



(51) International Patent Classification:

B01D 19/02 (2006.01) A01J 11/02 (2006.01)

B01J 3/03 (2006.01) A23L 3/005 (2006.01)

(21) International Application Number:

PCT/SG2019/050391

(22) International Filing Date:

06 August 2019 (06.08.2019)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

10201806764S 08 August 2018 (08.08.2018) SG

(71) Applicant: **AGENCY FOR SCIENCE, TECHNOLOGY AND RESEARCH** [SG/SG]; 1 Fusionopolis Way, #20-10, Connexis North Tower, Singapore 138632 (SG).

(72) Inventors: **TEO, Ee Jin**; c/o Institute of Materials Research and Engineering, 2, Innovis, Fusionopolis Way, #08-03, Singapore 138634 (SG). **YANG, Chengyuan**; c/o Institute of Materials Research and Engineering, 2, Innovis, Fusionopolis Way, #08-03, Singapore 138634 (SG).

nopolis Way, #08-03, Singapore 138634 (SG). **NEO, Chi Jin Darren**; c/o Institute of Materials Research and Engineering, 2, Innovis, Fusionopolis Way, #08-03, Singapore 138634 (SG).

(74) Agent: **DONALDSON & BURKINSHAW LLP**; 24 Raffles Place, #15-00 Clifford Centre, Singapore 048621 (SG).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,

(54) Title: A METHOD OF REDUCING FOAM AND RELATED SYSTEMS

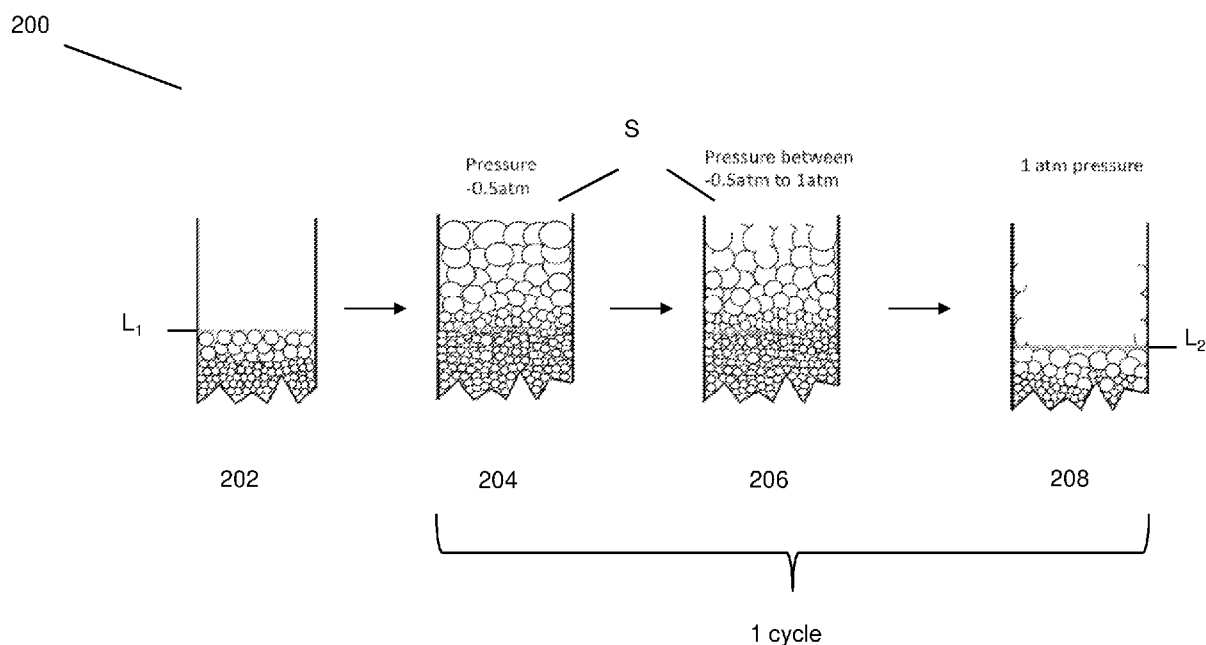


FIG. 2

(57) Abstract: There is provided a method of reducing foam from a foam-containing liquid, the method comprising: subjecting foam to a plurality of pressure cycles, each pressure cycle comprising a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first pressure for reducing the number of bubbles in the foam; and applying radiation to said foam to destabilize said foam. There is also provided a related system for reducing foam from a foam-containing liquid.



UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- *with international search report (Art. 21(3))*
- *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

A METHOD OF REDUCING FOAM AND RELATED SYSTEMS

5 TECHNICAL FIELD

The present disclosure relates broadly to a method of reducing foam from a foam-containing liquid and related systems.

10 BACKGROUND

Foam formation is a common problem faced by industries dealing with beverages (particularly soft drink), milk and fruits. The problem presents itself at various stages of production, such as during dispensing and bottling. For
15 instance, during bottling, liquid is dispensed rapidly into bottles or cartons on a conveyer belt, causing the formation of a huge amount of foam over the liquid surface. This not only results in overflow and wastage, it also hinders the proper sealing of cartons with adhesives.

20 Typically, at the production stage, the mixing of starch/gum powder and acid solution in concentrate plants creates a thick foam over the mixture. The mixture has to be completely defoamed before further processing can be carried out. However, due to the starchy nature of the foam contributing to high viscosity, it takes a long time (up to 12 hours) for the mixture to
25 completely defoam by natural deaeration. This decreases productivity and erodes revenue for a company.

In view of the above, there is thus a need to provide a method and a system that address or at least ameliorate one or more of the above
30 problems.

SUMMARY

In one aspect, there is provided a method of reducing foam from a foam-containing liquid, the method comprising: subjecting foam to a plurality
5 of pressure cycles, each pressure cycle comprising a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first pressure for reducing the number of bubbles in the foam; and applying radiation to said foam to destabilize said foam.

10 In one embodiment, the radiation comprises infra-red radiation.

In one embodiment, the first pressure is from 0.3 atm to 1 atm and the second pressure is from 0.8 atm to 1.2 atm.

15 In one embodiment, the first pressure is kept constant for a period of time until there is substantially no further enlargement of the bubbles in the foam.

In one embodiment, the second pressure is kept constant for a period
20 of time until there is substantially no further reduction in the number of bubbles in the foam.

In one embodiment, the subjecting step and the applying step are performed simultaneously.

25

In one embodiment, the first pressure is created by vacuum pumping and the second pressure is created by venting.

In one embodiment, the method is carried out under constant total
30 volume.

In one embodiment, prior to the subjecting and applying steps, the ratio of the volume of space external to the foam to the volume of the foam in the total volume is at least 1.

5 In one embodiment, the method is substantially devoid of the use of a defoaming agent.

In one aspect, there is provided a system for reducing foam from a foam-containing liquid, the system comprising: a chamber for containing the
10 foam-containing liquid; one or more pressure-regulating members in fluid communication with said chamber, the one or more pressure-regulating members adapted to introduce a first pressure within said chamber for enlarging the size of the bubbles in the foam and a second pressure within said chamber that is higher than the first pressure for reducing the number of
15 bubbles in the foam; and a radiation source arranged to irradiate the foam contained within the chamber to destabilize said foam.

In one embodiment, the one or more pressure-regulating members comprises a first pressure-regulating member adapted to introduce the first
20 pressure and a second pressure-regulating member adapted to introduce the second pressure.

In one embodiment, the first pressure-regulating member comprises a vacuum pump for actively causing air to flow from said chamber.
25

In one embodiment, the second pressure-regulating member comprises a ventilator for passively allowing air to flow into said chamber.

In one embodiment, the radiation source comprises an infra-red
30 radiation source.

In one embodiment, the chamber is a substantially air tight chamber when the first pressure is applied to the chamber.

5 In one embodiment, the chamber comprises at least a portion that allows radiation energy to be transmitted from the radiation source to the foam, optionally wherein the portion is a substantially transparent portion.

10 In one embodiment, the system further comprises a controller for implementing a plurality of pressure cycles within the chamber through the operation of the one or more pressure-regulating members, wherein each pressure cycle comprises a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first pressure for reducing the number of bubbles in the foam.

15 In one embodiment, the radiation source is disposed external to the chamber.

In one embodiment, the system further comprises a plurality of fins disposed within said chamber.

20

DEFINITIONS

The terms "coupled" or "connected" as used in this description are intended to cover both directly connected or connected through one or more intermediate means, unless otherwise stated.

25

The term "associated with", used herein when referring to two elements refers to a broad relationship between the two elements. The relationship includes, but is not limited to a physical, a chemical or a biological relationship.

30 For example, when element A is associated with element B, elements A and B may be directly or indirectly attached to each other or element A may contain element B or vice versa.

The term "adjacent" used herein when referring to two elements refers to one element being in close proximity to another element and may be but is not limited to the elements contacting each other or may further include the elements being separated by one or more further elements disposed therebetween.

The term "and/or", e.g., "X and/or Y" is understood to mean either "X and Y" or "X or Y" and should be taken to provide explicit support for both meanings or for either meaning.

Further, in the description herein, the word "substantially" whenever used is understood to include, but not restricted to, "entirely" or "completely" and the like. In addition, terms such as "comprising", "comprise", and the like whenever used, are intended to be non-restricting descriptive language in that they broadly include elements/components recited after such terms, in addition to other components not explicitly recited. For example, when "comprising" is used, reference to a "one" feature is also intended to be a reference to "at least one" of that feature. Terms such as "consisting", "consist", and the like, may in the appropriate context, be considered as a subset of terms such as "comprising", "comprise", and the like. Therefore, in embodiments disclosed herein using the terms such as "comprising", "comprise", and the like, it will be appreciated that these embodiments provide teaching for corresponding embodiments using terms such as "consisting", "consist", and the like. Further, terms such as "about", "approximately" and the like whenever used, typically means a reasonable variation, for example a variation of +/- 5% of the disclosed value, or a variance of 4% of the disclosed value, or a variance of 3% of the disclosed value, a variance of 2% of the disclosed value or a variance of 1% of the disclosed value.

Furthermore, in the description herein, certain values may be disclosed in a range. The values showing the end points of a range are intended to illustrate a preferred range. Whenever a range has been described, it is intended that the range covers and teaches all possible sub-ranges as well as individual numerical

values within that range. That is, the end points of a range should not be interpreted as inflexible limitations. For example, a description of a range of 1% to 5% is intended to have specifically disclosed sub-ranges 1% to 2%, 1% to 3%, 1% to 4%, 2% to 3% etc., as well as individually, values within that range such as 1%, 2%, 3%, 4% and 5%. The intention of the above specific disclosure is applicable to any depth/breadth of a range.

Additionally, when describing some embodiments, the disclosure may have disclosed a method and/or process as a particular sequence of steps. However, unless otherwise required, it will be appreciated that the method or process should not be limited to the particular sequence of steps disclosed. Other sequences of steps may be possible. The particular order of the steps disclosed herein should not be construed as undue limitations. Unless otherwise required, a method and/or process disclosed herein should not be limited to the steps being carried out in the order written. The sequence of steps may be varied and still remain within the scope of the disclosure.

Furthermore, it will be appreciated that while the present disclosure provides embodiments having one or more of the features/characteristics discussed herein, one or more of these features/characteristics may also be disclaimed in other alternative embodiments and the present disclosure provides support for such disclaimers and these associated alternative embodiments.

DESCRIPTION OF EMBODIMENTS

Non-limiting embodiments of a method of reducing foam from a foam-containing liquid and related systems are disclosed hereinafter.

