An optical mine clearance probe comprising a handle that is extended through a rod having a geometrical axis and adapted to be driven into a soil to search through it and including a first tubular part, a second part consisting of a movable rod end part including slots adapted to constitute at least two sectors and a mechanism capable of displacing the movable rod end between two extreme positions. One of the positions being one where a part of the rod end constitutes an extremity of the probe, the at least two sectors being adjacent one another in pairs and defining a conical member ending with a tip, and the other position being one in which extremities of the at least two sectors are spread apart from one another, the rod end then being of tubular shape. The mechanism is capable of displacing at least a part of at least one of the sectors in a direction that is different from that of the geometrical axis of the rod while maintaining the part of rod end at the end of the rod so that it always constitutes the extremity of the probe.
OPTICAL MINE CLEARANCE PROBE AND PROCESS FOR IDENTIFICATION OF A MATERIAL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of French Patent Application No. 0508901 filed on Aug. 31, 2005, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The invention concerns the field of mine detection and destruction, and more particularly, the subject of the invention is a mine clearance probe.

BACKGROUND

[0003] Within the framework of the operations of land mine clearance, one of the main problems that faces mine disposal units is the search for various explosive objects, and for example mines that do not contain metal. To this day, the means that is most often used consists in searching through the soil by means of a mine clearance probe. This probe includes a metallic tip with a cross-section of a few millimeters and, when it is in contact with an unknown object, it allows to locate same, and possibly to define its shape through multiple probes. However, it does not make it possible to acknowledge same as being a mine or a simple pebble, for example. After having ordered field personnel to move to a safe distance, of the order of about one hundred meters, the mine disposal unit must then dig out for the object in order to make sure that it consists of an explosive object, such as a mine, and in the affirmative, an operation of removal after defining or of destruction should be initiated. During this operation, the mine disposal unit is in nearly direct contact with the possible booby trap. If the solution that is envisaged is blasting, an explosive charge is placed and the initiation cable is unrolled. After having moved to a safe distance, the unit sets off the explosion. This operation not only involves a violent explosion, but also an important displacement of the material around the mine, generally earth and stones.

[0004] In order to overcome these drawbacks, Patent Application FR2852387 is known. It describes a mine clearance probe including a handle with a rod extension having a pointed end, and which is characterized in that the pointed end includes a removable core along its entire length. This removable core is removed when an object that is buried in the ground is detected and then means allowing its identification and including two optical fibers are substituted for the core. One of the fibers is intended to transmit an exterior radiation of the laser diode or halogen type to the object, and the other aims at transmitting to treatment means, part of the radiation that is reflected by the object for purpose of identification. When a material that makes up a mine is identified, the identification means are removed and replaced with means for destroying the mine, which mainly include a laser source, an optical fiber to guide the laser radiation up to the mine and a feed of oxidizing gas.

[0005] However, a probe of that nature requires that the removable core be taken out and that so-called optical fibers be introduced to allow for the identification of the material of an object that is detected, which constitutes a loss of time and may run the risk of modifying the positioning of the rod because of handling operations. This modification may lead the operator to analyze something else than the object that has previously been detected.

[0006] On the other hand, Patent Application EP1443319 is known, and it describes a mine clearance optical laser probe that includes a rod intended to be driven into a soil to search through it and including a first tubular part and a second truncated part including an unblocked bore, thus defining an opening, this probe including a movable rod end including slots so as to define at least two sectors and means adapted to move this rod end along a translation movement so that in one of its extreme positions, the extremity of the rod end cooperates with the interior of the second truncated part to constitute a tip and close the opening, while in the second position, the probe has ceased cooperating with the interior of the second truncated part and the ends of the sectors are spread apart from one another, the rod end being completely inside the rod of the probe and having a tubular shape, thereby permitting an irradiation of a detected object in order to form a plasma and thereafter to determine its nature by analysis of the wave lengths emitted by the plasma. In the case where a mine is recognized, the latter is thereafter destroyed.

