

SUMMARY

[0003] The systems, methods, and devices of the invention each have several aspects, no single one of which is solely responsible for its desirable attributes. Without limiting the scope of this invention as expressed by the claims which follow, some features will now be discussed briefly. After considering this discussion, and particularly after reading the section entitled “Detailed Description,” one will understand how the features of the various embodiments of this invention provide advantages that include improved cleaning and increased throughput.

[0003a] In one aspect, provided herein is a method for enhancing fluid flow, the method comprising: moving biopolymer molecules into contact with at least one fluidic channel in or on a device, whereby clogging occurs in the device due to coiling or aggregation of the biopolymer molecules, or adsorption or tangling of the biopolymer molecules around the channels or any other nano- or micro- features inside the channel or fluidic device; detecting a clogged or reduced flow condition, wherein the detection comprises identifying that a transport of the biopolymer molecules through the device falls below a threshold transport value; directing a light source at a region of the device in which said clogging has occurred in a manner effective to photocleave at least one of the biopolymer molecules that contribute to said clogging, thereby facilitating removal or reduction of said clogging; after directing the light source to the region, applying a motive force to fluid in the region in a manner effective to flush the photocleaved biopolymer molecules creating said clog from the region of the device in which said clogging has occurred; and applying a motive force to flow additional biopolymer molecules through the device for characterization, wherein flushing the photocleaved biopolymer molecules and flowing additional biopolymer molecules are concurrent.

[0004] One aspect of this disclosure provides a method for enhancing fluid flow. In one aspect, the method includes moving biopolymer molecules into contact with at least one fluidic channel in or on a device, whereby clogging occurs in the device due to coiling or aggregation of the biopolymer molecules or adsorption to or tangling around the channels or any other nano- or micro-patterned features inside the channel or fluidic device, and directing a light source at a region of the device in which said clogging has occurred in a manner effective to photocleave biopolymers that contribute to said clogging, thereby facilitating removal or reduction of said clogging. In some aspects, the method further includes applying a motive force to fluid in the region of the device in a manner effective to flush the photocleaved biopolymer molecules from the region of the device comprising said clogging. In some aspects, the motive force may comprise an electrostatic force, a pneumatic force, a capillary

force, or any combination thereof. In some aspects, the directing a light source comprises directing a light source having a wavelength of one of about 473 nm or about 488 nm to excite YOYO-1 bound to DNA. In some aspects, the biopolymer molecules being moved and photocleaved may comprise DNA or RNA.

[0005] In some aspects, the method also includes labeling the biopolymer molecules with an indicator or photon absorber to facilitate photocleavage of the biopolymer molecules when exposed to the light source. In some aspects, the light source may be configured to generate light matched to the indicator or photon absorber used to label the biopolymer molecules so as to maximize photocleavage of the biopolymer molecules when exposed to the light. In some aspects, the indicator used to label the biopolymer molecules may comprise one of YO, YOYO-1, YOYO-3, TOTO, methylene blue, Cu or Rh, compounds useful for photodynamic therapy, or any other photon absorber capable of facilitating photocleavage of the biopolymer. Each indicator can be excited with a specific wavelength or a range of wavelengths to induce photocleavage in an efficient manner. In some aspects, the method may further comprise detecting a clogged or reduced flow condition. In some aspects, the detecting comprises

identifying that a transport of the biopolymer molecules through the device falls below a threshold transport value. In some aspect, the detecting comprises direct imaging of at least one fluidic channel in or on the device to indicate clogging. In some aspects, the cleaning of the region of the device in which the clogging has occurred is implemented in an automatic fashion at one of a predetermined time or a predetermined transport threshold. In some aspects, the method may further include positioning the light source in a manner effective to minimize exposure of the device to the light source.

[0005a] In one aspect, provided herein is an apparatus for enhancing fluid flow, the apparatus comprising: a light source configured to generate a light beam configured to photocleave biopolymer molecules clogged within a channel, wherein the biopolymer molecules comprise DNA or RNA; a pillar region comprising a plurality of pillars configured to untangle, uncoil, and/or straighten biopolymer molecules; a controller configured to: control a movement of the biopolymer molecules into contact with at least one fluidic channel in or on a device, whereby clogging occurs in the device due to coiling or aggregation of the biopolymer molecules, or adsorption to or tangling of the biopolymer molecules around the channels or other nano- or micro-patterned features inside the channel or fluidic device; determine a region of the device in which the clogging has occurred; direct the light source at the region of the device in which the clogging has occurred; activate the light source to generate the light beam for an amount of time to facilitate a photocleaving of the biopolymer molecules causing said clogging; and after activating the light source, apply a motive force to fluid in the location in a manner effective to flush the photocleaved biopolymer molecules from the region of the device comprising said clogging, thereby enhancing fluid flow; and a detector configured to detect a clog or reduced flow condition through the at least one fluidic channel in or on the device, wherein the detector is further configured to identify that a transport of biopolymer molecules through the at least one fluidic channel in or on the device falls below a threshold transport value.