In various embodiments, there is provided a method of reducing foam from a foam-containing liquid, the method comprising: subjecting foam to a plurality of pressure cycles, each pressure cycle comprising a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first

pressure for reducing the number of bubbles in the foam; and applying radiation to said foam to destabilize said foam.

In various embodiments, the method comprises pulsing or alternating
5 between the first and second pressures. The steps of pulsing, alternating or conducting the pressure cycles may be automated. In various embodiments, the entire method is automated.

In various embodiments, the first pressure is from about 0 atm/bar to
10 about 1 atm/bar, from about 0.3 atm/bar to about 1 atm/bar, from about 0.3 atm/bar to about 0.8 atm/bar or from about 0.3 atm/bar to about 0.5 atm/bar. In various embodiments, the first pressure is about 0 atm/bar, about 0.1 atm/bar, about 0.2 atm/bar, about 0.3 atm/bar, about 0.4 atm/bar, about 0.5 atm/bar, about 0.6 atm/bar, about 0.7 atm/bar, about 0.8 atm/bar, about 0.9
15 atm/bar or about 1 atm/bar. In some embodiments, the first pressure comprises a sub-atmospheric pressure. In some embodiments, the first pressure is below 0.5 atm or 0.5 bar. In some embodiments, the first pressure comprises a negative pressure. In some embodiments, the first pressure comprises a vacuum pressure.

20 In one embodiment, the first pressure is created by vacuum pumping.

In various embodiments, the second pressure is from about 0.5 atm/bar to about 1.5 atm/bar, from about 0.7 atm/bar to about 1.3 atm/bar, from about
25 0.8 atm/bar to about 1.2 atm/bar or from about 0.9 atm/bar to about 1.1 atm/bar. In various embodiments, the second pressure is about 0.5 atm/bar, about 0.6 atm/bar, about 0.7 atm/bar, about 0.8 atm/bar, about 0.9 atm/bar, about 1 atm/bar, about 1.1 atm/bar, about 1.2 atm/bar, about 1.3 atm/bar, about 1.4 atm/bar or about 1.5 atm/bar. As the second pressure is higher than
30 the first pressure, a pressure/compressive force may be created that aids in the bursting of bubbles of the foam.

In one embodiment, the second pressure is created by venting, for example by allowing atmospheric air to enter the enclosure holding the foam. Advantageously, in various embodiments, the introduction/application of the second pressure is relatively energy efficient or energy-saving as it does not require the separate use of a pump or other energy-consuming elements.

In one embodiment, each of first and second pressures are independently part of a pressure ramp. In other words, the first pressure and/or the second pressure may be individual/single pressure points of a broader continuous pressure (increasing or decreasing) gradient or a changing pressure pattern. In one embodiment, each of the first and second pressures are independently kept constant for a period of time. For example, the first pressure may be kept constant for a period of time sufficient to enlarge the size of the bubbles in the foam or until there is substantially no further enlargement of the bubbles in the foam and the second pressure may be kept constant for a period of time sufficient to reduce the number of bubbles in the foam or until there is substantially no further reduction in the number of bubbles in the foam.

In various embodiments, the pressure cycle further comprises a third pressure, wherein the first pressure is about 0.5 atm, the second pressure is in the range of from 0.5 atm to 1 atm and the third pressure is about 1 atm. In various embodiments, the first pressure is kept constant for a period of time sufficient to enlarge the size of the bubbles in the foam or until there is substantially no further enlargement of the bubbles in the foam, the second pressure is part of a pressure ramp that leads from the first pressure to the third pressure, and the third pressure is kept constant for a period of time sufficient to reduce the number of bubbles in the foam or until there is substantially no further enlargement of the bubbles in the foam.

In various embodiments, the duration of each pressure cycle is from about 1 minute to about 10 minutes or from about 1 minute to about 3 minutes. In various embodiments, the duration of each pressure cycle is about 0.5 minute,

about 1 minute, about 2 minutes, about 3 minutes, about 4 minutes, about 5 minutes, about 6 minutes, about 7 minutes, about 8 minutes, about 9 minutes or about 10 minutes. In various embodiments, the pressure cycle is repeated every about 0.5 minute to about 10 minutes or every about 1 minute to about 3 minutes.

5 In various embodiments, the pressure cycle is repeated about every 0.5 minute, about every 1 minute, about every 2 minutes, about every 3 minutes, about every 4 minutes, about every 5 minutes, about every 6 minutes, about every 7 minutes, about every 8 minutes, about every 9 minutes or about every 10 minutes. In various embodiments, the pressure cycle is repeated one or more times until the
10 foam-containing liquid is completely or substantially defoamed. In various embodiments, the foam is subjected to at least about 10 pressure cycles, at least about 15 pressure cycles, at least about 20 pressure cycles, at least about 25 pressure cycles, at least about 30 pressure cycles, at least about 35 pressure cycles, at least about 40 pressure cycles, at least about 45 pressure cycles, at
15 least about 50 pressure cycles, at least about 55 pressure cycles, at least about 60 pressure cycles, at least about 65 pressure cycles, at least about 70 pressure cycles, at least about 75 pressure cycles, at least about 80 pressure cycles, at least about 85 pressure cycles, at least about 90 pressure cycles, at least about 95 pressure cycles or at least about 100 pressure cycles. In various
20 embodiments, the method further comprises the step of monitoring the pressure of the foam-containing liquid or the pressure of the environment containing the foam-containing liquid.

The radiation source may be one that emits radiation of wavelengths in the
25 electromagnetic spectrum. In some embodiments, the radiation source comprises an optical means. In various embodiments, the radiation source is one that is capable of imparting heat to the foam and therefore, the method may comprise the step of heating the foam. For example, infra-red radiation can cause foam temperature to increase to about 60°C after about 2 hours of continuous
30 heating. To minimize any heating effect on the foam by the radiation source, water may be added/sprayed occasionally over the foam to cool down/reduce the temperature of the foam and/or to prevent crystallization of any sugars in the foam

mixture. In various embodiments, the method further comprises the step of monitoring the temperature of the foam and/or the foam-containing liquid. In various embodiments, the radiation comprises infra-red radiation. In various embodiments, the radiation source comprises one or more infra-red lamps. In some embodiments, the one or more infra-red lamps operate at a power, e.g. an electrical power, of from about 100W to about 200W, or at a power of about 100W, about 110W, about 120W, about 130W, about 140W, about 150W, about 160W, about 170W, about 180W, about 190W or about 200W. In various embodiments, the optical power of the radiation source is in the range of a few watts, for example, from about 1W to about 10W. The optical power of the radiation source may be about 1W, about 2W, about 3W, about 4W, about 5W, about 6W, about 7W, about 8W, about 9W or about 10W.

In various embodiments, the radiation source is no less than about 10 cm, no less than about 20 cm, no less than about 30 cm, no less than about 40 cm, no less than about 50 cm or no less than about 60 cm from a base surface of the foam-containing liquid or from a base of a chamber/beaker/vessel containing the foam-containing liquid. In some embodiments, the radiation source is no less than about 10 cm, no less than about 20 cm, no less than about 30 cm, no less than about 40 cm, no less than about 50 cm or no less than about 60 cm from a top surface of the foam-containing liquid from a top opening of a chamber/beaker/vessel containing the foam-containing liquid. In one embodiment, the radiation source e.g. an infra-red lamp is kept fixed at about 30 cm from the base of a chamber/beaker/vessel containing the foam-containing liquid.

In various embodiments, the subjecting step and the applying step are performed simultaneously. Advantageously, this enhances the defoaming rate. In other embodiments, the subjecting step and the applying step are performed not simultaneously, for example, sequential, in succession or following a predetermined pattern. This may aid in reducing energy consumption as the radiation source does not need to be continuously turned

on. In various embodiments, radiation is applied during a low pressure cycle (e.g at a first pressure for enlarging the size of bubbles in the foam) to further increase the rate of defoaming. In various embodiments, radiation is not applied during a high pressure cycle (e.g. at a second pressure for reducing the number of bubbles in the foam). In various embodiments, the radiation source or intermittent heating from the radiation source is applied in synchronization to the lower pressure cycle/stage. In other words, the radiation may be applied during the phase (or at the initiation of the phase) where the first pressure is applied or where the pressure is dropped to reach the first pressure; and the radiation may be stopped/halted during the phase (or at the initiation of the phase) where the second pressure is applied or where the pressure is raised (e.g through venting) to reach the second pressure. Advantageously, this maximises the defoaming effect without causing significant heating of the foam and/or crystallization of the foam mixture.

In various embodiments, the method is carried out under constant total volume. For example, the method may be carried out in a chamber having a fixed volume that does not substantially change throughout the defoaming process. Accordingly, in various embodiments, the pressures applied to the chamber or foam are not a result of changing the volume of the chamber.

In some embodiments, the ratio of the volume of space external to the foam to the volume of the foam in the total volume is at least about 0.5, at least about 1, at least about 1.5, at least about 2, at least about 3, at least about 5, at least about 10, at least about 15 or at least about 20 prior to the subjecting and applying steps. In some embodiments, the volume of space above foam is similar to or larger than the volume of the foam. Advantageously, it has been found that when the volume of the space external to the foam is sufficiently large to allow rapid and non-restrictive bubble expansion, the rate of defoaming may be raised effectively. Further, as defoaming proceeds i.e. as the volume of the foam decreases, the ratio of

the volume of space external to the foam to the volume of the foam may increase. Accordingly, a defoaming efficiency of embodiments of the method may increase as defoaming progresses. In one embodiment, the ratio of the volume of space external to the foam to the volume of the foam in the total
5 volume is about 1 (or 1:1) prior to the subjecting and applying steps. As defoaming progresses, the ratio is slowly increased to about 2 (or 2:1).

In various embodiments, the method has a defoaming rate that is at least about 2 times, at least about 3 times, at least about 4 times, at least about 5
10 times, at least about 6 times or at least about 7 times faster than defoaming by standing the foam at atmospheric pressure. In various embodiments, the method has a defoaming rate that is at least about 2 times, at least about 3 times or at least about 4 times than defoaming by applying only vacuum to the foam.

15 In various embodiments, the method is substantially devoid of the use of a defoaming agent. In some embodiments, the method is substantially chemical-free and/or contact-free. In embodiments where the method is substantially contact-free, the method may be substantially free from moving physical/mechanical parts that are used to directly contact the bubbles in
20 order to burst them (e.g. a beater). Accordingly, embodiments of the method may be safely used to defoam liquid products for consumption or other food-grade product/material.

In various embodiments, the method is substantially devoid of the use
25 of gas spray, steam spray, sound wave, ultrasonic means or acoustic means to defoam a foam-containing liquid.

In various embodiments, the method is compatible for implementation in a variety of reactor systems including an open reactor system, a closed reactor
30 system, a continuous flow reactor system and a discontinuous flow reactor system. In various embodiments, the method is carried out in a mixing chamber of a reactor system. The mixing chamber may be the chamber where the

production of foam directly occurs, and the defoaming method may be applied *in situ* (i.e. in the same chamber) without the need for transference of the foam into a separate chamber. Accordingly, the mixing and defoaming may be carried out in a single chamber.

5

In various embodiments, the foam-containing liquid is an effervescent liquid. In various embodiments, the foam-containing liquid has a viscosity that is higher than water. For example, the viscosity of the foam-containing liquid may be at least about 2 times, at least about 3 times, at least about 4 times,
10 at least about 5 times, at least about 6 times, at least about 7 times, at least about 8 times, at least about 9 times, at least about 10 times, at least about 11 times or at least about 12 times the viscosity of water.