[0007] A probe of this nature has many disadvantages. Thus, when an object is detected, the retraction of the rod end inside the rod of the probe causes a movement of the rod of the probe towards the object and projections of soil inside the rod which may cause a blocking of the rod end or produce deposits in front of the optical fiber. There is provided for an injection of gas however, the soil has no other choice but to remain inside the probe and may at all moment, depending on the movements of the operator, disturb the plasma analysis or block the rod end during the use which will follow. In addition, the presence of soil that is stuck to the object may also disturb the analysis. Moreover, the recognition of a detected object requires the formation of a plasma and therefore the presence of an important source of energy.

SUMMARY

[0008] The aim of the invention is to propose a mine clearance probe allowing to remove all the mechanical risks involved with the blocking of movable parts and to limit, and even to eliminate the risks of disturbance of the analysis of the nature of a buried object because of the soil, and this, without requiring the removal of a core and the introduction, in lieu thereof, of the identification means.

[0009] The suggested solution is an optical mine clearance probe including a handle that has a rod extension with an XX' axis and which is adapted to be driven into a soil to search through it and including a first tubular part, a second part made of a movable rod end part including slots for defining at least two sectors and means adapted to displace the movable rod end between two extreme positions where in one of them part of the rod end constitutes the extremity of the probe, the sectors being adjacent to one another in pairs and defining a cone member ending with a pointed end, and while in the other position of the movable rod, the extremities of the at least two sectors are spread apart from one another, the rod end then having a tubular shape, this probe being characterized in that the means are adapted to
move at least part of at least one of the sectors in one direction that is different from that of axis $XX'$ of the rod while maintaining the part of the rod end at the extremity of the rod so that it continues to constitute the extremity of the probe.

0010. When the means are actuated, maintaining the rod end at the extremity of the probe permits, on the one hand, with respect to the ends of the sectors, to scratch the surface of the object and to detach soil therefrom, and on the other hand, with respect to the exterior surfaces of the sectors, to push away on the sides and pack down the soil that is present in order to provide a space without soil that is bound by the sectors in spread apart position and in which a radiation will be propagated, without disturbance, which makes it possible to analyze and eventually destroy a buried object that is located at the ends of the sectors.

0011. According to a specific characteristic, in its first position, the rod end includes at least a first part of conical shape constituting the tip and a second part of truncated shape which widens in the direction of the first part and the means capable of moving around at least part of at least one of the sectors in a direction that is different from that of axis $XX'$ of the rod include a tube member whose end includes, in the inner part thereof, a bevelled part along its entire circumference so as to constitute a truncated surface that is adapted to closely engage with the surface of the second part of the rod end.

0012. According to a first variant embodiment, the rod includes an exterior hollow tube and a second hollow tube which is disposed between the exterior tube and the rod end and including, at one of the extremities and in the interior part thereof, a bevelled part along its entire circumference so as to constitute a truncated surface adapted to follow the surface of the second part of the rod end.

0013. According to an additional characteristic, the second tube is movable in translation according to axis $XX'$ of the rod.

0014. According to a second specific variant embodiment, the means include second means adapted to longitudinally move the rod end along axis $XX'$ and which may consist of a first tube which is unitary, at one of its extremities, with the rod end, and at the other extremity, the second means may consist of a first cylinder whose external peripheral surface includes a first thread which is adapted to cooperate with that of a second threaded ring and to which means for guiding this cylinder in translation are associated, for example these means may consist of a rod, these guiding means being adapted to force a translation displacement to the cylinder when the ring is set up into rotation.

0015. According to a specific characteristic, a second tube, disposed inside the first tube, is unitary with the rod end at one of its extremities, and with a second cylinder at the other extremity, the second cylinder having an external peripheral surface that includes a second thread which is adapted to engage with that of a second threaded ring and with which means for guiding this cylinder in translation are also associated, for example these means may consist of a rod, these guiding means being adapted to force the cylinder into a translation displacement when the ring is set up into rotation.

0016. According to a particular characteristic, the means for guiding the first and second cylinders in translation consist of a single rod.

0017. According to a particular characteristic, the first and second rings are unitary.

0018. According to another particular characteristic, the pitch of the second thread is larger than that of the second thread.