[0006] Another aspect disclosed is an apparatus for enhancing fluid flow. In some aspects, the apparatus may include a light source configured to generate light configured to photocleave biopolymer molecules and a controller configured to control a movement of the biopolymer molecules into contact with at least one fluidic channel in or on a device, whereby clogging occurs in the device due to coiling or aggregation of the biopolymer molecules or adsorption to or tangling around the channels or other nano- or micro-patterned features inside the channel or fluidic device, direct the light source at a region of a device in which a clog of biopolymer molecules has formed, and activate the light source to generate the light beam for an amount of time to facilitate a photocleaving of the biopolymer molecules forming said clog.

[0007] In some other aspects, the apparatus further comprises a motive force generator configured to generate a motive force, wherein the controller is configured to control a movement of the biopolymer molecules via the generated motive force and wherein the controller is further configured to apply the motive force to fluid in the region of the device in which said clog occurred in a manner effective to flush the photocleaved biopolymer molecules from the region. In some other aspects, the motive force of the apparatus comprises at least one of an electrostatic force, a pneumatic force, a capillary force, or any combination thereof. In some aspects, the motive force generator is configured to generate one of an electrostatic force, a pneumatic force, a capillary force, or any combination thereof. In some aspects, the light beam generated by the light source may have a wavelength of one of about 473nm or 488nm. In some other aspects, wherein the biopolymer molecules or the apparatus may comprise DNA or RNA.

[0008] In some other aspects, the apparatus may further comprise a biopolymer molecule labeling device configured to label the biopolymer molecules with an indicator or photon absorber to facilitate photocleavage of the biopolymer molecules when exposed to the light beam generated by the light source. In some aspects, the indicator used to label the biopolymer molecules comprises at least one of YO, TOTO, methylene blue, Cu or RH, compounds useful

for photodynamic therapy, or any other suitable photon absorber. In some aspects, the apparatus may further comprise a detector configured to detect a clog or reduced flow condition through the at least one fluidic channel in or on the device. In some aspects, the detector may be further configured to identify that a transport of biopolymer molecules through the at least one fluidic channel in or on the device falls below a threshold transport value. In some aspects, the detector may be further configured to directly image the at least one fluidic channel in or on the device to indicate the clog.

[0009] In some other aspects, the controller is further configured to operate the light source and enhance fluid flow in at automatic fashion at one of a predetermined time or a predetermined transport threshold. In some other aspects, the apparatus further comprises an x, x-y, or x-y-z translation motor configured to position the light source in a manner effective to minimize exposure of the device to the light source and further configured to allow positioning of the light source at any location in relation to the device.

[0010] In another implementation, light is directed to the region of the fluidic structure for the purposes of photocleavage by bringing a light-source such as an LED into close proximity to the fluidic structure without use of lenses or other optical systems. Either the LED or the fluidic structure could be translated into position to accomplish this. The controller would coordinate movements, light intensity and duration of exposure. A mask in between the light and the fluidic structure can be used to minimize exposure to regions that should not be subject to photocleavage or degradation, such as the sample well containing molecules that have yet to be loaded into the interrogation region of the chip.

[0011] Another implementation is to include light emitting regions into the fluidic device to apply local excitation and photocleavage to a particular region of the fluidic device that is subject to blockage or clogging.

[0011a] In another aspect, provided herein is an apparatus for characterizing a biopolymer molecule, the apparatus comprising: a fluidic device comprising a detection region comprising at least one channel, and further comprising the biopolymer molecule; a pillar region comprising a plurality of pillars configured to untangle, uncoil, and/or straighten biopolymer molecules; a motive force generator to move biopolymer molecules into the detection region; wherein the movement of the biopolymer molecules causes at least one of the biopolymer molecules to at least one of coil, aggregate, adsorb to, or tangle around at least a portion of the fluidic device, causing a clog which hampers further flow of new biopolymer molecules to the detection region; a detection system for determining a characteristic of the biopolymer molecules in the detection region; a light source set to deliver a light comprising a

