Title: APPARATUS AND METHOD FOR IMAGING FLUIDS DOWNHOLE

Abstract: The disclosure, in one aspect, provides a method for providing an image of a fluid that includes passing light through the fluid, detecting light passing through the fluid at at least one wavelength and producing signals corresponding to the detected light, and processing the signals to provide the image of the fluid.
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BACKGROUND OF THE DISCLOSURE

Field of the Disclosure

[0001] The disclosure herein relates to imaging fluids downhole.

Description of the Related Art

[0002] Oil wells (also referred to as wellbores or boreholes) are drilled into subsurface formations to produce hydrocarbons (oil and gas). A drilling fluid, also referred to as mud, is supplied under pressure to drill the wellbores. A majority of the wellbores are drilled under over-burdened or overpressure conditions, i.e., the pressure gradient in the wellbore due to the weight of the mud column is greater than the natural pressure gradient of the formation in which the wellbore is drilled. Because of the overpressure condition, the mud penetrates into the formation surrounding the wellbore to varying depths, thereby contaminating the natural fluid contained in the formation, which fluid also is referred to herein as the "connate formation fluid" or the "connate fluid."

[0003] To estimate or determine the type or the components of the fluid, including oil, gas and water, in a formation at a particular wellbore depth or to estimate the condition of the reservoir surrounding the wellbore at the particular
depth, tools, referred to as the formation evaluation tools, are used during drilling of the wellbore and after the wellbore has been drilled to obtain samples of the connate fluid for analysis. After drilling the wellbore, such tools are conveyed via a wireline or coiled tubing. During drilling of the wellbore, such tools are disposed in a bottomhole assembly above the drill bit, which assembly is conveyed by a drill string that may include a coiled tubing or may be made up of jointed tubulars. To obtain a sample of the connate fluid, a probe is often used to withdraw the fluid from the formation. However, the formation fluid up to a certain distance adjacent the wellbore is contaminated with the mud (i.e., it includes the mud filtrate). Therefore, to obtain a clean sample of the formation fluid, the formation fluid withdrawn from the formation for an initial time period is discarded to ensure that the sample is a clean sample. Various sensors have been used to estimate when the fluid being drawn is clean or of an acceptable quality level, i.e., that the contamination level is acceptable. However, such methods do not provide a visual image of the fluid being withdrawn. Real time visual images can be helpful to an operator for taking samples. Therefore, there is a need for an apparatus and method for obtaining visual images of the fluid downhole.
SUMMARY OF THE DISCLOSURE

[0004] The disclosure herein, in one aspect, is a method that provides an image of a fluid: the method, in one aspect includes exposing the fluid to light, detecting light received from the fluid at a plurality of selected wavelengths, and processing signals corresponding to the detected light at the selected wavelengths to provide a visual image of the fluid. The image may include an image of interfaces between immiscible fluids or between solids, such as sand, and a fluid or between bubbles and a liquid. In another aspect, the method includes estimating darkness of the fluid from light detected at a plurality of selected wavelengths and providing a visual image of the fluid using the estimated darkness of the fluid at the selected wavelengths. In another aspect, the disclosure provides an apparatus for imaging a fluid that includes a light source that exposes the fluid to light, a detector that detects light received from the fluid at a plurality of wavelength and a processor that processes signals corresponding to the detected light to provide an image of the fluid. The detector, in one aspect, is a pyroelectric detector that is tuned to detect light at the selected plurality of the wavelengths. In one aspect, a hyperspectral imaging technique is used to produce the image of the fluid. The image may be a chemical specific image, which may include images corresponding to oil, gas and water, among other things.
BRIEF DESCRIPTION OF THE DRAWINGS

[0005] For detailed understanding of the disclosure, references should be made to the following detailed description of the drawings, taken in conjunction with the accompanying drawings, in which like elements in general have been given like numerals, wherein:

FIG. 1 is a schematic illustration of a tool made according to one embodiment of the disclosure conveyed into a wellbore for imaging a fluid obtained from the formation surrounding the tool;