0019. According to another characteristic, the rod end includes a third cylindrical part having a bore drilled through it along its axis of revolution. This bore could have a conical end which terminates in the first part of the rod end, a spring being mounted therein.

0020. According to another characteristic, the probe includes at least one optical fiber that extends through at least part of the rod end. This fiber could be of the multi-cladding type or be associated with a capillary, which is preferably disposed around it.

0021. According to a particular characteristic, the probe includes at least one of the following characteristics:

0022. means for generating at least two pulsed radiations of different wave lengths and having different and non harmonic pulsed frequencies, which possibly consist of diodes which for example may be pulsed through a sine-wave voltage.

0023. means for analyzing a radiation, possibly including a photodetector and band pass filters centered on the diode frequencies

0024. display means.

0025. The invention also concerns a process for identifying a material that is capable of being implemented within the framework of the invention, characterized in that it includes a step consisting of emitting, in the direction of this material in order to irradiate same, at least two pulsed radiations having different wave lengths, for example a red light at 632 nm and a green light at 552 nm and at pulsed frequencies which are different and non harmonic, for example 10 luminous pulses per second (10 Hz) for one pulsed radiation and 11 luminous pulses per second (11 Hz) for the other pulsed radiation.

0026. According to an additional characteristic, it includes a step consisting in collecting part of the radiation which has been reflected or emitted by the material following its radiation with the at least two radiations and analyzing this reflected or emitted radiation, and preferably an additional step of calculation of the ratio between the intensity of the reflected or emitted radiation associated with one the at least two radiations and the intensity of the reflected or emitted radiation associated with the other of the at least two radiations.

0027. To ease the work of the mine disposal units, a process according to the invention also includes a step which consists in associating a name of a material with the calculated value of the ratio and/or a step which consists in displaying an information that is representative of the ratio, such as the ratio itself or the name of the symbol of a material, on displaying means.
Other characteristics and advantages of the invention will appear from reading the following description of many embodiments of the invention, given by way of simple examples which are illustrative and non-limitative, and the annexed drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the appended drawings:

FIG. 1 presents a schematic illustration of a mine clearance probe according to the state of the art,

FIG. 2 presents a mine clearance probe according to an embodiment of the invention,

FIGS. 3a, 3b and 3c show different views of the rod end of the probe according to this embodiment,

FIG. 4 presents a schematic illustration of the front part, on the rod end side, of this mine clearance probe,

FIG. 5 presents a schematic illustration of the rear part, on the handle side, of this mine clearance probe,

FIG. 6 shows the oscillograms of the outlet signal of a photodiode obtained by measuring the reflection in the blue and red of different materials in photovoltaic mode,

FIG. 7 shows the signals obtained by Fourier transform (FFT) of the oscillograms of FIG. 6,

FIG. 8 illustrates the reflection spectra of mine sheath TA5 and of green blades of grass as well as the visible spectrum used for FFT measurements by means of a blue diode and a locally infrared diode (NIR),

FIG. 9 presents another variant of embodiment of the means for identifying the nature of a material,

FIG. 10 shows another variant of embodiment of the means for identifying the nature of a material,

FIG. 11 presents an example of embodiment of the means associated with the invention for destroying a mine,

FIG. 12 shows an example of embodiment of the means for positioning an intermediate tube,

FIGS. 13, 14a and 14b present schematic illustrations of another embodiment of the invention.

DETAILED DESCRIPTION

As shown in FIG. 1, the mine clearance probes presently in use include a handle 1 and a cylindrical rod 2 terminated with a tip 3.

Within the framework of the invention and as shown on FIG. 2, a mine clearance probe includes elements that appear to be similar to those of a probe according to the state of the art with however the following modifications: rod 4, in particular, consists of a hollow metallic tube 5 and a movable rod end 6 disposed at the end 7 of hollow tube 5 opposite handle 8. As shown on FIGS. 3a, 3b and 3c, the rod end 6 presents a rotational symmetry according to a longitudinal axis XX' which also corresponds to the axis of the rod and includes a first part 9 whose external surface defines a cone, a second part 10 of cylindrical external shape and with a diameter D1 smaller than that of the base of the cone, and a second part 11 of truncated external shape which spreads apart in the direction of the first part 9 and connecting the first and second parts.