In various embodiments, there is provided a system for reducing foam
15 from a foam-containing liquid, the system comprising: a chamber for containing the foam-containing liquid; one or more pressure-regulating members in fluid communication with said chamber, the one or more pressure-regulating members adapted to introduce a first pressure within said chamber for enlarging the size of the bubbles in the foam and a second
20 pressure within said chamber that is higher than the first pressure for reducing the number of bubbles in the foam; and a radiation source arranged to irradiate the foam contained within the chamber to destabilize said foam.

In various embodiments, the one or more pressure-regulating
25 members comprises at least one member selected from the group consisting of a pump, a valve, a ventilator, a vent, an opening and combinations thereof. In various embodiments, the one or more pressure-regulating members comprises a first pressure-regulating member adapted to introduce the first pressure and a second pressure-regulating member adapted to introduce the
30 second pressure. In various embodiments, the first pressure-regulating member comprises a vacuum pump for actively causing air to flow from said chamber. In one embodiment, the first pressure-regulating member further

comprises an opening and/or one or more valves. The vacuum pump may be coupled to the chamber via the opening and/or one or more valves. Advantageously, valves may facilitate the flow of air/gas in a single direction.

5 In various embodiments, the second pressure-regulating member comprises a ventilator for passively allowing air to flow into said chamber. In one embodiment, the ventilator comprises a vent. In other embodiments, the second pressure-regulating member comprises a pump for increasing the pressure within the chamber, for example, by applying positive pressure and
10 actively pumping air into said chamber. The pump may be coupled to chamber via the vent, an opening and/or one or more valves. In one embodiment, the first pressure-regulating member further comprises a valve.

 In some embodiments, the one or more pressure-regulating members
15 are coupled to the same pump that is capable of applying both positive pressure and negative pressure e.g. by alternating application of positive and negative pressures optionally with the aid of valves. It will be appreciated that other configurations of the one or more pressure-regulating members may be adopted for the purposes of applying the pressure cycles to the chamber.

20

 In some embodiments, the system further comprises one or more sensors for sensing the pressure within the chamber.

 In various embodiments, a pumping and venting process in the system
25 is automated to switch between low pressure and atmospheric/high pressure multiple times to defoam a foam-containing liquid. Accordingly, in various embodiments, the system further comprises a controller for implementing a plurality of pressure cycles within the chamber through the operation of the one or more pressure-regulating members, wherein each pressure cycle
30 comprises a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first pressure for reducing the number of bubbles in the foam.

In various embodiments, the chamber comprises a mixing chamber. In some embodiments, the chamber is not a mixing chamber. In various embodiments, the chamber is a substantially air tight chamber when the first
5 pressure is applied to the chamber, for e.g. through the operation of a first pressure-regulating member. For example, when the first pressure is applied to the chamber or when the first pressure-regulating member is in operation, no air is allowed to passively enter or exit the chamber. In various
10 embodiments, the air tight chamber meets the industry standards for leakage at a given pressure (positive or negative).

In various embodiments, the radiation source that is arranged to irradiate the foam is external to chamber. Advantageously, in embodiments where the radiation source is external to the chamber, any heating effect on the foam or any
15 potential contamination of foam by the radiation source is minimised. Further, the radiation source is not subjected to the pressure changes within the chamber and therefore the life of the radiation source can be prolonged. Furthermore, when the radiation source is external to the chamber, a wider field of vision/radiation may be achieved due to an increased distance between the radiation source and
20 the foam, thereby allowing a larger proportion of the foam to be irradiated. In other embodiments, the radiation source is internal to the chamber.

In various embodiments, the chamber comprises at least a portion that allows radiation energy to be transmitted from the radiation source to the
25 foam. In various embodiments, the portion that allows radiation energy to be transmitted from the radiation source to the foam is a substantially transparent portion. The transparent portion may be made of a substantially transparent polymer, glass, polymethyl pentene (TPX), polytetrafluoroethylene (PTFE), black acrylic, polycarbonate plexiglass and
30 the like. For example, the portion allows about 50% or more, about 60% or more, about 70% or more, about 80% or more, about 90% or more or about 95% or more of the radiation energy from the radiation source to be

transmitted to the foam. In some embodiments, where the radiation comprises infra-red radiation/illumination, the portion allows about 50% or more, about 60% or more, about 70% or more, about 80% or more, about 90% or more or about 95% or more of the incident infra-red light normal
5 to a surface of the portion to be transmitted to the foam. In some embodiments, the radiation source is arranged such that about 50% or more, about 60% or more, about 70% or more, about 80% or more, about 90% or more or about 95% or more radiation energy is transmitted to the foam. In some embodiments, where the radiation source comprises infra-red radiation,
10 the radiation source is arranged such that the angle of incidence of the infra-red light on a surface of the portion or on a surface plane of the foam-containing liquid is substantially perpendicular.

In various embodiments, the system further comprises a thermometer
15 arranged to monitor a temperature of the foam-containing liquid or a temperature within the chamber.

In various embodiments, the system further comprises a spray for spraying water over the foam to cool down the foam. This may also help to
20 reduce the foam level. Other appropriate means to cool the foam may also be used.

In various embodiments, the system further comprises a plurality of fins disposed within said chamber. Advantageously, the fins can increase the
25 surface area of foam exposed to low pressure and increase bubble size.

In various embodiments, the system further comprises a drainage system or outlet to drain liquid from the foam-containing liquid.

30 In various embodiments, there is provided a reactor system comprising: a chamber for containing a foam-containing liquid; one or more pressure-regulating members in fluid communication with said chamber, the one or more

pressure-regulating members adapted to introduce a first pressure within said chamber for enlarging the size of the bubbles in the foam and a second pressure within said chamber that is higher than the first pressure for reducing the number of bubbles in the foam; and a radiation source arranged to irradiate the foam
5 contained within the chamber to destabilize said foam.

It will be appreciated that, generally, the higher the viscosity of a foam-containing liquid/foam, the harder it is to defoam the liquid. In various embodiments, in order to maximize the defoaming efficiency, a larger number
10 of alternating pressure cycles and/or a higher intensity radiation (e.g. a higher optical intensity of infra-red radiation) may be employed.

Different approaches may also be used at various stages of the defoaming process to increase the overall defoaming efficiency, depending
15 on the level of the foam. For instance, at an initial stage/phase of a defoaming process, when the foam amount/level is high, a combination of low pressure e.g. 0.5 atm and radiation may be used. When the foam height is sufficiently reduced, e.g. from 100% to 20% of the original foam height, or when the volume of space above the foam is increased, alternating pressure may be
20 introduced to remove the remaining foam. In various embodiments therefore, there is provided a method of reducing foam from a foam-containing liquid, the method comprising: subjecting foam to low pressure and radiation until the foam amount is reduced by at least about 20%, about 30%, about 40%, about 50%, about 60%, about 70% or about 80%; and subjecting the
25 remaining foam to a plurality of pressure cycles/ an alternating pressure cycle and/or radiation until the foam is substantially removed. In various embodiments, there is provided a method of reducing foam from a foam-containing liquid, the method comprising: subjecting foam to low pressure and radiation until the volume of space external to the foam to the volume of the
30 foam in the total volume is increased to at least about 0.5, at least about 1, at least about 2, at least about 3, at least about 4 or at least about 5; and subjecting the remaining foam to a plurality of pressure cycles/ an alternating

pressure cycle and/or radiation until the foam is substantially removed. It will be appreciated that, at an initial stage/phase of a defoaming process, the foam level is high and there is not much room available for foam expansion in the chamber containing the foam. Hence, the application of alternating pressure
5 may not be efficient at this stage. As the defoaming process progresses, the foam amount is reduced and more space/room becomes available for foam/bubbles expansion. Hence, the application of alternating pressure becomes more efficient at this stage. Further, in various embodiments, radiation is synchronized to the low pressure cycles. Advantageously, this
10 minimises any heating effect caused by optical irradiation which may lead to the undesirable crystallization of sugars in the foam which hinders further defoaming. Advantageously, embodiments of the method that utilises different approaches at different phases/stages of the defoaming process maximize the defoaming efficiency while minimizing the amount of
15 power/energy consumed.

For large area defoaming, a larger number of radiation source may be employed. For example, multiple infra-red lamps may be shone at various spots on a foam surface to increase the defoaming efficiency. The area of
20 irradiation also depends on the distance of foam-to-lamp and also size of the lamp. To increase the area of irradiation therefore, the distance of foam-to-lamp may be increased and larger lamps may be used. Rotating foam with a rotating shaft (e.g. mixer) can produce uniform irradiation.

25 BRIEF DESCRIPTION OF FIGURES

FIG. 1 is a schematic diagram of a method of reducing foam from a foam-containing liquid in an example embodiment.

30 FIG. 2 illustrates a defoaming mechanism/process when foam is being subjected to a pressure cycle in an example embodiment.

FIG. 3 is an example of a mucilage mixture being defoamed in accordance with an example embodiment disclosed herein.

FIG. 4 is a graph showing the higher rate of defoaming achieved by a method in accordance with an example embodiment as compared to defoaming by natural deaeration.

FIG. 5 is a graph showing the effect of a chamber size on the defoaming rate of an example embodiment of the method disclosed herein.

FIG. 6 is a graph comparing the defoaming efficiency of 4 different defoaming methods in accordance with various embodiments disclosed herein.

FIG. 7 depicts the mucilage mixture being defoamed by the alternating pressure and optical method described in FIG. 6.

FIG. 8 is a schematic diagram of system setup for reducing foam from a foam-containing liquid in accordance with an example embodiment disclosed herein.

FIG. 9 depicts a system setup comprising a radiation source for reducing foam from a foam-containing liquid in accordance with an example embodiment disclosed herein.

FIG. 10A and FIG. 10B are examples of systems for reducing foam that incorporate modifications to existing reactors in accordance with example embodiments disclosed herein.

FIG. 11 shows a system in the form a modified reactor comprising a chamber for defoaming coupled to a mixing chamber in accordance with an example embodiment disclosed herein.

FIG. 12 is an example of a system for reducing foam that incorporate modifications including the addition of a radiation source to an existing reactor in accordance with an example embodiment disclosed herein.

5

DETAILED DESCRIPTION OF FIGURES

Example embodiments of the disclosure will be better understood and readily apparent to one of ordinary skill in the art from the following discussions and if applicable, in conjunction with the figures. It should be appreciated that other modifications related to structural, electrical and optical changes may be made without deviating from the scope of the invention. Example embodiments are not necessarily mutually exclusive as some may be combined with one or more embodiments to form new example embodiments.

15

FIG. 1 is a schematic diagram of a method 100 of reducing foam from a foam-containing liquid in an example embodiment. At step 102, foam is subjected to a plurality of pressure cycles, wherein each pressure cycle comprises a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first pressure for reducing the number of bubbles in the foam. At step 104, radiation is applied to the foam to destabilize the foam. Steps 102 and 104 may be performed simultaneously or separately i.e. step 102 followed by step 104, or step 104 followed by step 102. The method 100 may be carried out under constant total volume.