FIG. 2 is a schematic illustration of certain details of a portion of the tool of FIG. 1 placed at a selected location or depth in the wellbore for retrieving fluid from the formation and for providing in-situ visual images of the retrieved fluid;

FIG. 3 is a schematic diagram showing the tool of FIG. 2 attached to a drill string that is conveyed in a wellbore for providing images of the fluid during drilling of the wellbore;

FIG. 4 is a schematic diagram of certain elements of an imaging device made according to one embodiment of the disclosure;

FIG. 5 shows absorbance spectra of certain crude oil grades and water;

FIG. 6 shows absorbance spectra of methane at various pressures and temperatures compared to a laboratory spectrum of a particular crude oil; and

FIG. 7 is an exemplary visual image of a fluid that may be provided by the imager made according to one embodiment of the disclosure.
DETAILED DESCRIPTION OF THE DRAWINGS

[0006] The present disclosure, in one aspect, provides an apparatus for imaging a fluid downhole. In another aspect, the disclosure provides an apparatus for in-situ imaging of a fluid downhole that utilizes a broadband light source and a tunable thermal detector, such as an array of pyroelectric detectors. In another aspect, the disclosure provides a method of imaging a fluid downhole during withdrawal or extraction of the fluid from a formation.

[0007] FIG. 1 is a schematic representation of a cross-section of an earth's subsurface along the length of a wellbore 11 drilled in the formation 10. Usually the wellbore is at least partially filled with a mixture of liquids 16, which typically include water, drilling fluid (mud) and formation fluids indigenous to the earth formations, such as oil, gas and water. The fluid in the wellbore is referred to herein as the "wellbore fluid." The term "connate fluid" or "natural fluid" herein refers to the fluid that is naturally present in the formation, exclusive of any substantial contamination by fluids not naturally present in the formation, such as the mud, other chemicals that may have been introduced into the wellbore, or fluids that may have migrated from other formations or wells. Conveyed in the wellbore 11 at the bottom end of a wireline 12 is a formation evaluation or testing tool 20 that includes a subassembly or module 1 containing the imaging apparatus 400, according to one embodiment of the present disclosure, as described in more detail in reference to FIGS. 2-7. The wireline 12 typically is an armored cable that carries data and power conductors for providing power to the tool 20 and a two-way data communication (telemetry) between a tool processor 50 and a controller 40 at a surface unit 15. The wireline 12 typically is carried from the surface unit 15 over a pulley 13 supported by a derrick 14. The surface
unit 15 may be a mobile unit for land operations and a fixed unit on an offshore rig or vessel for underwater operations. The surface controller 40 may include a computer or a microprocessor; data storage devices, such as solid state memory and magnetic tapes; peripherals, such as data input devices; display devices; and other circuitry for controlling and processing data received from the tool 20. The surface controller 40 also includes one or more computer programs embedded in a computer-readable medium accessible to the processor in the controller 40 for executing instructions contained in the computer programs to perform the various methods and functions associated with the operations of the tool 20, including, but not limited to, processing data from the tool 20 and providing images of the fluid.

[0008] FIG. 2 illustrates in more detail an embodiment of the formation evaluation or sampling tool 20 that includes an imaging apparatus 400 for providing images of the fluid being withdrawn from the formation 10. The sampling tool 20 is shown to be an assembly of several tool segments or modules that are mechanically joined end-to-end by a suitable mechanism 23, such as threaded joints or mutual compression unions. The tool 20 includes a power unit 21, (a hydraulic or electromechanical) segment and a formation fluid extractor 22 segment. Below (downhole) the extractor 22, a large displacement volume motor/pump unit 24 is provided for pumping fluid from the formation 10 into the wellbore 11 and/or one or more sample tanks or chambers 30. Below the large volume pump 24 is shown a similar motor/pump unit 25 having a smaller fluid displacement volume, which fluid may be imaged by the imaging apparatus. Ordinarily, one or more sample tank magazine sections 26 are assembled below the small volume pump 25. Each sample tank magazine section 26 may include
one or more fluid sample tanks, such as tanks 30. The formation fluid extractor 22 comprises an extensible suction probe 27 that is opposed by wall feet 28. Both the suction probe 27 and the opposing feet 28 are extensible (hydraulically or electromechanically) to firmly engage the wellbore wall. A fluid extraction tool is described in U.S. Patent No. 5,303,775, which is incorporated herein by reference.