configuration for photocleaving the biopolymer molecules forming the clog; a light delivery system to deliver the light to any region of the fluidic device; a detector configured to detect a clog or reduced flow condition through the at least one fluidic channel in or on the device, wherein the detector is further configured to identify that a transport of biopolymer molecules through the at least one fluidic channel in or on the device falls below a threshold transport value; a positioning system to target the detection system to the detection region for characterization of the biopolymer molecules, and to target the light comprising the photocleaving configuration to a region of the device where the clog has formed; and a controller configured to: activate the motive force generator to move the biopolymer molecules into the detection region; direct the detection system to the detection region; activate the detection system to determine the characteristics of the biopolymer molecules; direct the light source configured for photocleaving biopolymer molecules to the region where the clog has formed; activate the light source to generate a light for photocleaving biopolymer molecules forming the clog; and activate the motive force generator after activating the light source to flush out the photocleaved biopolymer molecules; wherein additional new biopolymer molecules flow into the detection region for characterization after the motive force generator flushes out the photocleaved biopolymer molecules.

[0012] Another aspect includes an apparatus for characterizing a biopolymer molecule. The apparatus comprises a fluidic device comprising a detection region comprising at least one channel and the biopolymer molecule. The apparatus further comprises a motive force generator that moves biopolymer molecules into the detection region, where a clog of biopolymer molecules may occur in the fluidic device and hamper further flow of new biopolymer molecules to the detection region. The apparatus further comprises a detection system for determining a characteristic of the biopolymer molecules in the detection region and a light source set to deliver a light comprising a configuration for photocleaving the biopolymer molecules forming the clog. The apparatus further comprises a light delivery system to deliver

the light to any region of the fluidic device and a positioning system to target the detection system to the detection region for characterization of the biopolymer molecules, and to target the light comprising the photocleaving configuration to a region of the device where the clog has formed. The apparatus also comprises a controller configured to activate the motive force generator to move the biopolymer molecules into the detection region, direct the detection system to the detection region, activate the detection system to determine the characteristics of the biopolymer molecules, direct the light source configured for photocleaving biopolymer molecules to the region where the clog has formed, activate the light source to generate a light for photocleaving biopolymer molecules forming the clog, and activate the motive force generator to flush out the photocleaved biopolymer molecules; wherein additional new biopolymer molecules flow into the detection region for characterization.

[0013] Another aspect may include a method for characterizing a biopolymer. The method may comprise moving biopolymer molecules into a detection region of a fluidic device, whereby clogging may occur in the device, hampering further flow of biopolymers to the detection region. The method may further comprise detecting a characteristic of the biopolymer molecules in the detection region. The method may further comprise directing a light source at a region of the device where the clog has formed and photocleaving the biopolymer molecules causing the clogging. Then, the method may comprise applying a motive force to flush the photocleaved biopolymer molecules and applying a motive force to flow additional biopolymer molecules for characterization.

[0014] Another aspect may include another method for characterizing a biopolymer. The method may comprise moving biopolymer molecules into a detection region of a fluidic device and detecting a characteristic of the biopolymer molecules in the detection region. The method may further comprise directing a light source at the detection region wherein the light source comprises a configuration for photocleaving biopolymer molecules. The method further comprises photocleaving biopolymer molecules which have been characterized and flushing photocleaved molecules, allowing entry of new molecules for characterization.

[0015] Another aspect may include a system for characterizing a biopolymer. The system may comprise a fluidic device comprising a detection region comprising at least one channel, and further comprising the biopolymer and a detection system for determining a characteristic of the biopolymer molecule in the detection region. The system may further comprise a photocleaving system comprising a light source set to deliver a light comprising a configuration for

WHAT IS CLAIMED IS:

1. A method for enhancing fluid flow, the method comprising:

moving biopolymer molecules into contact with at least one fluidic channel in or on a device, whereby clogging occurs in the device due to coiling or aggregation of the biopolymer molecules, or adsorption ~~to~~ or tangling of the biopolymer molecules around the channels or any other nano- or micro- features inside the channel or fluidic device; ~~and~~ _____

detecting a clogged or reduced flow condition, wherein the detection comprises identifying that a transport of the biopolymer molecules through the device falls below a threshold transport value;

directing a light source at a region of the device in which said clogging has occurred in a manner effective to photocleave at least one of the biopolymer molecules that contribute to said clogging, thereby facilitating removal or reduction of said clogging;

after directing the light source to the region, applying a motive force to fluid in the region in a manner effective to flush the photocleaved biopolymer molecules creating said clog from the region of the device in which said clogging has occurred; and

applying a motive force to flow additional biopolymer molecules through the device for characterization, wherein flushing the photocleaved biopolymer molecules and flowing additional biopolymer molecules are concurrent.