25

FIG. 2 illustrates a defoaming mechanism/process 200 when foam is being subjected to a pressure cycle (e.g. a pressure cycle similar to the pressure cycle described in step 102 of FIG. 1) in an example embodiment. As shown in the figure, at stage 202, the initial level of the foam in a chamber is at level L_1 at atmospheric pressure or about 1 atm. At stage 204, when the pressure within the chamber is reduced to about 0.5 atm, for example, by vacuum pumping, the pressure difference between the internal and external

30

environment of the bubble (attributed by the reduction in pressure outside the foam) causes the bubble size of the foam to increase. This leads to an increase in the foam volume. As the bubble size continues to increase with the reduction in the pressure external to the bubble, the bigger bubbles near the surface S of the chamber start to burst due to their thinner films. The gaseous contents of the burst bubbles then escape to the region of low pressure within the chamber to be sucked out, for example, by the vacuum pump. At this stage, the pressure within the chamber may be kept constant at 0.5 atm for a period of time until there is substantially no further enlargement of the bubbles in the foam before compression is initiated. At stage 206, when the pressure within the chamber is increased or returned to atmospheric pressure, for example, by venting, the force that accompanies the rise in pressure external to the bubbles causes the bigger bubbles near the surface S to burst while other bubbles reduce in size. During this compression process, the bubbles close to the side walls of the chamber also experience shearing force, causing them to burst. Thus, when the pressure within the chamber is returned to atmospheric pressure at stage 208, the foam level is reduced to level L_2 from the initial level L_1 . The pressure may be kept constant for a period of time at stage 208 until there is substantially no further reduction in the number of bubbles in the foam before a second decompression is initiated (i.e. before stage 204 is repeated) to further reduce the foam amount. In the defoaming mechanism/process 200, stages 204, 206 and 208 together form one pressure/pump-vent cycle. The pressure/pump-vent cycle may be repeated one or more times. With each pressure/pump-vent cycle, the foam volume decreases while the liquid level (and overall bubble size) increases until the foam is substantially removed. When the foam level is reduced to less than 20% of its original height, alternating high and low pressure becomes more effective in removing the foam due to the larger volume above the foam that is available for expansion of the bubbles.

To further increase the defoaming efficiency, radiation may be applied to the foam at any of the stages 202, 204, 206 and 208. In one example,

radiation is applied during the low pressure cycle (e.g. stage 204). During the low pressure cycle, the pressure in the chamber is reduced to allow the bubbles expand to their maximum allowable level and radiation in the form of infra-red irradiation is used at this time to further heat the bubbles to aid bursting (heat can assist in the further expansion of bubbles). After that, the pressure within the chamber can be further reduced to increase the bubble size again. In the example, infra-red irradiation is terminated upon transition to a high pressure cycle (e.g. stage 208). During the high pressure cycle, the bubble sizes are much smaller and hence, infra-red irradiation may not be as effective in bursting the bubbles.

FIG. 3 is an example of a mucilage mixture being defoamed in accordance with an example embodiment disclosed herein. Mucilage is a mixture of starch/gum powder and acidic solution, and is used as a base ingredient for many soft drink beverages. It is highly viscous (viscosity $\approx$ 12 cP, or 12 times higher than water), gluey and starchy in nature. In this example, with reference to FIG. 3A, acidic/mixing solution 302 and starch/gum powder 304 were mixed in an air-tight chamber 306, in the form of a dessicator, to form a mucilage mixture 308. As shown in FIG. 3A and FIG. 3B (which shows a full view of the mucilage mixture 308), immediately after mixing, a large amount of foam was created over the surface of the mucilage mixture 308, with the foam height reaching to about 8.5 cm and the liquid height measuring about 3.0 cm in a 6" beaker (2 litres capacity). The mixture 308 was subjected to repeated pressure/pump-vent cycles, and the amount of foam was observed to decrease with each cycle. As shown in FIG. 3C to FIG. 3H, there was a clear and visible reduction in the foam amount/volume from cycle 61 to cycle 66. After 66 cycles, the mucilage mixture 308 was observed to be completely defoamed, with the foam height dropping to about 0 cm from the initial about 8.5 cm, and the liquid level rising to about 6.85 cm from the initial about 3.0 cm. The final defoamed mixture is depicted in FIG. 3I.

FIG. 4 is a graph showing the higher rate of defoaming achieved by a method (e.g. a method similar to method 100 described in FIG. 1) in accordance with an example embodiment disclosed herein as compared to defoaming by natural deaeration. The lines in the graph are used to guide the eye. As can be seen from the graph, when a mucilage mixture was left to defoam naturally in air, the foam level came down very slowly (the foam height at each time point is represented by square data points). Even after 8 hours, the mixture was still not completely defoamed, and 6% of the foam (measured by the foam height remaining in a 6" beaker (2L capacity) used to hold the mixture) still remained. In contrast, when a mucilage mixture was subjected to pulsed/alternating pressure/pump-vent cycle in accordance with an example embodiment disclosed herein, a dramatic improvement in the defoaming rate was observed. Using this method, it took only about 155 minutes for the foam height to be reduced to 6% of its original height. This represents a more than 3 times improvement in the defoaming rate as compared to defoaming by natural deaeration. Furthermore, complete defoaming was observed after about 3.3 hours or about 198 minutes. Without being bound by theory, it is believed that the larger bubble size attributed by decompression, combined with the introduction of subsequent positive pressure and shearing force cause the bubbles to burst at a much faster rate and consequently the foam amount reduces at a much faster rate, as compared to defoaming by natural deaeration.

The effects of applying vacuum only (without alternating the gas pressure) was also investigated. To this end, a mucilage mixture was left to defoam at a constant low pressure of 0.5 atm without alternating the gas pressure. As compared to defoaming by natural deaeration at atmospheric pressure, the vacuum only method/technique showed a slight improvement in the defoaming rate of about 1.4 times (compare with the 3 times improvement showed by the alternating pressure method in accordance with an example embodiment disclosed herein). Thus, this shows that the combination of a pressure-gradient and shearing force in embodiments of the

method created an additional force that increased defoaming efficiency. As compared to a vacuum only method/technique therefore, embodiments of the method lead to faster/more efficient defoaming. Further, since a vacuum only method/technique relies heavily on bubble expansion (to the point for bursting) for defoaming, the efficiency of the method is limited by a greater extent on the size of the chamber i.e. a bigger chamber is required for more efficient defoaming.

FIG. 5 is a graph showing the effect of a chamber size on the defoaming rate of an example embodiment of the method disclosed herein. In this example, two identical mucilage mixtures were defoamed separately in a 3" beaker of 2L capacity (data points represented by triangles) and in a 6" beaker of 2L capacity (data points represented by circles) by subjecting the mixtures to pulsed/alternating pressure/pump-vent cycles. In the control sample (data points represented by squares), a mucilage mixture was left to deaerate naturally at atmospheric pressure in a 6" beaker of 2L capacity. As can be seen from the graph, the rate of defoaming was slower in the 3" beaker as compared to the 6" beaker. Without being bound by theory, it is believed that as there is a bigger volume in 6" beaker available for expansion of bubbles to a larger size, this leads to a faster rate of defoaming.

In embodiments of the method, alternating pressure can be combined with infra-red radiation of the foam to achieve higher defoaming efficiency. FIG. 6 is a graph comparing the defoaming efficiency of 4 different defoaming methods: (1) the natural run method (data points represented by squares) wherein natural defoaming was carried out at atmospheric pressure without infra-red radiation; (2) the alternating pressure only method (data points represented by circles) wherein defoaming was carried out under alternating high and low pressure without infra-red radiation of foam. (3) the optical only method (data points represented by upright triangles) wherein defoaming was carried out under infra-red radiation at atmospheric pressure; and (4) the alternating pressure and optical method (data points represented by inverted

triangles) wherein defoaming was carried out under a combination of alternating pressure and infra-red radiation of foam. In this example, a combination of low pressure (at 0.5 atm) and infra-red radiation of foam was used until the foam height was reduced to 20% of its original height. Then, alternating pressure was applied to remove the last 20% of the foam height.

As shown by the graph, complete defoaming by natural deaeration (method 1) in a 6" beaker of 2L capacity took about 9 hours. Using the alternating pressure method (method 2), the defoaming efficiency was increased and the foam was dissipated in about 200 minutes. While optical defoaming (method 3) can be used on its own, in this example, it was not able to achieve complete defoaming. This may be because the efficiency of this method decreases with foam height. In this example, the optical method (method 3) took about 110 minutes to reduce the foam level to about 13% of its original height. A significant improvement in defoaming efficiency was observed when optical defoaming was combined with alternating pressure (method 4). Complete defoaming was achieved in only about 80 minutes. This is about 6-7 times faster than defoaming by natural deaeration (method 1). This method (method 4) is also faster than using alternating pressure on its own (method 2) or optical radiation on its own (method 3). In method 4, a combination of low pressure and optical radiation was used in an initial phase to achieve higher defoaming efficiency. When the foam level was sufficiently reduced, alternating pressure was introduced to complete the defoaming process. Table 1 below summarizes the features of each of the optics only method, the alternating pressure only method and the combined optics and alternating pressure method.

Table 1

Performance	Optics	Alternating pressure	Optics and alternating pressure
Defoaming time	Can achieve fast defoaming till 20% of foam height and is ineffective after that when increase in bubble diameter <critical diameter for destabilization of bubble.	Complete defoaming in 200min.	Complete defoaming in 80 min.
Cons	Heating of foam, temperature can go up to 65 °C on foam. This causes crystallization of the sugars in the foam.	Larger tank size may be needed.	Only slight heating of foam up to 40 °C, with negligible change in temp. of liquid.
Defoaming area	Limited to size of lamp	Whole tank	Whole tank
Ease of implementation in reactor tank	Easy	Easy	Easy

FIG. 7 depicts the mucilage mixture being defoamed by the alternating pressure and optical method (method 4) described in FIG. 6. As shown, there was a visible reduction in the amount of foam from the 30-minute timepoint to the 80-minute timepoint. Due to the high efficiency of this combined method, complete defoaming can be achieved in a shorter amount of time and hence, any by-effect heating of the foam by infra-red radiation is minimised.

FIG. 8 is a schematic diagram of system setup 800 for reducing foam from a foam-containing liquid 802 in accordance with an example embodiment disclosed herein. In the example embodiment, the system setup 800 comprises a chamber 804, in the form of an air-tight acrylic desiccator comprising a beaker e.g. a 6" beaker, for containing a foam-containing liquid 802. The system setup 800 further comprises a first pressure-regulating member 806, in the form of a vacuum pump, in fluid communication with the chamber 804. In the example embodiment, the vacuum pump actively causes air to flow from or out of the chamber 804. The first pressure-regulating member 806 is adapted to introduce a first pressure, e.g. a pressure lower than atmospheric pressure, within chamber 804 for enlarging the size of the bubbles of the foam. The system setup 800 further comprises a second pressure-regulating member 808, in the form of a vent/ventilator, in fluid communication with the chamber 804. In the example embodiment, the

vent/ventilator passively allows air to flow into the chamber 804. This results in an energy-efficient system. The second pressure-regulating member 808 is adapted to introduce a second pressure within chamber 804 that is higher than the first pressure for reducing the number of bubbles of the foam. The system setup 800 may further comprise a vacuum/pressure gauge 810 for measuring the pressure in the chamber 804. In the example embodiment, the system setup 800 is programmed/automated to alternate between pumping and venting, with each pump-vent cycle lasting 3 minutes. The system setup 800 is further configured to reduce the pressure or maintain the pressure at a target pressure of 0.5 atm in chamber 804 during the pumping process and increase the pressure to or maintain the pressure at a target pressure of 1 atm in chamber 804 during the venting process. Although the target pressures of 0.5 atm and 1 atm are used in this example embodiment, it should be understood that other target pressures may also be used in the alternating pressure cycle to achieve a defoaming effect. In various embodiments, the chamber is a substantially air tight chamber when the first pressure-regulating member (e.g. a pump) is in operation.

In various embodiments, the system may further comprise a controller for implementing a plurality of pressure cycles within the chamber through the operation of the first pressure-regulating member and the second pressure-regulating member, wherein each pressure cycle comprises a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first pressure for reducing the number of bubbles in the foam.

