and 23°)

teases (e.g., no digestion, Pronase E digested, trypsin digested, Pronase E control, and trypsin control).

[0067] FIG. **19**. Images (before evaporation and after

3 carbon atoms. Alkyl groups include medium length alkyl groups having from 4-10 carbon atoms. Alkyl groups include long alkyl groups having more than 10 carbon

more hydrogens replaced with one or more fluorine atoms halogenated arylalkyl groups, such as arylalkyl groups hav-

herein. Alkylene groups in some embodiments function as ability to sense, discriminate between, and report on the

Advanced Materials, 2015, 27 (10): 2007-2012. U.S. Pat. Milwaukee, Wis.). Unlaminated PTFE membrane filters

solutions were prepared by adding food coloring to enhance visual contrast of the sliding droplets. For characterization of the sliding times of different bacterial strains, three biological replicates were performed. After each measurement, the surface was washed by depositing multiple water droplets and allowing them to slide down the surface until the sliding time of the water droplets returned to a value of ~3 s. For each surfactant solution, the sliding times of at least 3-5 droplets were measured and used to calculate an average sliding time with standard deviation. Each experimental series was performed on one common LC infused

by reactive/covalent layer-by-layer assembly can be used to design SLIPS that respond actively to changes in the chemical composition of the contacting liquid (e.g., the presence or absence of surfactants) (Manna and Lynn, Advanced Materials 2015, 27 (19): 3007-3012). As a step toward investigating the broader utility of this approach and addressing practical challenges associated with the use of layer-by-layer coatings, it was sought to characterize the infusion of LCs into commercially available and single-component nanoporous PTFE membranes that have been used as matrices for the infusion of conventional isotropic

shown in FIG. **2**, panel B, result from dynamic changes in the anchoring of the LCs (see schematic in FIG. **2**, panels D and E) as aqueous/LC interfaces are formed beneath a droplet and surfactant adsorbs there. It is well understood that thermotropic LCs such as E7 and 5CB adopt so-called homeotropic anchoring when hosted at LC-air interfaces (i.e., the mesogens are generally aligned perpendicular to the interface), and that they adopt so-called planar anchoring when hosted at interfaces created between LCs and water (i.e., the mesogens are generally aligned parallel to the interface) (Sadati et al., Journal of the American Chemical Society 2017, 139 (10): 3841-3850; Ramezani-Dakhel et al., Journal of Chemical Theory and Computation 2017, 13 (1): 237-244; Carlton et al., Langmuir 2012, 28 (35): 12796-12805; Carlton et al., Langmuir 2012, 28 (1): 31-36; and de Mul et al., Langmuir 1994, 10 (7): 2311-2316).

[0123] In addition, previous studies have reported that adsorption of surfactants such as SDS at aqueous/LC interfaces can result in an orientational transition in the anchoring of LCs from planar to homeotropic orientations at the interface (Popov et al., Journal of Materials Chemistry B 2017, 5 (26): 5061-5078; Carlton et al., Liq Cryst Rev 2013, 1 (1): 29-51; Gupta et al., Langmuir 2009, 25 (16): 9016-

areas behind a sliding droplet (that is, sliding droplets could leave behind 'trails' of adsorbed surfactants as they move across a surface, which would result in a concomitant reduction in surfactant concentration in the droplet). Changes in surfactant concentration were not measured in the droplets in the examples performed here, and if surfactant depletion does occur, it did not occur to extents that resulted in significant changes in droplet sliding speed at the surfactant concentrations and path lengths evaluated in the experiments above. It is noted, however, that PBS droplets placed on surfaces previously exposed to sliding SDS-containing droplets were observed to slide over a distance of 4 cm over ~7 s, a time that is slower than the sliding times of PBS droplets on fresh LC-infused PTFE membranes that were never exposed to surfactant-containing droplets (~4 s, as described above).

[0126] This difference in sliding times is generally consistent with the view that surfactant from sliding droplets could remain at LC/air interfaces after surfactant-laden droplets have moved along the surface. It is further noted, in this context, that the sliding times of PBS droplets on 'previously used' LC-infused SLIPS returned to values of ~4 s and were otherwise indistinguishable from freshly-pre-

contact angle (77°±1°) and droplet base diameter (4.0±0.04 mm) of 50 μL 100 mM DBTAB-containing aqueous droplets on LC-infused SLIPS is similar to the contact angle (74. exhibited sliding times of ~63 s. The sliding times of SDS-containing droplets exhibited uniform sliding times of ~3 s on PTFE membranes infused with silicone oil regard-

droplet sliding speeds, consistent with the fact that $C_{ox}E_{ox}$ is [illegible] from 60 μL to 40 μL magnifies the difference in sliding time

visually and unambiguously in the absence of any additional specialized equipment or assays.