[0009] The imaging apparatus 400 (also referred to herein as the imager) may provide continuous or substantially continuous images of the fluid as it is being withdrawn. In operation, the probe 27 and the feet 28 are extended so that the probe sealingly presses against the borehole wall. The pump 24 is used to pump the fluid from the formation into the tool 20 via the probe 27. A portion of the fluid is passed into or through a sample chamber (such as chamber 406, FIG. 4) associated with an imaging apparatus 400. The imager 400 detects light that passes through or reflected by (depending upon the configuration used) the fluid at one or more selected wavelengths and processes signals corresponding to the detected light to provide images of the fluid. The components or elements in the fluid detected by the imager 400 may include methane (which is a main component of natural gas), asphaltenes, oil, water, solids (such as sand) and known tracers added into a drilling fluid during drilling of the wellbore. The imager 400 alone or in combination with the surface controller 40 provides visual images of the fluid that may show the presence of the various elements in different colors or in different shades of grey. To reproduce a sample’s visible colors, the imager may be configured to combine red, green, and blue monochrome images. To image chemical composition, the imager may be configured to combine various infrared monochrome images and use them to
generate selected (or false) colored images, which represent particular chemical compounds. For example, a faded red may be used to indicate a lesser amount of gas compared to deep red, etc. The imager 400 may be configured to process the data or signals corresponding to the light detected at the various wavelengths and send to the surface controller 15 in-situ images of the fluid that may be displayed on a suitable display for visual presentation. Alternatively, the imager 400 may be configured to process signals to certain extent and transmit the processed signals to the surface processor 40 for further processing of such signals and for providing visual images of the fluid. The operation of the imager is explained in more detail in reference to FIGS. 4-6.

[0010] The imager 400 may be incorporated into a bottomhole assembly attached to a bottom end of drill string 30 above a drill bit 33 for providing images during drilling of the wellbore 11, such as shown in FIG. 3. In this configuration, the imager 400 provides images to a surface controller 40 or sends data relating to the images of the fluid via a suitable telemetry system, such as mud pulse telemetry, electromagnetic telemetry or an acoustic telemetry system.

[0011] FIG. 4 is a schematic diagram showing a configuration of a portion of the imager 400 according to one exemplary embodiment. The imager 400 is shown to include a light source 402 that may be a broadband light source, such as a tungsten light source or any other light source that produces light within a desired or selected wavelength range, which light is used to illuminate the fluid. In one aspect, a light modulator 404 is provided. The modulator may be any suitable device that can vary the intensity of the light source, including, but not limited to, an electronic pulser that provides power to the light source, a mechanical chopper that interrupts the path of the light source to the downhole
fluid, and an optical beam steering device. Thus, any suitable modulator may be used to modulate the light intensity that impinges on the fluid and the detector. A reflector or collimator 403 may be provided to focus and/or concentrate light from the light source 402 toward an optical window 408a of a fluid chamber 406. The optical window, in one aspect is a sapphire window. The fluid 407 extracted from the formation passes through the chamber 406. The various elements in the fluid, such as oil, gas, water, asphaltenes, solids etc., absorb the incident light received via the optical window 408a. The unabsorbed light passes through the fluid 407 and leaves the chamber or conduit 406 via an opposing window 408b.