The third part includes a first longitudinal bore 12 having a diameter D2 which extends about one third of its length and a second longitudinal bore 13 having a diameter D3 smaller than D2 so as to define a shoulder 14 at the junction of the first and second bores. The second longitudinal bore 13 extends into second part 11. Thus, the second and third parts 11 and 10 have a tubular shape.

The second longitudinal bore 13 only partially extends into first part 8 in which it ends in the shape of a cone 15.

This rod end 6 additionally includes three parallel slots 16 extending substantially from the middle 17 of the third part up to the top of the cone that defines the first part 9. These slots 16 are distributed so as to constitute three independent sectors 18a, 18b and 18c of substantially the same dimensions. This independence of the sectors allows for a displacement of the free end 19 in a direction which is perpendicular to the longitudinal axis XX', the extent of this displacement being dependent on the modulus of elasticity of the material constituting same and, possibly, on the force that is applied thereto.

FIG. 4 shows a cross-section of the front part of the rod located on the rod end side.

This rod end 6, in which the first part 9 is of conical shape and ends with a tip 116, is unitary with a tube 20 of outer diameter that is substantially equal to D1 for a first part 21 and with an exterior diameter that is substantially equal to D2 for a second part intended to cooperate with bore 12 so as to constitute an assembly by tight fitting, the longitudinal axis of tube 20 being co-linear with axis XX' of rod end 6.

The internal diameter D4 of the second part 22 is slightly larger than that of the remaining part of tube 20 so as to define a shoulder 23.

Hollow metallic tube 5 is separated from tube 20 and from the second and third parts 11 and 10 of rod end 6 by an intermediate tube 24 which is movable along a straight line according to axis XX' and whose end 25 includes, in its inner part, a beveled part 26 along its entire circumference so as to form a truncated surface that is capable of firmly engaging that of the second part 11 of rod end 6.

On the other hand, a spring 27 is positioned on the one hand against shoulder 23 that is located inside tube 20 and on the other hand against truncated part 15 of bore 13 located in the first part 9 of rod end 6.

Finally, a multilayer optical fiber 29 is placed on axis XX' of rod 4. In this embodiment, the central part 30 of this fiber extends from the handle of the probe to a distance close to tip 116 of the cone defining the first part 9 of the rod end, while the peripheral part 32 of the fiber extends from the handle to the conically shaped part 15 of bore 13.

FIG. 5 shows a cross-section of the rear part of the rod and of the handle 8 which is in part unitary therewith.

Handle 8 is unitary, on the one hand, with hollow metallic tube 5 and on the other hand with tube 20 to which rod end 6 is fixed.
In order to make the probe completely self-contained for the operator, the handle contains means for identifying a material including:

- means for feeding the peripheral section 32, called periphery from now on, of fiber 29 with at least two spectral band pulsed radiations, which are preferably narrow and different and having pulse frequencies which are different and non-harmonic,

- means 34 for analyzing the visible radiation that originates from the central part 30 of fiber 29,

- means 35 for displaying results of the analysis of the visible radiation.

The whole may also be disposed in a portable sheath connected to the probe by means of a cable.

The means for feeding the peripheral section 32 of fiber 29 with at least two spectral band radiations, preferably narrow and different, consist of two diodes (LED) 36, 36, which are pulsed by a sine-wave voltage at different frequencies, these frequencies being non-harmonic with respect to one another.

The peripheral section 32 of fiber 29 is hereinafter called periphery 32.

The analyzing means 34 of the visible radiation which originates from the central part 30 of fiber 29, consist of a photodiode 37, means 38 for dividing the signal that exits from the photodiode into two identical signals, means adapted to direct these two signals respectively towards two band pass filters 39, 40 in which one is centered on the transmit frequency of one of the diodes 36 while the other is centered on the transmit frequency of the other diode, and means 41 for calculating the ratio of the current capacity that originates from each of the pass band filters 39, 40. These calculation means consist of a microcontroller which is associated with a memory and is provided with a suitable connection to an outside computer for storage, in the memory, of a data bank including, for each ratio or range of ratios, the name of the most probable corresponding material(s).