FIG. 9 depicts a system setup 900 comprising a radiation source 910, such as an infra-red radiation source, for reducing foam from a foam-containing liquid in accordance with an example embodiment disclosed herein. FIG. 9A is a schematic diagram of the system setup 900 and FIG. 9B is a picture of the system setup 900. With reference to FIG. 9A, the system setup 900 comprises a chamber 904 for containing a foam-containing liquid 902. The chamber 904 comprises at least a portion 912 e.g. a substantially

transparent portion that allows radiation energy to be transmitted from the radiation source 910 to the foam. In the example embodiment, the chamber 904 is in the form of a glass desiccator which allows infra-red wavelengths to be transmitted so that the foam is able to absorb a large portion of the energy.

5 In the example embodiment, the radiation source 910 in the form of an infra-red lamp is arranged to irradiate the foam contained within the chamber 904 to destabilize the foam. In the example embodiment, the radiation source 910 is disposed external to the chamber 904. It will be appreciated that the radiation source 910 may also be disposed within the chamber 904 to
10 irradiate the foam. The system setup 900 may further comprise a first pressure-regulating member 906 (similar to the first pressure-regulating member 806 in FIG. 8) and a second pressure-regulating member 908 (similar to the second pressure-regulating member 908 in FIG. 8) both in fluid communication with the chamber 904. In the example embodiment, the
15 system system 900 is configured to to irradiate the foam during a decompression/pumping process e.g. when the pressure within the chamber 904 is reduced to or at 0.5 atm. During a decompression/pumping process, the pressure inside the chamber 904 is reduced and this causes the bubbles of the foam to expand. When infra-red light/radiation is shone on/applied to
20 the foam at this stage, further expansion of the bubbles occurs and when the bubbles are large enough, they start to burst. A defoaming effect is thus achieved.

FIG. 10A and FIG. 10B are examples of systems for reducing foam that
25 incorporate modifications to existing reactors in accordance with example embodiments disclosed herein. As shown by the figure, a cover/lid comprising one or more pressure regulating members can be disposed over a chamber e.g. a mixing chamber of an available reactor to produce a system that is capable reducing foam. FIG. 10A shows an air-tight cover/lid 1002 comprising
30 pressure regulating members 1004 and 1006 in the form of an inlet for pump and an inlet for vent respectively being disposed over a chamber of a Silverson ultramixer 1008 for mixing mucilage to form a system 1000 for

reducing foam. The air-tight cover/lid 1002 seals the chamber and the pressure regulating members 1004 and 1006 in the form of an inlet for pump and an inlet for vent establish fluid communication with the chamber. FIG. 10B shows an example of a Silverson inline Flashmix 2008 for mixing mucilage that is fitted with a similar air-tight cover/lid 2002 over its chamber to form a system 2000 that is capable of defoaming. The cover/lid 2002 also comprises pressure regulating members 2004 and 2006 in the form of an inlet for pump and an inlet for vent respectively. Embodiments of the systems minimize aeration and therefore foaming in a mixing chamber, and also additionally allows for defoaming of any foam produced to be carried out directly in a mixing chamber, simultaneously with or subsequent to mixing. To increase/optimize the defoaming efficiency, a bigger chamber may be used. A bigger chamber provides more space for bubbles of the foam to expand so that bursting can occur at a faster rate. If the chamber/container size is fixed, mucilage or any other liquid product may be made in smaller batches at a time to increase/optimize the defoaming efficiency.

FIG. 11 shows a system 1100 in the form a modified reactor comprising a chamber 1102 for defoaming coupled to a mixing chamber 1104 in accordance with an example embodiment disclosed herein. In the example embodiment, the chamber 1102 is a designated chamber for defoaming (contrast with system 1000 of FIG. 10 wherein defoaming and mixing may be carried out in the same chamber). The chamber 1102 comprises a pump 1106 that is in fluid communication with the mixing chamber 1104 for sucking any foam into the chamber 1102 for defoaming. The chamber 1102 may further comprise a cover/lid 1108 e.g. an air-tight lid comprising pressure regulating members 1110 and 1112 in the form of an inlet for pump and an inlet for vent respectively for pumping to reduce a pressure and venting to increase a pressure within the chamber 1102. In the example embodiment, the chamber 1102 further comprises a plurality/number of fins 1114 disposed therein. The fins increase the surface area that the foam is exposed to and also increase a bubble size of the foam when reduction of pressure/decompression takes

place within the chamber 1102. A gas pressure may be subsequently introduced to further burst the bubbles. Any excess liquid 1116 that is produced from defoaming can be drained into a pipeline which joins a main reactor (not shown in the figure). In this way, the defoaming efficiency can be increased.

FIG. 12 is an example of a system 1200 for reducing foam that incorporate modifications including the addition of a radiation source to an existing reactor in accordance with an example embodiment disclosed herein.

In the system 1200, a radiation source 1202 in the form of an infra-red lamp is disposed external to a tank/chamber 1204 of an existing reactor and arranged to irradiate any foam contained within the tank/chamber 1204 to destabilize the foam. The positioning of the infra-red lamp is such that the angle of radiation is substantially perpendicular to the surface plane of the foam. As the infra-red lamp is disposed external to a tank/chamber 1204, heating of the contents in the chamber 1204 is reduced and chances of any potential contamination is also reduced. The system 1200 may further comprise a glass cover/lid/port 1206 fitted to the opening of the chamber 1204 to allow infra-red radiation from the infra-red lamp to pass through to reach the foam contained in the chamber 1204. It will be appreciated that a cover/lid/port of another material that is not glass may also be used if it allows a large fraction of the radiation such as infra-red radiation from the radiation source to pass through. For example, other materials that allow high transmittance in the infra-red range include glass, polymethyl pentene (TPX), polytetrafluoroethylene (PTFE), black acrylic, polycarbonate plexiglass and the like. The cover/lid/port 1206 may further comprise pressure regulating members 1208 and 1210 comprising valves for pumping to reduce a pressure inside the chamber 1204 and venting to increase a pressure inside the chamber 1204. The cover/lid/port 1206 may be further configured to render the chamber 1204 air-tight when fitted to an opening of the chamber 1204. This example shows that slight modifications may be made to an existing

reactor to produce a system 1200 for reducing foam by irradiation, and optionally also by alternating pressure.

APPLICATIONS

5

As compared to existing defoaming methods (e.g. defoaming by mechanical or acoustic disruption), most of which are designed for defoaming over a small/localized area, embodiments of the method and system are advantageously suitable for large area defoaming of
10 bubbles/foam. Further, embodiments of the method and system are also demonstrated to be capable of defoming highly viscous liquid.

Advantageously, in embodiments of the disclosed method, the combination of the step of subjecting foam to a plurality of pressure cycles and
15 the step of applying radiation to said foam has an unexpected synergistic effect in increasing defoaming efficiency. Such synergistic combination results in a defoaming efficiency that is much higher as compared to applying vacuum pressure alone or irradiation alone.

20 In embodiments of the method, an alternating/pulsed pressure of between 1 atm and 0.5 atm is applied to a foam-containing liquid/solution in a sealed chamber. The pressure and shearing force caused by alternating between high and low pressure cause bubbles to burst faster. Embodiments of the method are capable of achieving complete defoaming of a mucilage
25 mixture in about 3 hours and 20 minutes, which is 2-3 times faster than defoaming by natural dearation which take about 9 hours. Further, by combining the application of alternating pressure with irradiation of foam, embodiments of the method can further reduce the defoaming time by about 6-7 times from 9 hours to about 1 hour 20 minutes.

30

In other words, the combination is capable of increasing the defoaming rate by at least twice that of using only alternating pressure. Without being

bound by theory, it is believed that the combination can increase the bubble size of the foam and create an unstable foam which is easier to burst. The combination may also increase the bubble size at a much faster rate to the point of bursting. This combination process also reduces heating of foam as compared to the optical only method. Advantageously, embodiments of the method have high defoaming efficiency and significantly reduce the amount time for defoaming by up to 6-7 times as compared to defoaming by natural deaeration.

Besides having high defoaming efficiency, embodiments of the method are also relatively chemical-free, contact free and have minimal/no wastage.

Embodiments of the method can be operated in a closed system (i.e. a mixing tank) and the liquid or foam stays in the system without the need for contacting other surfaces.

Embodiments of the method can also be easily implemented in existing reactors with only slight modifications to the reactors. For example, glass ports can be fitted on the lid so as to allow infra-red illumination on the foam from an infra-red source located outside the reactor/tank. Although a separate chamber may be used for defoaming, embodiments of the method do not necessarily require a separate chamber and may also be implemented in a mixing chamber of a reactor. Embodiments of the method are thus more flexible and less complex to implement than existing methods that require a separate vacuum chamber for defoaming.

It will be appreciated by a person skilled in the art that other variations and/or modifications may be made to the embodiments disclosed herein without departing from the spirit or scope of the disclosure as broadly described. For example, in the description herein, features of different example embodiments may be mixed, combined, interchanged, incorporated, adopted, modified, included etc. or the like across different example embodiments. The

present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A method of reducing foam from a foam-containing liquid, the method comprising:

5 subjecting foam to a plurality of pressure cycles, each pressure cycle comprising a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first pressure for reducing the number of bubbles in the foam; and
 applying radiation to said foam to destabilize said foam.

10

2. The method according to claim 1, wherein the radiation comprises infra-red radiation.

15

3. The method according to claim 1 or claim 2, wherein the first pressure is from 0.3 atm to 1 atm and the second pressure is from 0.8 atm to 1.2 atm.

20

4. The method according to any one of the preceding claims, wherein the first pressure is kept constant for a period of time until there is substantially no further enlargement of the bubbles in the foam.

25

5. The method according to any one of the preceding claims, wherein the second pressure is kept constant for a period of time until there is substantially no further reduction in the number of bubbles in the foam.

30

6. The method according to any one of the preceding claims, wherein the subjecting step and the applying step are performed simultaneously.
7. The method according to any one of the preceding claims, wherein the first pressure is created by vacuum pumping and the second pressure is created by venting.

8. The method according to any one of the preceding claims, wherein the method is carried out under constant total volume.
9. The method according to claim 8, wherein prior to the subjecting and
5 applying steps, the ratio of the volume of space external to the foam to the volume of the foam in the total volume is at least 1.
10. The method according to any of the preceding claims, wherein the method is substantially devoid of the use of a defoaming agent.
- 10 11. A system for reducing foam from a foam-containing liquid, the system comprising:
a chamber for containing the foam-containing liquid;
one or more pressure-regulating members in fluid
15 communication with said chamber, the one or more pressure-regulating members adapted to introduce a first pressure within said chamber for enlarging the size of the bubbles in the foam and a second pressure within said chamber that is higher than the first pressure for reducing the number of bubbles in the foam; and
20 a radiation source arranged to irradiate the foam contained within the chamber to destabilize said foam.
12. The system of claim 11, wherein the one or more pressure-regulating members comprises a first pressure-regulating member adapted to
25 introduce the first pressure and a second pressure-regulating member adapted to introduce the second pressure.
13. The system according to claim 12, wherein the first pressure-regulating member comprises a vacuum pump for actively causing air to flow from
30 said chamber.

14. The system according to claim 12 or claim 13, wherein the second pressure-regulating member comprises a ventilator for passively allowing air to flow into said chamber.
- 5 15. The system according to any one of claims 11 to 14, wherein the radiation source comprises an infra-red radiation source.
16. The system according any one of claims 11 to 15, wherein the chamber is a substantially air tight chamber when the first pressure is applied to
10 the chamber.
17. The system according any one of claims 11 to 16, wherein the chamber comprises at least a portion that allows radiation energy to be transmitted from the radiation source to the foam, optionally wherein
15 the portion is a substantially transparent portion.
18. The system according any one of claims 11 to 17, further comprising a controller for implementing a plurality of pressure cycles within the chamber through the operation of the one or more pressure-regulating
20 members, wherein each pressure cycle comprises a first pressure for enlarging the size of the bubbles in the foam and a second pressure higher than the first pressure for reducing the number of bubbles in the foam.
- 25 19. The system according any one of claims 11 to 18, wherein the radiation source is disposed external to the chamber.
20. The system according any one of claims 11 to 19, further comprising a plurality of fins disposed within said chamber.