[0012]The imager 400 further includes a detector 412 for detecting light that passes through the fluid 407. In one configuration, the detector 412 is a suitable thermal detector, which may be a pyroelectric detector array. Pyroelectric detectors respond to changes in the detector temperature and not to the ambient temperature. Therefore, they respond to changes in the intensities of any wavelength (color) of light that strikes them regardless of the ambient temperature. The detector 412, in one aspect, may be configured or tuned to detect (or view) any suitable wavelength or wavelengths, including, but not limited to, wavelengths sufficiently long to detect light beyond the asphaltene-absorbing region of crude oil, at which wavelengths crude oils tend to be translucent. The imager 400 utilizes a tunable filter 416 to create images of the fluid downhole at any desired wavelength of light, including infrared wavelengths, which can allow chemical imaging. In this manner, selective images of oil, water gas and other elements can be obtained. The imager 400 thus in one aspect utilizes suitable filter 416 interposed between the light 440 radiating from the fluid.
and the detector 412. In one aspect the light source 407 provides broadband light and the filter 416 is tuned to sweep a selected range of wavelengths. Alternately, the filter 416 may sequentially allow selected wavelengths of light to pass to the detector 412. Thus, the detector 412 detects light at a number of selected wavelengths. In one aspect, the wavelength range may be from about 400nm to about 2000-nm, which includes relevant wavelengths at which elements like water, methane at various temperatures and pressures, asphaltenes and various grades of oil absorb light. In another aspect, the detector may be tuned to a number of specific or particular wavelengths of light that are used by the imager 400 to provide images of the fluid or signals corresponding to the light detected at such wavelengths to the surface controllers 40 (FIG. 1), which processes such signals to provide the visual images.

[0013] In one aspect, the imager 400 includes a spectrometer 414 and processor 422 for analyzing the signals from the detector 412 and to provide images of the fluid. The detector 412 detects the intensity of light at the selected wavelengths or narrow bands (channels) of light, as described above, and provides signals corresponding to the detected light to the spectrometer 414. The light that is provided to the fluid is known. The absorbance of the light at each of the selected wavelength or narrow bands (channels) is determined. In other words the detector can provide signals that correspond to the observed darkness of the sample at these selected wavelengths or channels. A high gain amplifier 420 may be used to amplify the signals from the detector 412. The spectrometer 414 provides a spectrum of the light detected by the detector 412. The processor 422 utilizing the spectrum provides the images of the fluid. The processor 422 or
the processor 40 at the surface may be configured to utilize a hyperspectral imaging technique to create visual images of the components of the fluid. A memory associated with the processor 422 contains computer programs, algorithms and data that are used by the processor 422 to provide the images of the fluid.

[0014] There are certain wavelengths at which most fluids absorb little or no light. Water absorbs very little light at 1300nm and crude oils absorb very little light at either about 1300nm or about 1600nm. However, solids obstruct light at all wavelengths including 1300nm and 1600nm. Therefore, the processor may use the received light at or about either of these wavelengths, compare it with the induced light or an established baseline to estimate the size and location of the solids in the fluid and provide an image of the solids in the fluid. The processor also may be programmed to assign a color and a shade within the color based on the estimated quantity of the solid, such as the sand concentration. The detector may be made to contain an array of individual detectors so that they can provide the signals corresponding to corresponding areas of the window. The size of the individual detectors can define the spatial resolution of the image.

[0015] The peak absorbance for water at 25 degrees centigrade in the range of 400nm to 2000nm has been found to occur at wavelengths of about 1452nm and 1933nm. Water absorbance remains high over the wavelength range 1400nm to 1525nm and the range 1880nm to 2100nm. The detector may be tuned to detect light at or near such wavelengths and the processor 422 then may determine the absorbance at such wavelengths and utilize such information to
provide images of water. Other wavelengths, such as 1420nm and 1935nm also have been found to provide adequate measurements of absorbance by water.

[0016]Absorbance of liquid oil is relatively high from about 1700nm to 1775nm with peaks occurring at around 1725nm and 1765nm, where the middle of the absorbing region is around 1740nm. The processor 422 may be programmed to determine the absorbance of oil at selected wavelengths in the above noted range. The difference in absorbance at wavelengths of 1740nm and 1600nm may be used to estimate the fractional concentration of liquid hydrocarbon for various grades of crude oil by dividing this absorbance difference by the typical absorbance difference when the oil concentration is 100%. The subtraction of the absorbance at 1600nm removes a portion or substantial portion of the baseline rise caused by the underlying tail of the asphaltene peak, which varies from one crude oil to another crude oil.