The displaying means 35 are capable of directly displaying the ratio that is calculated by the calculating means or, preferably, the name of the most probable corresponding material.

Metallic tube 5 consists of two elements 51 and 52 which are unitary with a thread/tapping 42, 43 so as to constitute a rectilinear tube of identical inner and outer diameters. The first element 51 includes a first part 44 a few centimeters long including a thread 45 and a second part 47 including two oblong openings 48, 49 longitudinally disposed and diametrically opposite one another, and a third part 50 of larger inner diameter D5 and including a tapping 43 capable of cooperating with the thread 42 located on a portion of the second part 52 of tube 5 whose diameter is substantially equal to D5.

Tube 24, disposed between outer tube 5 and inner tube 20, includes two diametrically opposite rods 51, 52 which are disposed perpendicularly with respect to tube 24 and are adapted to cooperate with the oblong openings 48, 49 to constitute a crosshead-slider assembly.

The mode of operation of the means 53 for positioning the median tube 24 is the following:

When rods 51 and 52 abut tube 5, at the rod end side, the latter and tube 24 are in the general shape presented in FIG. 4, with respect to tube 5, namely the ends of tubes 5 and 24 and the first part of rod end 6 are generally shaped so as to substantially constitute a top cone 31 and whose diameter is the same as that of tube 5.

When hollow cylinders 54 and 61 are rotated by an operator along the only possible direction, the rotation causes a displacement of these cylinders in the direction of handle 8, and the second part 63 of the second hollow cylinder then pushes rods 51, 52 in this same direction along a straight line. Since these rods are unitary with intermediate tube 24, the latter is also moved in the direction of handle 8. This displacement of tube 24 allows the three sectors 18, 18, 18, to be released and their ends spread apart from one another under the action of spring 27.

Following this, if the hollow cylinders 54 and 61 are rotated in the other direction by the operator, this rotation will cause a displacement of these cylinders in a direction that is opposite to that of the handle. The end 66 of the first hollow cylinder 54 then pushes the rods 51, 52 and tube 24 in the same direction. This displacement of the tube causes sectors 18, 18, 18, to move closer together, which results in a compression of the spring, due to the conical shape of the end of bore 13, and a progressive return in the general shape illustrated in FIG. 4. Thus, the means 24, 27, 51, 52, 54, 61 constitute a mechanism adapted to move rod end 6 between two extreme positions, in one of which it constitutes the end of the probe, sectors 18, 18, and 18, being adjacent to one another by pairs and defining the first conically shaped first part 9 ending with a tip 116, and where in the other position, the extremities 19 of sectors 18, 18, and 18, are spread apart from one another, the rod end then being of tubular shape, these means being adapted to move at least one part of the sectors in a direction that is perpendicular to that of axis XX of rod 4 while maintaining the first
part 9 of rod end 6 at the end of rod 4 so that it always constitutes the extremity of the probe.

[0074] When a material is located close to the rod end where sectors 18, 18, 18, are in spread apart position, there is made an analysis of its constitution by lighting it with the two diodes 36, 36, and via periphery 32 of the optical fiber 29, which is followed by an analysis of the reflected signal that is picked up by the central part 30 of fiber 29.

[0075] The intensity $I_{\text{reflect}}$ of this signal as reflected by the lighted surface is measured by photodiode 37. It is directly proportional to the integral of the product of the lighting spectral intensity $I_{\lambda}$, of the spectral coefficient of reflection of the object $R_{\lambda}$, of a geometrical factor that characterizes the lighted surface and characterizes the optical flux that reaches surface $A_{\lambda}$, as well as of another geometrical factor $A_{\lambda}$, which characterizes the optical flux that is reflected and is collected by the center 30 of the optical fiber according to the following equation:

$$I_{\text{reflect}} = \int_{\lambda} R_{\lambda} A_{\lambda} d\lambda$$

[0076] The coefficient sought after here is the one that characterizes the material, i.e. the coefficient of spectral reflection $R_{\lambda}$. The lighting spectral intensity being fixed by the electrical signal of excitation of the lighting diodes, the objectionable unknowns are the geometrical factors of lighting and of measurement of the reflected optical flux. As a first approximation, these geometrical factors $A_{\lambda}$, are independent of the lighting wavelength on a narrow range. They are solely dependent on the installation of the probe and of the fiber as well as on the impurities that are present between the lighting source and the material, and between the latter and the measuring fiber.