1/11

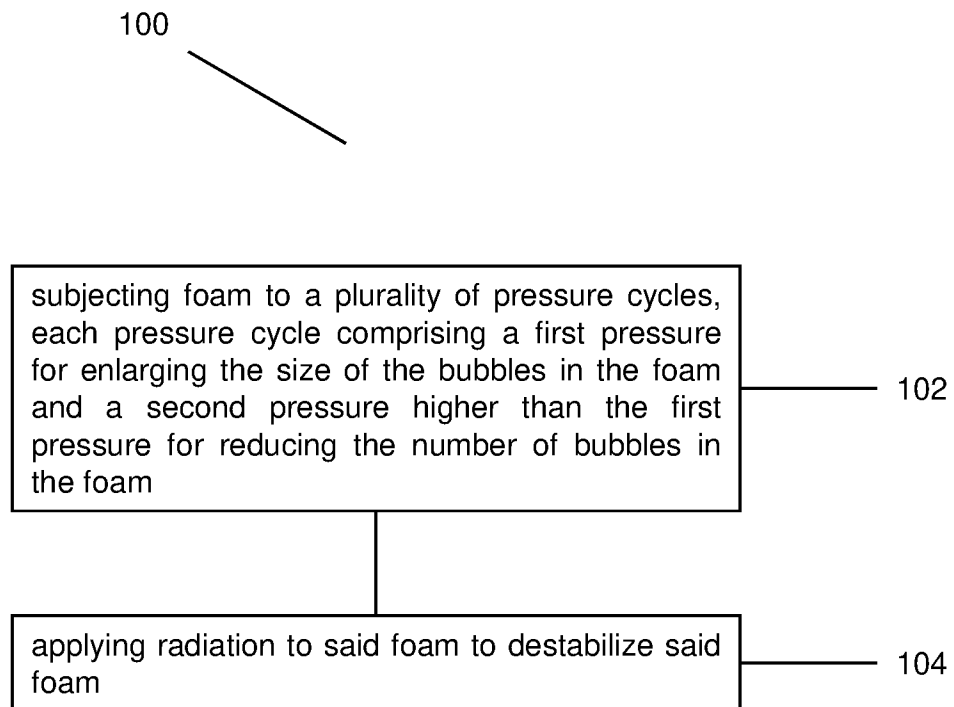


FIG. 1

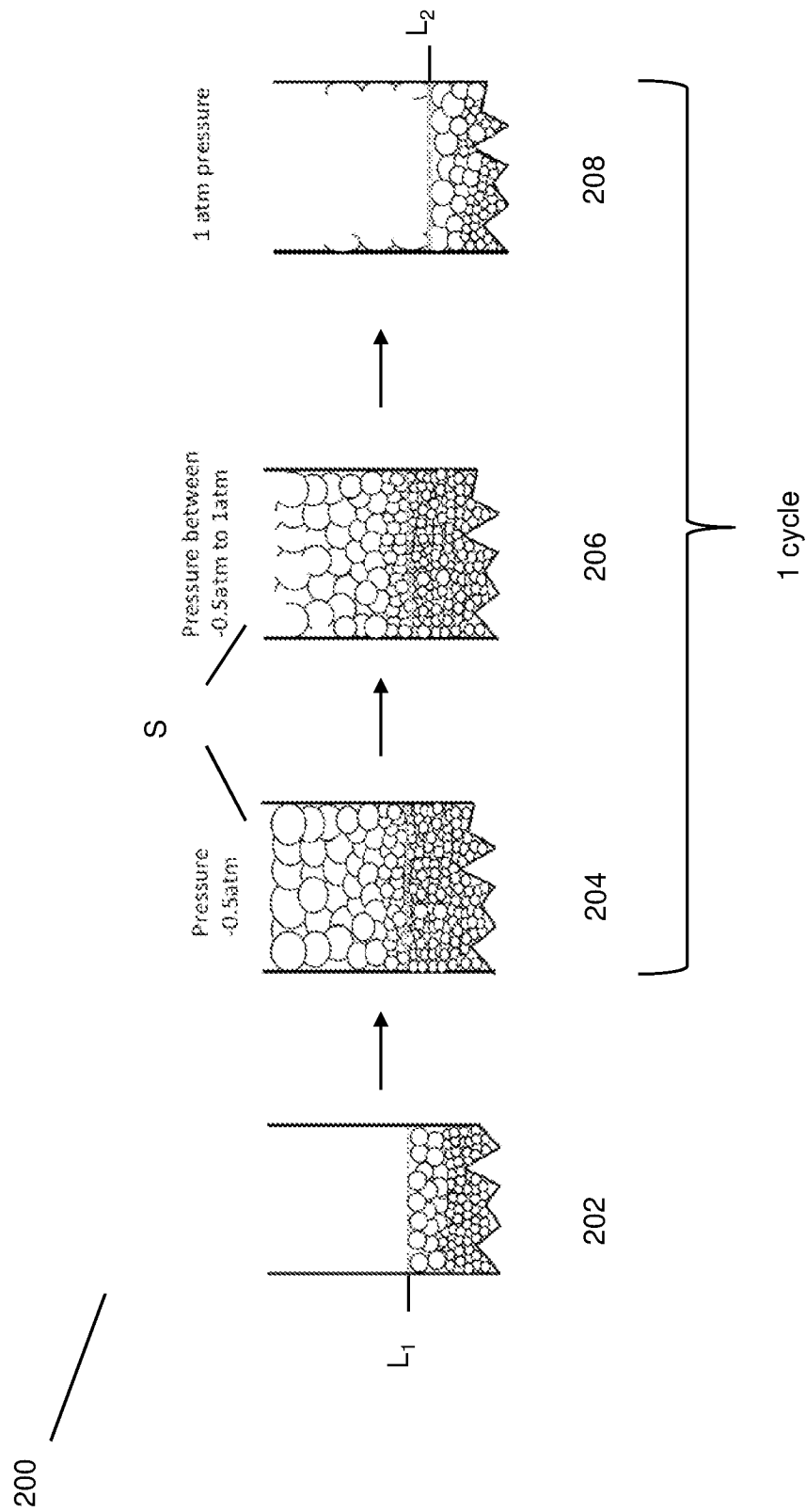


FIG. 2

3/11

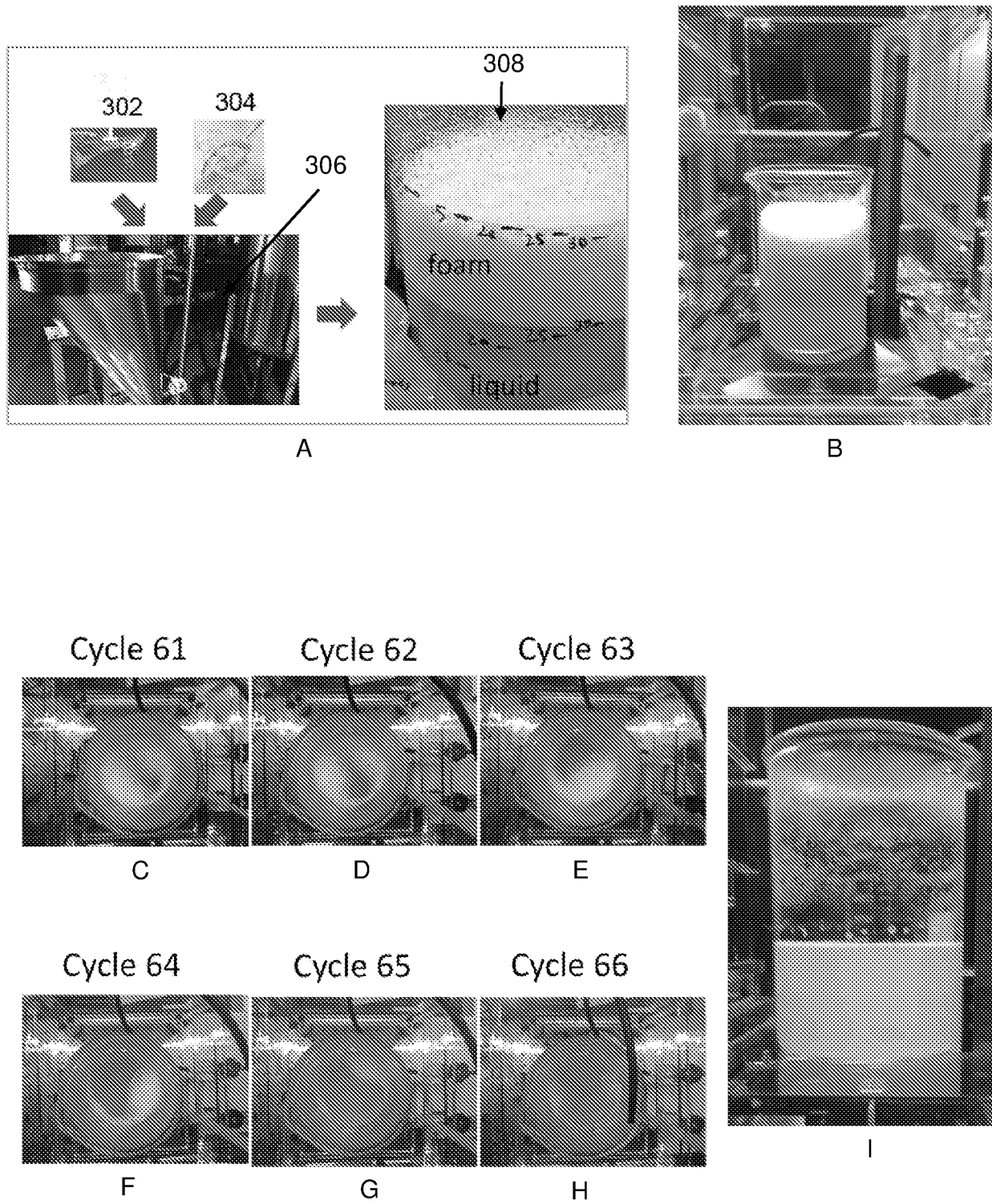


FIG. 3

4/11

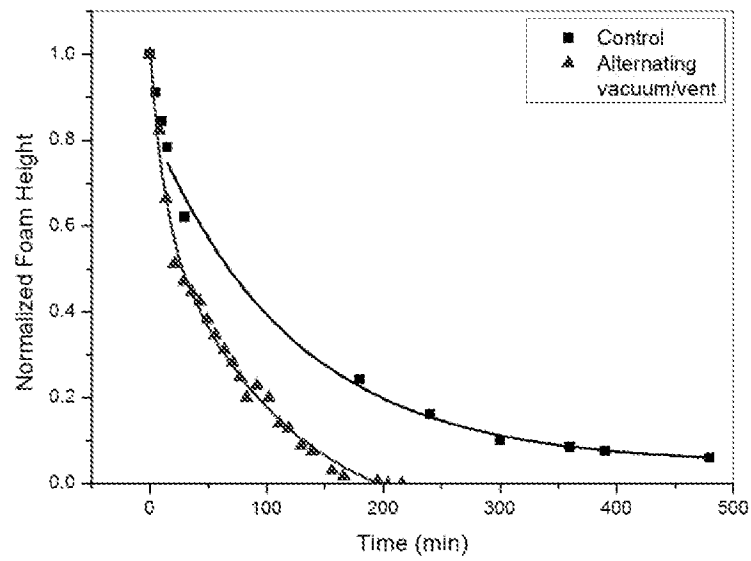


FIG. 4

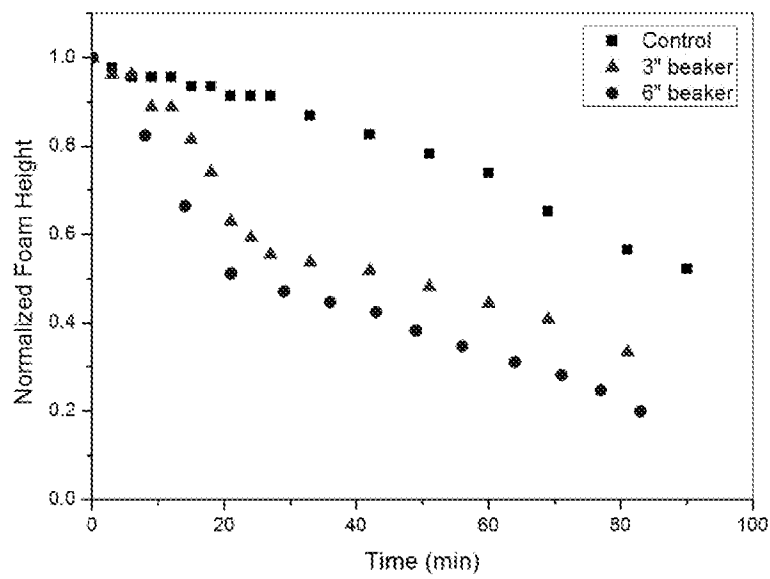


FIG. 5