[0017]Asphaltenes, which are dark brown in color, absorb more light at wavelengths corresponding to violet light than they do at yellow light and even less at red light. Gas typically appears less absorbing than crude oil at 1740nm both because it is less dense than a liquid hydrocarbon (so its concentration of carbon-hydrogen bonds is lower) and because its peak absorbance occurs at 1667nm, which is on the left side of the liquid hydrocarbon peak.

[0018]Still referring to FIG. 4, the processor 422 may be programmed to determine the absorbance for asphaltene and gas in the same manner as described for oil and water at selected wavelengths. The processor 422, therefore, utilizing the absorbance (or intensity of light) at one or more selected wavelengths, provides an image of the downhole fluid. The processor 422 compares the absorbance values at certain wavelengths and utilizes data and/or
algorithms that may be based on laboratory tests to estimate the amounts and location of the various elements present in the fluid and provide an image of the fluid. The processor 422 may send the relevant data to the processor 40 at the surface, which then may perform the above-noted functions to provide the images. The fluid images may be provided in-situ, i.e., while the fluid is being extracted from the formation.

[0019] In another aspect, one or more known chemicals or tracers may be introduced into the drilling fluid and the detector may be tuned to specific wavelengths at which such known tracers have high absorbance compared to the elements of the connate fluid. The imager may use such information to estimate the mud filtrate and provide a corresponding image.

[0020] In another aspect, the processor 422 or 40 may assign different colors to the different chemicals in the fluid, thereby providing a false-colored image in which color indicates the chemical being imaged. Alternatively, various shades of gray or intensities any single color may be used to provide the images.

[0021] The imager 400 may be configured to use any suitable method or circuitry to create images. For example, a control circuit for the imager 400 may cycle at a rapid speed to allow the generation of one-dimensional high resolution image, for example, by using a high resolution array such as a linear 64-pixel pyroelectric array. Arrays having any other resolution may also be used. The imager 400, using a moving mirror or another suitable scanner, can create a two-dimensional image from a series of such one-dimensional scans. Thus, in one aspect, a single detector and a two-dimensional scanning mirror may be used to create two-dimensional images. In another aspect an array of detectors tuned to scan selected wavelengths may be utilized. In another aspect, an acousto-optic
tunable filter may be utilized to project only one color of light at a time and so create images at any wavelength of light, including infrared wavelengths, which can allow chemical imaging. In this manner, the scanner can selectively image elements, such as oil and water. With the pyroelectric array set up to view long wavelengths, one can see beyond the asphaltene peaks of crude oils, making them translucent.

[0022] FIG. 5 shows absorbance spectra 500 for three selected crude oil grades and water. The absorbance spectra 500 are provided herein to illustrate certain aspects of the method or process used by the imager to provide images of a downhole fluid. The graph of FIG. 5 shows absorbance (in a log scale) along the vertical axis and the wavelength of the detected light by the detector of the imager along the horizontal axis. The vertical bars shown refer to the channels that may be used by the imager for processing signals. The channel size (wavelength band) and the number of channels used are for illustration purposes only. Each channel, however, typically corresponds to a narrow wavelength band. As shown, absorbance for water has a peak around 1452nm while the various crude oil grades have absorbances peaks at 1725nm and 1760nm, which can be monitored by a single channel at 1740nm. The imager 400 determines absorbance for oil at one or more wavelengths in the wavelength band 1725nm-1765nm and for water around 1452nm. The imager may determine the absorbance for solids at one or more wavelengths, such as around 1300nm and/or 1600nm where absorbance by the solids is substantially greater than the absorbance by either oil or gas. Thus, in essence, the imager 400 is configured to detect light at selected wavelengths where each such
wavelength is highly absorbed by a particular chemical of interest and minimally absorbed by another chemical of interest.

[0023] FIG. 6 shows absorbance spectra for methane (gas) at various temperatures and pressures and an absorbance spectrum for a particular grade (31.7°API) of crude oil. Absorbance peak for natural gas, which is mostly methane, occurs around 1667nm compared to oil, whose absorbance peak is centered around 1740nm. The absorbance at 1740nm for gas is lower than that of oil so, at that wavelength, gas typically appears as a weakly absorbing hydrocarbon. The imager 400 may be tuned to detect gas peaks and compare with the oil and water peaks to estimate the presence and amount of gas in the fluid.