[0077] The use of the ratio $S$ of the intensity of two signals obtained in different spectral bands by means of diodes of different colors and having a spectral emission band $2\Delta\lambda$, respectively centered on $\lambda_{d}$ and $\lambda_{u}$, allows not to depend on the geometrical factors. There is thus obtained a non-dimensional arithmetic value that characterizes an object that is subject to the lighting flux used or more specifically to its spectral reflection. This ratio is characterized by the following equation:

$$S = \frac{\int_{\lambda_{d}}^{\lambda_{u}} I_{\lambda} R_{\lambda} A_{\lambda} d\lambda}{\int_{\lambda_{d}}^{\lambda_{u}} I_{\lambda} A_{\lambda} d\lambda}$$

[0078] From this value of $S$, two materials each having a characterizing ratio can very simply be differentiated. These ratios may be registered in a dedicated data base that may be completed with in situ established data.

[0079] The oscillograms of the output signal of photodiode 37 obtained by measuring the reflection in blue and red of different materials in photovoltaic mode by means of an oscilloscope of type 54621 A (AGILENT J brand), are represented on FIG. 6. The lighting is obtained with the aid of a LED 36 multi-colors SSL-LX5095S/H254US known under the trademark LUMEX, placed 2 to 3 cm from the surface of the material under study while measurement of the reflected radiation is carried out via the central part 30 of fiber 29 with a diameter of 400 µm and upon near contact with the object (at a distance of 0.1 or 0.2 mm). This LED comprises two diodes 36, 36, which emit at different wave lengths, namely in blue for one of them and in red for the other, and which are supplied by means of sine-wave signal generators respectively at pulse frequencies which are different and non-harmonic, namely 1.2 Hz for one of them and 10.3 Hz for the other with highly diverse amplitudes. The signal obtained with white paper may be considered here as a reference with a constant reflection coefficient in the blue or red in a first approximation.

[0080] Besides this measurement, considered as a standard, there are also represented the signals obtained with a sheet of a clean TMA5 green mine, but also covered with a fine film of soil, as well as that obtained with a leaf of a green plant.

[0081] These different measurements may be considered as representative since no positioning has been carried out between the different elements with respect to the object, thus illustrating the influence of the geometrical factors of lighting and collection. The practical influence of this positioning is to cause a considerable variation of the amplitude of the signal. It has practically no effect on the final result obtained by Fourier transform, FFT, which is an automatic function of the oscilloscope used, followed by establishing the ratio between the signals measured at 1.2 and 10.3 Hz. FIG. 7 shows the signals obtained by Fourier transform of the oscillograms of FIG. 6.

[0082] The oscillograms were decomposed by frequency, each element of sine-wave frequency being quantized in attenuation with respect to a signal of one volt (allowable rms voltage) and represented in attenuation (log (signal/1 volt)). From these values respectively at 1.2 and 10.3 Hz, the ratio of the signal reflected in the blue and in the red can be calculated separately although measurement is simultaneous. The measurement lasts less than one second, which means it is nearly instantaneous. It makes it possible to ignore the geometric coefficients associated with the positioning of the probe or of the measurement fiber with respect to the object as well as the presence of impurities at the surface of the object such as soil.

[0083] The following table summarizes the ratios which correspond to the signal modulated at 10.3 Hz, corresponding to the reflection of light emitted by the red diode, over the one that is modulated at 1.2 Hz which corresponds to the reflection of light emitted by the blue diode.