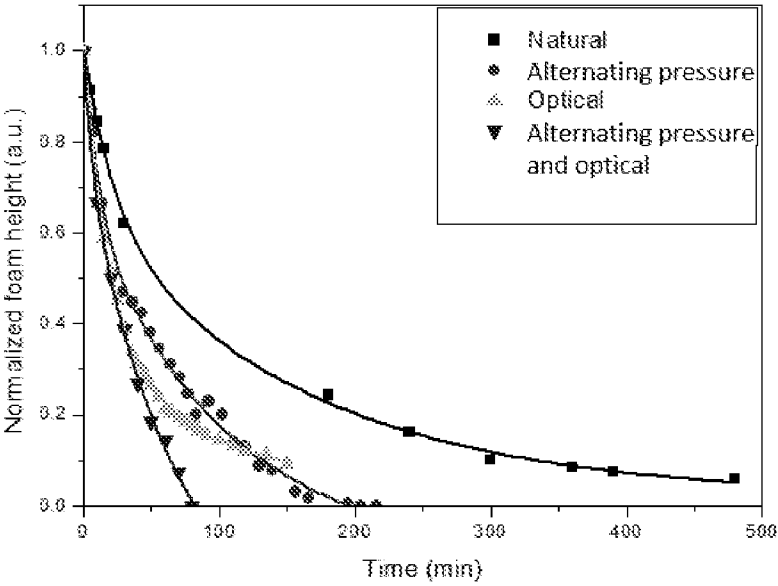


FIG. 6

6/11

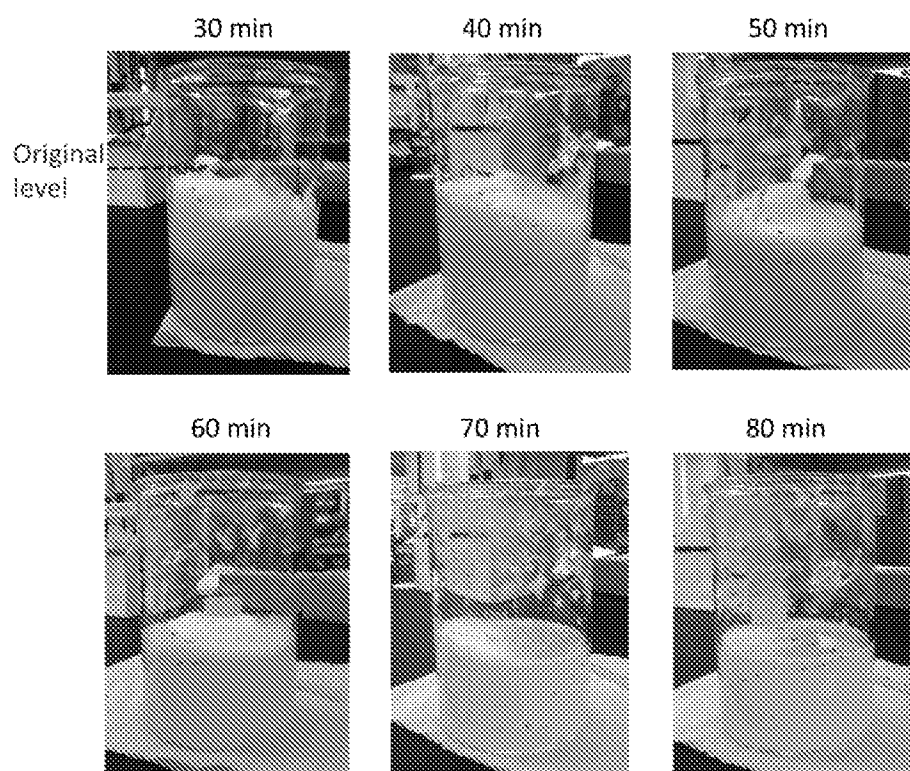


FIG. 7

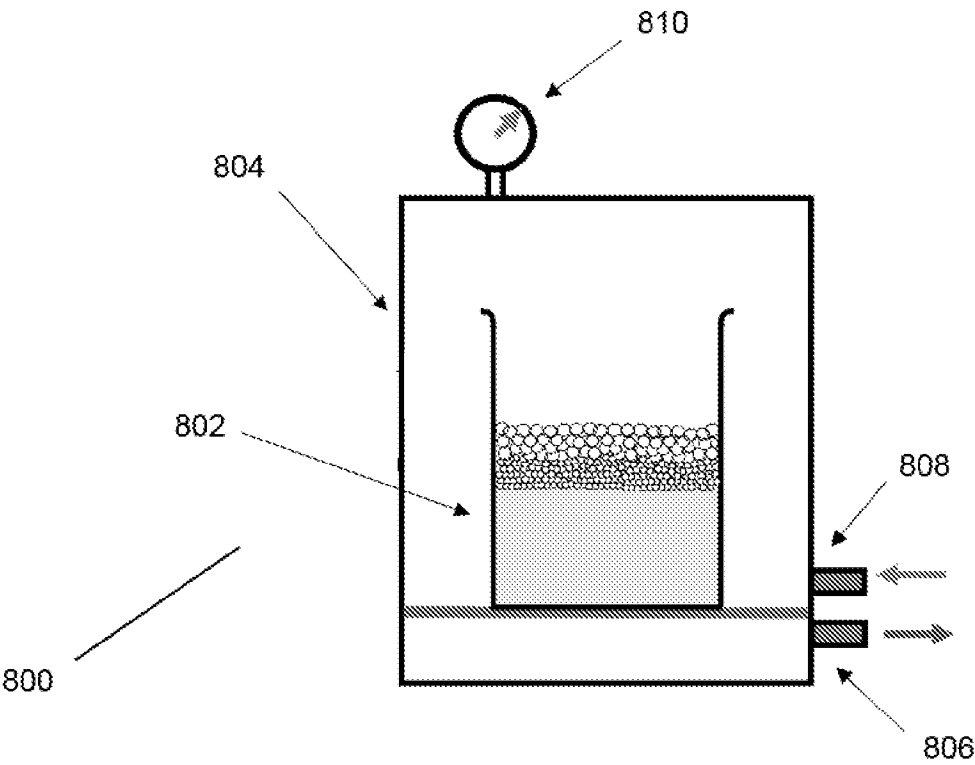


FIG. 8

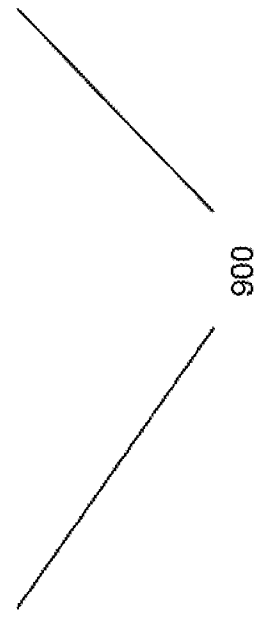
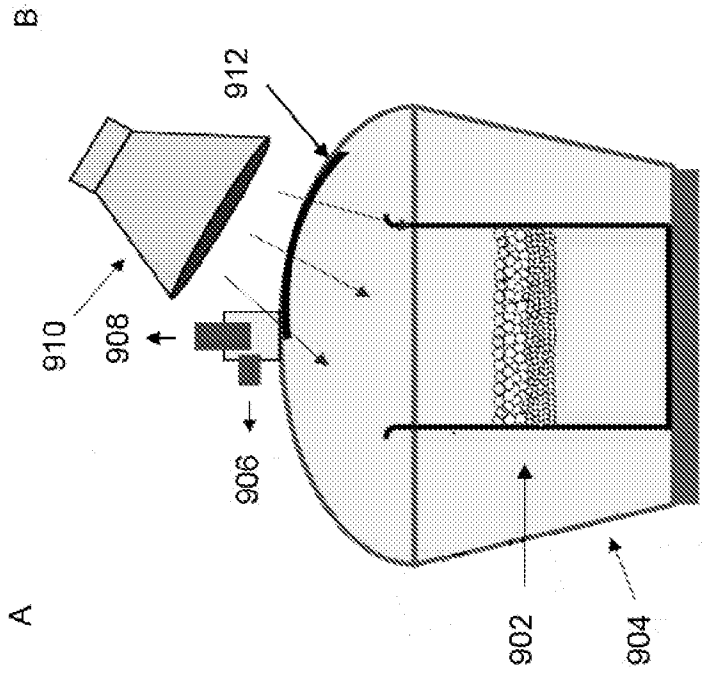
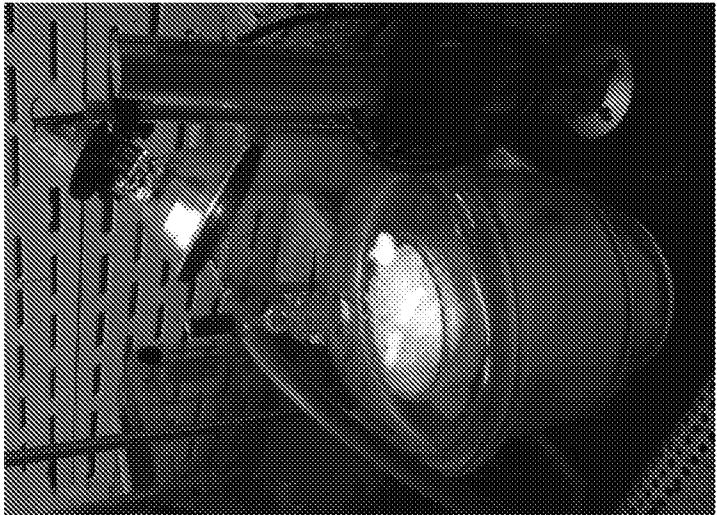