[0024] Thus, as described above, the disclosure herein, in one aspect, provides an apparatus for imaging a fluid that includes a light source for illuminating a fluid downhole, a detector for detecting from the fluid at one or more selected wavelengths and provides signals corresponding to the detected light, a spectrometer that provides a spectrum of the detected light and a processor that utilizes the spectrum to provide images of the fluid. In one aspect, the light source is a broad band light source, such as a tungsten light source. Any other suitable light source may also be utilized. In one aspect, the detector is a thermal detector, such as a pyroelectric detector that may include a single detector or an array of detectors. A suitable tunable filter may be utilized to provide light to the detector at selected wavelengths within a selected range of wavelengths where the various elements or chemicals of interest in the downhole fluid absorb light.
The filter may be tuned to any suitable wavelength that may be one or more of: (i) a wavelength at which light is not substantially absorbed by natural oil present in a downhole formation; (ii) a wavelength at which light is not substantially absorbed by natural oil present in a formation and a wavelength at which light is absorbed by the natural oil present in the formation; (iii) about 1300nm and 1600nm; and (iv) a wavelength at which light is not substantially absorbed by a natural oil present in a formation downhole but is absorbed by water present in the formation. The apparatus further may include a spectrometer and a processor. The processor may utilize signals provided by the detector corresponding to at least two wavelengths to provide the image of the fluid.

The image provided by the processor may include images of oil, gas, water, known tracers added to the drilling fluid and solids present in the fluid. The apparatus may include a pump that extracts the fluid from the formation via a probe. In one aspect, a chamber or a flow line receives the extracted fluid. The chamber includes one or more optical windows, such as sapphire windows, for receiving light from the light source and for transmitting light after it has passed through the fluid. The detector is positioned to receive the light from the fluid. The spectrometer apparatus herein may provide absorbance of light at the wavelengths exposed to the detector. The processor may process the information from the spectrometer and additional information that may be stored for the processor to provide two-dimensional or three-dimensional images. The stored information may be laboratory data, baseline information, color assignments, etc. The imager may be conveyed into the wellbore via any suitable conveying member, including a wireline, slickline, coiled tubing and a
drill string. Additionally, in any embodiment, the downhole processor 422, or the surface processor 40 or combination of the two may be configured to perform any of the aspects relating to the processing of detected signals to produce desired images.

[0027] FIG. 7 shows an example of an image of the fluid that may be produced by the imager 400. In this particular image the processor assigns color blue for water, red for oil, yellow for gas and black for solids. Any other color scheme may also be used. Also, different gray scales may be used to depict the images. Different shades of a same color may be used to show a measure of a particular component (such as volume). The image may be a two-dimensional image or a three-dimensional image. Referring to FIGS. 4 and 7, in practice, the system may produce images periodically or substantially continuously so that images of the fluid 407 flowing through channel 406 may be viewed in motion (video). The controller also may be programmed to estimate the percent of cleanup based on the amount and intensity of colors in the image.

[0028] In another aspect, a method is disclosed for providing an image of a fluid downhole that includes: illuminating the fluid downhole to light; detecting light from the fluid at a plurality of selected wavelengths of light by a detector that provides signals corresponding to the detected light; and processing the signals to provide a visual image of the fluid. The light source, in one aspect, is a broadband light source, such a tungsten light source. The method further may include tuning a filter to the selected wavelengths during withdrawal of the fluid from a formation downhole and processing the signals to provide the image in-situ. In the method, the processing may be done by a processor downhole and/or at the surface to provide an image that provides visual indication of one or
more elements or chemicals of the fluid, including oil, water, methane, asphaltene, tracers added into the drilling fluid and solids. The fluid may be passed through a chamber and the light passing through the fluid may be detected continuously over a selected period of time to provide in-situ images of the fluid over the selected time period. Fluid contamination may be visually estimated or quantified by the imager.