<table>
<thead>
<tr>
<th>Material</th>
<th>Ratio S</th>
<th>Red/blue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet of white paper</td>
<td>45.71</td>
<td>60.26</td>
</tr>
<tr>
<td>TMA5</td>
<td>61.26</td>
<td>98.86</td>
</tr>
<tr>
<td>TMA5 + soil</td>
<td></td>
<td>129.0</td>
</tr>
</tbody>
</table>

[0084] Example of red over blue signal ratios of some specific materials by FFT

[0085] It is noted that in the case of the measurements that were carried out, a coefficient higher than 100 corresponds...
to a green leaf while a lower value corresponds here to the sheath of a clean TMA5 mine or one covered with a film of organic soil.

[0086] On FIG. 8, there are illustrated reflection spectra of a sheath of a TMA5 mine and green blades of grass as well as the lighting spectrum used for measurements by FFT with a blue diode and a nearly infrared diode (NIR). It is made of the emission spectrum of the blue diode at about 470 nm and of the emission spectrum of the LED NIR at about 880 nm. By multiplying this lighting spectrum with the reflection spectrum, spectral reflectivity curves of the materials under study are obtained, in our case the mine sheath and the grass. A difference of behavior in the near IR between the two materials is easily noted, while they have a similar behavior in the blue. By integrating these two reflection peaks separately and by calculating the ratio according to the principle previously presented, the materials are easily recognized by ignoring the measurement problems. The following table gives some ratios thus measured on different materials. The white standard in spectrolon allows to calibrate the system on the basis of the light intensity of each of the diodes 36, 36, of the measuring system and the spectral response of the photodetector 37 used. The discrimination rate represents these “normalized” ratios with respect to the ratio of the TMA5 mine sheath. The more different they are from 1, the easier is the discrimination. Thus, it is noted that the ratio of a green sheet is from 5 to 6 times greater that that of the mine and will be easily recognizable even though the mine sheath is designed to look like it (green camouflage). In the same manner, wood, which is a source of very possible false signal in the soil, is easily recognizable (ratio 4 to 10 times more intense). One may also notice that the presence of a film of soil on the mine sheath does not cause the measured ratio to vary considerably. It is thereafter noted that the spreading of the sectors in a direction that is perpendicular to axis XX’ of the rod allows to scratch and push the film of soil or sand that is in contact with the surface of the detected object and to thus improve the quality of the analysis.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ratio measured by FFT</th>
<th>Rate of discrimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrolon standard</td>
<td>4.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Green leaf</td>
<td>20.2</td>
<td>6.7</td>
</tr>
<tr>
<td>Shabby green leaf</td>
<td>15.7</td>
<td>5.2</td>
</tr>
<tr>
<td>TMA5 clean surface</td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td>TMA5 covered with soil</td>
<td>4.9</td>
<td>1.6</td>
</tr>
<tr>
<td>PMMA black</td>
<td>6.6</td>
<td>2.2</td>
</tr>
<tr>
<td>Wood perpendicular to fiber axis</td>
<td>11.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Wood in fiber axis</td>
<td>29.8</td>
<td>9.9</td>
</tr>
<tr>
<td>White paper</td>
<td>7.2</td>
<td>2.4</td>
</tr>
</tbody>
</table>

[0087] The examples of applications are not limiting. The use of a diode that emits in the near infrared as well as an optimization of the relative amplitude between the two diodes used, allow a significant increase of this contrast. In theory, this ratio will be at a maximum by selecting a colored diode for which the mines are particularly absorbing, typically the color green, and a spectral band located in a range for which the impurities are reflecting while the mines are clearly more absorbing, for example the near infrared in the case of a discrimination between green mines and green vegetation.

[0088] The two examples that are presented make it possible to have a good appreciation of the interest of a previous selection of the lighting spectral bands. With a red/blue ratio, the discrimination rate between a TMA5 mine sheath and grass is from 1.5 to 2, while it is from 5 to 7 for an infrared/blue ratio.

[0089] Mine clearance of a mine field, using a probe according to the described embodiment, may include the following steps.