~~2. The method of claim 1, further comprising applying a motive force to fluid in the region of the device in a manner effective to flush the photocleaved biopolymer molecules from the region of the device comprising said clogging.~~

~~3.~~2. The method of claim ~~2~~1, wherein the motive force comprises an electrostatic force, a pneumatic force, a capillary force, or any combination thereof.

~~4.~~3. The method of ~~any one of claims 1-3~~, wherein the biopolymer molecules comprise DNA or RNA.

~~5.~~4. The method of ~~any one of claims 1-4~~, further comprising labeling the biopolymer molecules with an indicator to facilitate photocleavage of the biopolymer molecules when exposed to the light source, wherein the light source is configured to generate a light matched with the indicator to enhance photocleaving capabilities.

~~6.~~5. The method of claim ~~5~~4, wherein the indicator used to label the biopolymer molecules comprises one or more of YOYO-1, YOYO-3, TOTO, methylene blue, Cu, Rh, compounds useful for photodynamic therapy, and other photon absorbers capable of facilitating cleavage of the biopolymer upon irradiation with photons.

~~7.~~6. The method of claim ~~6~~5, wherein the indicator is YOYO-1 and the light source has a wavelength of one of about 473 nm or about 488 nm.

~~8. The method of any one of claims 1-7, further comprising detecting a clogged or reduced flow condition.~~

~~9. The method of claim 8, wherein the detection comprises identifying that a transport of the biopolymer molecules through the device falls below a threshold transport value.~~

~~10.~~7. The method of claim ~~8~~1, wherein the detection comprises direct imaging of at least one fluidic channel in or on the device to indicate clogging.

~~11.~~8. The method of ~~any one of claims 1-10~~, wherein a cleaning of the region of the device in which the clogging has occurred is implemented in an automatic fashion at one of a predetermined time or a predetermined transport threshold.

~~12.~~9. The method of ~~any one of claims 1-11~~, further comprising positioning the light source in a manner effective to minimize exposure of the device other than the region of the device in which said clogging has occurred to the light source.

~~13.~~10. An apparatus for enhancing fluid flow, the apparatus comprising:

a light source configured to generate a light beam configured to photocleave biopolymer molecules clogged within a channel, wherein the biopolymer molecules comprise DNA or RNA; ~~and~~

a pillar region comprising a plurality of pillars configured to untangle, uncoil, and/or straighten biopolymer molecules;

a controller configured to:

control a movement of the biopolymer molecules into contact with at least one fluidic channel in or on a device, whereby clogging occurs in the device due to coiling or aggregation of the biopolymer molecules, or adsorption to or tangling of the biopolymer molecules around the channels or other nano- or micro-patterned features inside the channel or fluidic device;

determine a region of the device in which the clogging has occurred;

direct the light source at the region of the device in which ~~a clog of biopolymer molecules has formed~~ the clogging has occurred; ~~and~~

activate the light source to generate the light beam for an amount of time to ~~facilitate a photocleaving of the biopolymer molecules forming said clog;~~ causing said clogging;
and

after activating the light source, apply a motive force to fluid in the location in a manner effective to flush the photocleaved biopolymer molecules from the region of the device comprising said clogging, thereby enhancing fluid flow; and

a detector configured to detect a clog or reduced flow condition through the at least one fluidic channel in or on the device, wherein the detector is further configured to identify that a transport of biopolymer molecules through the at least one fluidic channel in or on the device falls below a threshold transport value.

~~14.11. The apparatus of claim 1310, further comprising a motive force generator configured to generate a motive force, wherein the controller is configured to control a movement of the biopolymer molecules via the generated motive force and wherein the controller is further configured to apply the motive force to fluid in the region of the device in which said clog occurred in a manner effective to flush the photocleaved biopolymer molecules from the region.~~

~~15.12. The apparatus of claim 1411, wherein the motive force comprises an electrostatic force, a pneumatic force, a capillary force, or any combination thereof.~~

~~16.13. The apparatus of claim 1310, wherein the motive force generator is configured to generate one of an electrostatic force or a pneumatic force.~~

~~17.14. The apparatus of any one of claims 13 16 claim 10, wherein the light beam generated by the light source has a wavelength of one of about 473nm or about 488nm.~~

~~18. The apparatus of any one of claims 13-17, wherein the biopolymer molecules comprise DNA or RNA.~~