Example 6

[0149] Detection and Monitoring of Amphipathic Peptide Toxins Produced by Cultures of *S. aureus*. A series of experiments was performed to determine whether the results

Example 7

[0153] Detection of Anti-Microbial Peptides, Peptide Primary and Secondary Structures, and Enzymatic Activity Using LC-Infused SLIPS

[0154] Antimicrobial peptides (AMPs), have been shown to exhibit antifungal activity but have not been effective as pharmaceuticals because of low activity and selectivity in physiologically relevant environments. However, studies on

placing a droplet of a sample liquid on the surface of the SLIP and allowing the droplet to slide off or along the surface of the material. This can be performed with the surface of the SLIP placed vertically or at a slight angle from horizontal. Alternatively, the SLIP may be placed horizontally (e.g., an angle of 0°) so that the droplet does not slide or move along the surface. The droplet will eventually evaporate depositing any impurities or molecules on the surface as the droplet contracts. However, the impurities and molecules will produce different deposition patterns from the evaporative process based on the hydrophobicity or amphiphilic properties of the impurities or molecules and the interaction with the SLIPS material.

[0160] For example, FIG. **19** shows liquid droplets of water and droplets of water containing rhamnolipid placed on horizontal liquid crystal-infused SLIPS (LC SLIP) and silicone oil-infused SLIPS (Si SLIP). As can be seen in the images taken after evaporation, the droplet containing the rhamnolipid placed on the LC SLIP produced a distinctive pattern not seen with the water droplets or the rhamnolipid droplet placed on the Si SLIP.

[0161] Thus, the presence of hydrophobic and/or amphiphilic materials within a liquid droplet can be determined by imaging or analyzing (including in some instances by using a naked eye test) the evaporation patterns.

[0162] Summary and Conclusions. The above experiments demonstrate that thermotropic LCs can be infused into microporous PTFE membranes to design slippery liquid-infused surfaces that can detect, monitor, and report on the presence of natural and synthetic amphiphiles in aqueous solution. In contrast to the behaviors of aqueous droplets on the surfaces of conventional slippery surfaces infused with isotropic oils, aqueous droplets slide on LC-infused SLIPS at speeds that depend strongly upon the presence, concentrations, and/or structures of dissolved amphiphiles. Sliding times of droplets on the LC-infused PTFE membranes low cost and ease of preparation of these materials, suggest opportunities to deploy these materials in the field and in low resource environments (e.g., ranging from clinics to water sampling studies to school science classes). To explore the feasibility of this approach and provide proof of concept in an applied context, the utility of these LC-infused surfaces were demonstrated for naked-eye detection and monitoring of the production of small-molecule and peptidic amphiphilic bio-toxins in small droplets of fluid extracted directly from cultures of *P. aeruginosa* and *S. aureus*, two clinically important bacterial pathogens. The ability of these LC-infused materials to translate molecular interactions at aqueous/LC interfaces into large and readily-observed, unambiguous changes in the sliding times of small aqueous droplets could open the door to new applications for anti-fouling, liquid-infused materials in the context of environmental sensing and in many other fundamental and applied areas.

[0164] Having now fully described the present invention in some detail by way of illustration and examples for purposes of clarity of understanding, it will be obvious to one of ordinary skill in the art that the same can be performed by modifying or changing the invention within a wide and equivalent range of conditions, formulations and other parameters without affecting the scope of the invention or any specific embodiment thereof, and that such modifications or changes are intended to be encompassed within the scope of the appended claims.

[0165] One of ordinary skill in the art will appreciate that starting materials, reagents, purification methods, materials, substrates, device elements, analytical methods, assay methods, mixtures and combinations of components other than those specifically exemplified can be employed in the practice of the invention without resort to undue experimentation. All art-known functional equivalents, of any such materials and methods are intended to be included in this

other grouping is used herein, all individual members of the group and all combinations and subcombinations possible of the group are intended to be individually included in the disclosure. Every formulation or combination of components described or exemplified herein can be used to practice the invention, unless otherwise stated. Whenever a range is given in the specification, for example, a temperature range, a time range, or a composition range, all intermediate ranges and subranges, as well as all individual values included in the ranges given are intended to be included in the disclosure. In the disclosure and the claims, "and/or" means additionally or alternatively. Moreover, any use of a term in the singular also encompasses plural forms.

[0168] All references cited herein are hereby incorporated by reference in their entirety to the extent that there is no inconsistency with the disclosure of this specification. Some references provided herein are incorporated by reference to provide details concerning sources of starting materials, additional starting materials, additional reagents, additional methods of synthesis, additional methods of analysis, additional biological materials, and additional uses of the invention. All headings used herein are for convenience only. All patents and publications mentioned in the specification are indicative of the levels of skill of those skilled in the art to which the invention pertains, and are herein incorporated by reference to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated by reference. References cited herein are incorporated by reference herein in their entirety to indicate the state of the art as of their publication or filing date and it is intended that this information can be employed herein, if needed, to exclude specific embodiments that are in the prior art. For example, when composition of matter are claimed, it should be understood that compounds known and available in the art prior to Applicant's invention, including compounds for which an enabling disclosure is provided in the references cited herein, are not intended to be included in the composition of matter claims herein.