FIG. 9

9/11

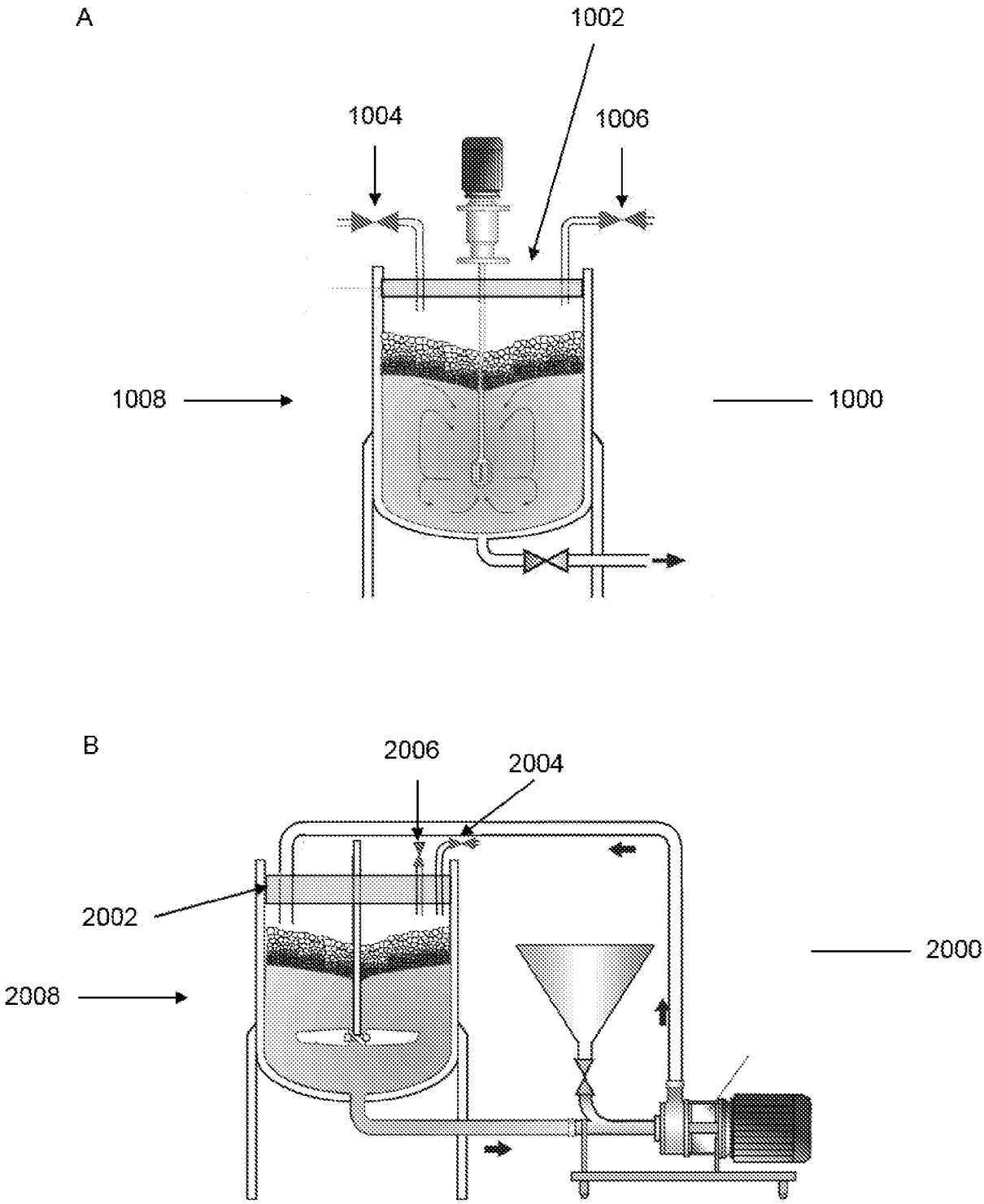


FIG. 10

10/11

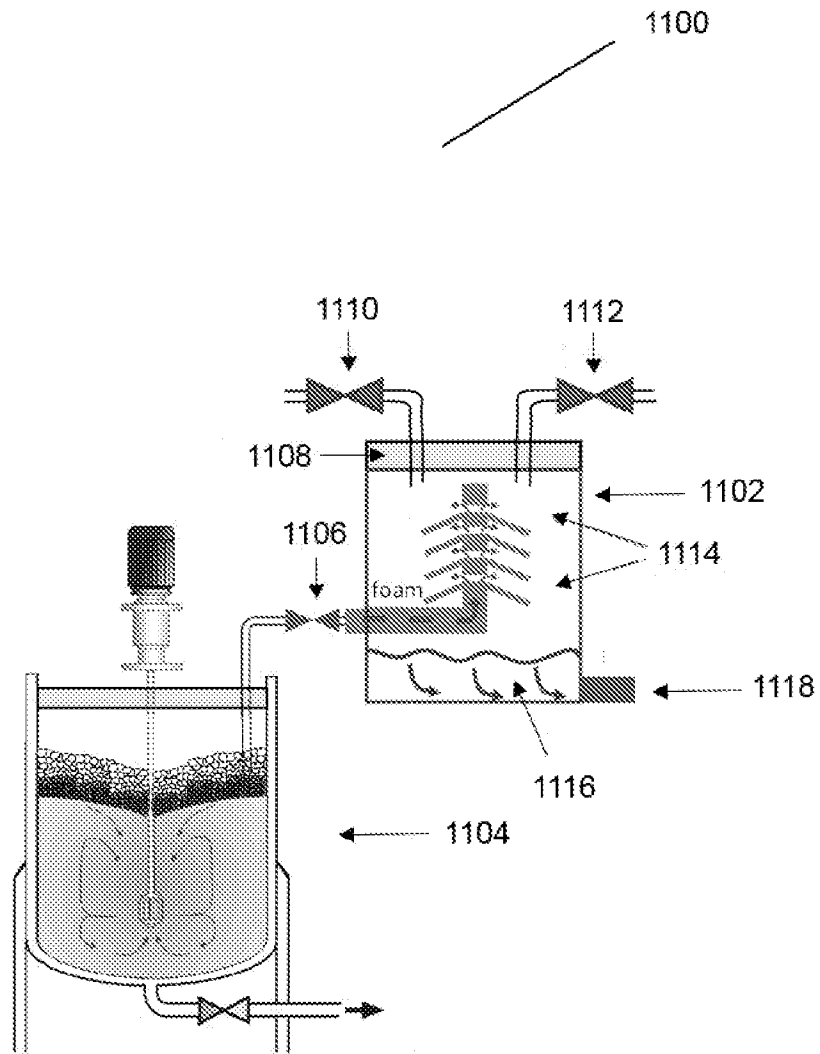


FIG. 11

11/11

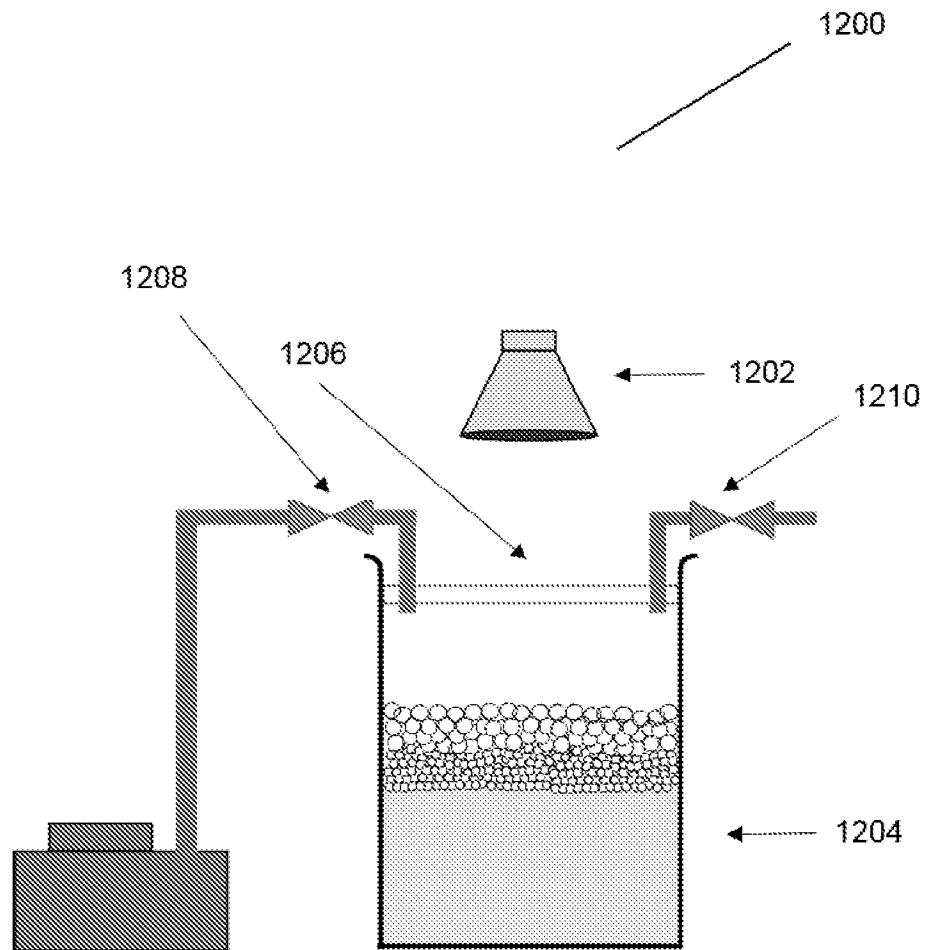


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2019/050391

A. CLASSIFICATION OF SUBJECT MATTER

B01D 19/02 (2006.01) B01J 3/03 (2006.01) A01J 11/02 (2006.01) A23L 3/005 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B01D

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

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

Database: FAMPAT

Keywords: reduce, destory, break, destabilise, foam, bubble, froth, expansion, contraction, pump-vent cycle, pressurise, depressurise, radiation, infra-red, 脱泡, 去泡, 红外线, 减压, 真空 and related terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 105153645 A (CHANGZHOU UNIVERSITY) 16 December 2015 see abstract, pg. 5, para. 6, examples of the machine translation	1-20
X	CN 206381689 U (JIANGXI HAOPU HIGH-TECH COATED FABRIC CO LTD) 8 August 2017 see abstract, pg. 2, pg. 4, Fig. 1 of the machine translation	11-20
A	US 2011/0191965 A1 (BALTSSEN, L. E. T. ET AL.) 11 August 2011 see [0002], [0066]-[0075]	1-20
A	US 4898020 A (VASSILIOU, E.) 6 February 1990 see col. 2 line 7-36, col. 3 line 29 – col. 4 line 65, Fig. 1	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"D" document cited by the applicant in the international application

"E" earlier application or patent but published on or after the international filing date

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

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

30/09/2019

(day/month/year)

Date of mailing of the international search report

04/10/2019

(day/month/year)

Name and mailing address of the ISA/SG



Intellectual Property Office of Singapore

1 Paya Lebar Link, #11-03

PLQ 1, Paya Lebar Quarter

Singapore 408533

Email: pct@ipos.gov.sg

Authorized officer

Zhuo Mingkun (Dr)

IPOS Customer Service Tel. No.: (+65) 6339 8616

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2019/050391

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 105153645 A	16/12/2015	NONE	
CN 206381689 U	08/08/2017	NONE	
US 2011/0191965 A1	11/08/2011	RU 2011124535 A JP 2012508606 A WO 2010/055121 A1 MX 2011005114 A CN 102216509 A AU 2009315653 A1 BR PI0921846 A2 EP 2358936 A1 CA 2739726 A1 AR 074195 A1	27/01/2013 12/04/2012 20/05/2010 16/06/2011 12/10/2011 20/05/2010 12/01/2016 24/08/2011 05/04/2011 29/12/2010
US 4898020 A	06/02/1990	DE 3875932 T2 EP 0321888 A2 JP H02-071141 A	15/04/1993 28/06/1989 09/03/1990