~~19. The apparatus of any one of claims 13-18, further comprising a detector configured to detect a clog or reduced flow condition through the at least one fluidic channel in or on the device.~~

~~20. The apparatus of claim 19, wherein the detector is further configured to identify that a transport of biopolymer molecules through the at least one fluidic channel in or on the device falls below a threshold transport value.~~

~~21. The apparatus of claim 20, wherein the detector is further configured to directly image the at least one fluidic channel in or on the device to indicate the clog.~~

~~22. The apparatus of any one of claims 13-21, wherein the controller is configured to operate the light source and enhance fluid flow in at automatic fashion at one of a predetermined time or a predetermined transport threshold.~~

~~23. The apparatus of any one of claims 13-21, further comprising an x-y-z translation motor configured to position the light source in a manner effective to minimize exposure of the device other than the region of the device in which a clog of biopolymer molecules has formed to the light source and further configured to allow positioning of the light source at any location in relation to the device.~~

24.15. An apparatus for characterizing a biopolymer molecule, the apparatus comprising:

a fluidic device comprising a detection region comprising at least one channel, and further comprising the biopolymer molecule;

a pillar region comprising a plurality of pillars configured to untangle, uncoil, and/or straighten biopolymer molecules;

a motive force generator to move biopolymer molecules into the detection region; ~~wherein a clog of biopolymer molecules occurs in the fluidic device hampering further flow of new biopolymer molecules to the detection region~~
wherein the movement of the biopolymer molecules causes at least one of the biopolymer molecules to at least one of coil, aggregate, adsorb to, or tangle around at least a portion of the fluidic device, causing a clog which hampers further flow of new biopolymer molecules to the detection region;

a detection system for determining a characteristic of the biopolymer molecules in the detection region;

a light source set to deliver a light comprising a configuration for photocleaving the biopolymer molecules forming the clog;

a light delivery system to deliver the light to any region of the fluidic device;

a detector configured to detect a clog or reduced flow condition through the at least one fluidic channel in or on the device, wherein the detector is further configured to identify that a transport of biopolymer molecules through the at least one fluidic channel in or on the device falls below a threshold transport value;

a positioning system to target the detection system to the detection region for characterization of the biopolymer molecules, and to target the light comprising the photocleaving configuration to a region of the device where the clog has formed; and

a controller configured to: ~~1)~~

activate the motive force generator to move the biopolymer molecules into the detection region; ~~2)~~

direct the detection system to the detection region;~~3)~~

activate the detection system to determine the characteristics of the biopolymer molecules;~~4)~~

direct the light source configured for photocleaving biopolymer molecules to the region where the clog has formed;~~5)~~

activate the light source to generate a light for photocleaving biopolymer molecules forming the clog;~~and-6)~~

activate the motive force generator after activating the light source to flush out the photocleaved biopolymer molecules; wherein additional new biopolymer molecules flow into the detection region for characterization after the motive force generator flushes out the photocleaved biopolymer molecules.

16. The apparatus of claim 15, further comprising a plurality of relaxation channels having a wider dimension at an end adjacent to the pillar region and a narrow dimension at the other end.

~~25. A method for characterizing a biopolymer, the method comprising:~~

~~moving biopolymer molecules into a detection region of a fluidic device, whereby clogging occurs in the device hampering further flow of biopolymers to the detection region;~~

~~detecting a characteristic of the biopolymer molecules in the detection region;~~

~~directing a light source at a region of the device where the clog has formed; photocleaving biopolymers causing clogging;~~

~~applying a motive force to flush the photocleaved biopolymer molecules; and~~

~~applying a motive force to flow additional biopolymer molecules for characterization.~~

~~26. A method for characterizing a biopolymer, the method comprising:~~

~~moving biopolymer molecules into a detection region of a fluidic device;~~

~~detecting a characteristic of the biopolymer molecules in the detection region;~~

~~directing a light source at the detection region wherein the light source comprises a configuration for photocleaving biopolymer molecules;~~

~~photocleaving biopolymer molecules which have been characterized; and~~

~~flushing photo-cleaved molecules, allowing entry of new molecules for characterization.~~

~~27. A system for characterizing a biopolymer, the system comprising:~~

~~a fluidic device comprising a detection region comprising at least one channel, and further comprising the biopolymer;~~

~~a detection system for determining a characteristic of the biopolymer molecule in the detection region; and~~

~~a photo-cleaving system comprising a light source set to deliver a light comprising a configuration for photo-cleaving biopolymer molecules that have already been interrogated or were not interrogated and do not need to be, for loading new molecules for characterization.~~