1. A liquid crystal-infused material comprising:

a) a lubricating liquid, wherein the lubricating liquid is a liquid crystalline material;

b) a solid substrate able to immobilize or host the lubricating liquid, wherein the lubricating liquid wets and coats at least a portion of the substrate;

wherein the portion of the substrate coated by the lubricating fluid forms a slippery surface able to allow droplets of various materials to move across the slippery surface.

2. The material of claim **1**, wherein the lubricating liquid is a thermotropic liquid crystal immiscible or substantially immiscible with aqueous fluids.

3. The material of claim **1**, wherein the substrate has nanoscale or microscale porosity, wherein the lubricating fluid at least partially fills the pores of the substrate.

4. The material of claim **1** further comprising a solid support formed into a tube, wherein the substrate and lubricating liquid are deposited on the inner surface of the tube.

5. The material of claim **1**, wherein the droplets comprise water and an amphiphilic or lipophilic molecule.

6. The material of claim **1**, wherein the droplet comprises one or more of the following: suspended particles, viruses, vesicles, polymers, proteins, peptides, microorganisms, or combinations thereof.

7. The material of claim **1**, wherein the thermotropic liquid crystal exhibits planar anchoring at aqueous/liquid crystal interfaces when an analyte of interest is not present in an aqueous fluid, and exhibits homeotropic anchoring at aqueous/liquid crystal interfaces when the analyte of interest is present in the aqueous fluid.

8. The material of claim **1**, where the droplets move across the slippery surface more slowly when an analyte of interest is present compared to when an analyte of interest is not present.

9. The material of claim **1**, wherein the droplets are able to move across the slippery surface when the slippery surface is at an angle of 10° or less.

10. A method for detecting an analyte, substance, or impurity in a sample liquid comprising the steps of:

a) providing a sensor having a first surface area comprising:

i) a lubricating liquid, wherein the lubricating liquid is a liquid crystalline material;

ii) a solid substrate able to immobilize or host the lubricating liquid, wherein the lubricating liquid wets and coats at least a portion of the substrate, and wherein the portion of the substrate coated by the lubricating fluid forms a slippery surface able to allow droplets of liquids to move across the slippery surface in a manner dependent on the chemical composition of the droplet;

b) providing said sample liquid to said first surface area;

c) comparing the mobility of the sample liquid on said first surface area to a control sample or known standard of said sample liquid, wherein a change in the mobility of said sample liquid to said first surface area indicates an analyte, substance, or impurity in said sample liquid.

11. The method of claim **10**, wherein the lubricating liquid is a thermotropic liquid crystal that is immiscible or substantially immiscible with water.

12. The method of claim **10**, wherein the analyte, substance, or impurity is an amphiphilic molecule or particle.

13. The method of claim **10**, wherein the analyte, substance, or impurity is a peptide.

14. The method of claim **10**, wherein the analyte, substance, or impurity is selected from the group consisting of: suspended particles, viruses, vesicles, polymers, proteins, peptides, microorganisms, or combinations thereof.

15. The method of claim **10**, wherein comparing the mobility of said sample liquid on said first surface area comprises comparing a time said sample liquid travels across said first surface area to time the control sample or known standard of said sample liquid travels across said first surface area.

16. The method of claim **10**, further comprising measuring sliding times of one or more droplets of said liquid sample and one or more droplets of the control sample or known standard on a fixed length of the slippery surface and at a fixed angle, wherein the angle is selected from 1° to 20°.

17. The method of claim **10**, wherein comparing the mobility of said sample liquid comprises placing one or more droplets of the liquid sample and one or more droplets of the control sample or known standard on said first surface area, at least partially evaporating the droplets of the liquid

sample and droplets of the control sample or known standard to form evaporation patterns on said first surface area, and comparing one or more evaporation patterns formed from the liquid sample to one or more evaporation patterns formed from the control sample or known standard.

18. The method of claim **10**, further comprising adding an agent to said sample liquid, wherein the addition of the agent improves levels of detection of the analyte, substance, or impurity present in said sample liquid.

19. The method of claim **18**, wherein the agent is added to said sample liquid prior to providing said sample liquid to said first surface area, and the agent physically or chemically interacts with the analyte, substance, or impurity present in said sample liquid and increases or decreases the mobility of said sample liquid on said first surface area.

20. The method of claim **19**, wherein the agent is a surfactant that slows or stops the mobility of said sample liquid on said first surface area when the analyte, substance, or impurity is present in said sample liquid.

21. The method of claim **19** wherein the agent increases the mobility of said sample liquid on said first surface area when the analyte, substance, or impurity is present in said sample liquid.

22. The method of claim **18**, wherein the agent is a fluorescent compound or dye.

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