[0029] Additionally, a computer-readable medium that is accessible to a processor for executing instructions contained in a computer program embedded in the computer-readable medium to provide image of downhole fluids is provided. In one aspect, the computer program includes: instructions to activate a light source for illuminating a fluid; instructions to tune a detector that is positioned to detect light from the fluid at a plurality of wavelengths; instructions to receive signals from the detector; and instructions to process the received signals to provide an image of the fluid. The computer program further may include instructions to compare absorbance at a plurality of wavelengths to provide the image of the fluid. The computer program may also include instructions to provide the image that shows the presence of one or more elements of the fluid, such as oil, methane, water, tracers and solids. Additionally, a system is disclosed for providing images of a fluid extracted from a formation, wherein the system includes a tool that is deployable into a wellbore by a conveying member from a surface location, wherein the tool includes: a pump for extracting the fluid from the formation; a chamber for receiving the extracted fluid; a light source that generates light that is exposed to the fluid in the chamber; a detector that receives light from the fluid in the chamber at a plurality of wavelengths and produces signals corresponding to the detected
light; and a processor that utilizes the signals produced by the detector to provide an image of the fluid.

[0030] The foregoing disclosure is directed to the preferred embodiments of the disclosure various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope of the appended claims be embraced by the foregoing disclosure. Examples of the more important features of the disclosure have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will form the subject of the claims appended hereto.
CLAIMS

1. An apparatus for imaging a fluid downhole, comprising:
   a light source for illuminating the fluid downhole;
   a detector that detects light from the fluid at a plurality of wavelengths
       and provides signals corresponding to the detected light; and
   a processor that processes the signals to provide an image of the fluid.

2. The apparatus of claim 1, wherein the light source is a broad band light source.

3. The apparatus of claim 1 or 2, wherein the detector is a thermal detector.

4. The apparatus of any of the claims 1-3, wherein the plurality of wavelengths includes at least one of: (i) a wavelength at which light is not substantially absorbed by natural oil present in the formation; (ii) at least two wavelengths, one at which light is not substantially absorbed by natural oil, and the other at which light is substantially absorbed by the natural oil present in the formation; (iii) at least two wavelengths, one about 1300nm and the other 1600nm; (iv) a wavelength at which light is absorbed by water present in the formation and not substantially absorbed by natural oil present in the formation; and (v) a plurality of wavelengths where light at each such wavelength is highly absorbed by a first element of interest and relatively minimally absorbed by a second element of interest.

5. The apparatus of any of the claims 1-4 further comprising a filter for tuning the detector at the plurality of wavelengths.

6. The apparatus of any of the claims 1-5, wherein the detector provides signals corresponding to each wavelength in the plurality of wavelengths and the
processor processes such signals provided by the detector to create a visual image of the fluid.

7. The apparatus of any of the claims 1-6, wherein the image provided by the processor is at least one of: (i) an image of oil; (ii) an image of gas; (iii) an image of water; and (iv) an image of a solid.

8. The apparatus of any of the claims 1-7 further comprising a chamber configured to receive the fluid, the chamber including at least one optical window that allows the fluid in the chamber to receive light from the light source to illuminate the fluid.

9. The apparatus of claim 8 further comprising a pump that pumps fluid from a formation into the chamber.

10. The apparatus of any of claims 1-9, wherein the processor is located at one of: (i) a surface location; and (ii) in a downhole tool.

11. A method for providing an image of a fluid downhole, comprising:

   illuminating the fluid downhole with light;

   detecting light from the fluid at at least one wavelength by a detector and providing signals corresponding to the detected light; and

   processing the signals to provide a visual image of the fluid.

12. The method of claim 11, wherein the light is a broadband light.

13. The method of claim 12 or 13, wherein the at least one wavelength includes at least two wavelengths and wherein one of the two wavelengths is one of: (i) a wavelength at which light is minimally absorbed by natural oil present in a downhole formation; (ii) a first wavelength at which light is minimally absorbed by a natural oil present in a formation and a second wavelength at which light is highly absorbed by the natural oil present in the formation; (iii) a
first wavelength that is about 1300nm and a second wavelength that is about 1600nm; and (iv) a wavelength at which light is minimally absorbed by a natural oil present in a formation and is highly absorbed by water present in the formation.

14. The method of any of the claims 11-13, further comprising:
   tuning the detector at at least two wavelengths during withdrawing of the fluid from a formation downhole; and
   processing the signals from the detector to provide the image in-situ.

15. The method of any of the claims 11-14, wherein the image includes at least an image of one of: oil; water; gas; and solid.

16. The method of any of the claims 11-15 further comprising:
   passing the fluid through a hollow member;
   continuously detecting the light from the fluid; and
   providing in-situ images of the fluid over a selected time period.

17. The method of any of the claims 11-16, wherein detecting light comprises detecting light by a pyroelectric detector.

18. A computer-readable medium accessible to a processor for executing instructions contained in a computer program embedded in the computer-readable medium, wherein the computer program comprises:
   instructions to activate a light source for illuminating a fluid;
   instructions to tune a detector that is positioned to detect light from the fluid at a plurality of wavelengths;
   instructions to receive signals from the detector; and
   instructions to process the received signals to provide a visual image of the fluid.
19. The computer-readable-medium of claim 18, wherein the computer program further comprises instructions to compare absorbance at the plurality of wavelengths to provide the image of the fluid.

20. The computer-readable-medium of claim 18 or 19, wherein the computer program further comprises instructions to provide the image that includes images of an oil, a gas, water and a solid present in the fluid.

21. A system for providing images of a fluid extracted from a formation, comprising:

- a tool that is deployable into a wellbore by a conveying member from a surface location, wherein the tool includes:
  - a pump for extracting the fluid from the formation;
  - a chamber for receiving the extracted fluid and allowing the received fluid to pass therethrough;
  - a light source that illuminates the fluid in the chamber;
  - a detector that detects light from the fluid in the chamber at a plurality of wavelengths and produces signals corresponding to the detected light; and
  - a processor that utilizes information relating to the signals produced by the detector to provide images of the fluid.

22. The system of claim 21, wherein the processor compares absorbance at least two wavelengths to provide the image of the fluid.

23. The system of any of claims 21-22, wherein the processor assigns a different color to each of oil, water, gas and solids in the image.
INTERNATIONAL SEARCH REPORT

A CLASSIFICATION OF SUBJECT MATTER

IPC(8)- G01V 5/08 (2008.04)

According to International Patent Classification (IPC) or to both national classification and IPC

B FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8)- G01V 5/08, G06K 9/00, E21B 47/00 (2008 04)

USPC - 166/250 01, 250/209 1, 382/100

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)

USPTO EAST System (US, USPG-PUB, EPO, DERWENT)

C DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No</th>
</tr>
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<tbody>
<tr>
<td>Y</td>
<td>US 7,095,012 B2 (FUJISAWA et al) 22 August 2006 (22 08 2006) entire document</td>
<td>2, 12, 13</td>
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</tbody>
</table>

Further documents are listed in the continuation of Box C

* Special categories of cited documents
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "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 referred to in an oral disclosure, use, exhibition or other means
  "T" document published prior to the international filing date but later than the priority date claimed

Date of the actual completion of the international search
27 June 2008

Date of mailing of the international search report
08 JUL 2008

Name and mailing address of the ISA/US
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
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Facsimile No. 571-273-3201

Authorized officer
Blaine R Copenheaver
PCT/Phy 571-272-4300
PCT/SP 571-272-7774
### INTERNATIONAL SEARCH REPORT

**International application No**
PCT/US2008/052551

**Box No. II** Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2Xa) for the following reasons:

1. **Claims Nos** because they relate to subject matter not required to be searched by this Authority, namely:

2. **Claims Nos** because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. **Claims Nos** 4-10, 14-17 because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6 4(a)

**Box No. III** Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. **As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims**

2. **As all searchable claims could be searched without effort, justifying additional fees, this Authority did not invite payment of additional fees**

3. **As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos**

4. **No required additional search fees were timely paid by the applicant** Consequently, this international search report is restricted to the invention first mentioned in the claims. It is covered by claims Nos

**Remark on Protest**

- ![Blank] The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee
- **D** The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation
- ![Blank] No protest accompanied the payment of additional search fees

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)