[0090] At first, the positioning means of tube 24 are such that the rods 51, 52 abut tube 5 on the opening side that is opposite the handle so that the ends of tubes 5 and 24 as well as the first part of rod end 6 define a cone which ends in a top 31 as shown on FIG. 4. The mine clearance unit may then probe the mine field. When a suspicious object is detected, the mine clearance unit rotates hollow cylinders 54, 61 in a manner that they are moved in the direction of handle 8, this displacement then producing a translation movement of rods 51, 52 and therefore of tube 24. This displacement of tube 24 releases sectors 18, 18, and 18, whose extremities 19 are spread apart under the action of spring 27. By means of a switch not illustrated, the operator then initiates the phase of analysis of the material that constitutes the detected object. The two diodes 36, which are pulsed with a sine-wave tension at different frequencies, both emit a radiation, these radiations being different, each having a narrow frequency band and being non harmonic relative to one another. These radiations illuminate, via periphery 32 of optical fiber 29, the surface of the object and a portion of the radiation that is reflected by the surface of the object is picked up by the center 30 of fiber 29 and is analyzed using the analyzing means as specified previously. The nature of the material that corresponds to the results of the analysis is then displayed on displaying means 35.

[0091] FIG. 9 presents another variant of embodiment of the means for analyzing the nature of a material in which the analyzing means include:

[0092] means 69 for feeding a capillary tube 70 with two pulsed radiations of different spectral bands, these means including a power supply, such as a button cell not illustrated, two diodes 71, 72 such as those previously referred to, which are cast in a plastic envelope of about 5 mm diameter and whose lens was removed and which has been bored in its center to allow for passing a measuring optical fiber 73 therethrough and which is disposed longitudinally according to axis XX’ of rod 4. The diodes are disposed so as to emit a radiation mainly according to axis XX’. According to this same axis, means 74 are disposed for guiding the radiation sent out by the diodes 71, 72 in the capillary tube 70. These means 74 consist of a truncated cone which is made of a material that is transparent in the emission spectral band of the diodes, for example glass, and whose cross-section of larger diameter 75 is disposed opposite diodes 71, 72 while cross-section 76 of smaller diameter is placed opposite capillary tube 70 and is of slightly smaller size than the diameter of the capillary tube 70. This truncated cone 74 is longitudinally bored in its center to allow the measurement optical fiber 73 to extend therethrough. The capillary tube 70 extends from the end 76 of the truncated cone to reach the end of bore 13. In this embodiment, the
The means for generating a laser radiation have a radiant flux of the order of 10 to 20 Watt.

When the means for destroying the mine are set up, the operator may then initiate laser firing. In the presence of an oxidizing gas, the laser radiation initiates combustion of the object, which combustion is controlled by regulating the concentration of oxygen of the covering gas. An analysis of the gases sampled by capillary 105 allows some one to follow the evolution of this combustion. When the detonator of the mine is heated, it detonates, however it is in the presence of a highly reduced charge thus limiting the damages produced.

The first tests made with buried PVC made it possible to validate this combustion process of a buried organic object after installing the probe. Punching an envelope a few millimeters thick may be carried out by laser radiation in the presence of a gas with a low concentration of oxygen in order to reach the explosive contained therein. The latter is then vaporized and possibly analyzed by mass spectrometry in gaseous phase with a known portable system which is used for detecting vapors of an explosive material. Infrared reflection optical spectrometry may also be used by utilizing infrared optical fibers of 2 to 6 μm or fibers with a wider transmission band such as for example 3 to 30 μm, knowing that an infrared spectrum of 2 to 15 μm may be considered as a typical means of chemical analysis. This fiber type may obviously be introduced into an optical probe according to the invention.

The main advantage of the invention is to improve the working method of the mine clearance operator, this method being accessible to a mine clearance operator who has not received an extensive scientific training. Moreover, this method strongly limits the problems closely related to blasting charges (transportation, safety, risks of diversion) since it does not involve any added explosive material.

Since all the elements that are used are easily transportable, the method can be optimized in the form of a mine clearance station that is not self propelled and portable and whose cost is low. In view of the first tests made, the same probe may be used a plurality of times, which limits the price per unit of the operation.

Another notable advantage of this proposal resides in the acceleration of the operation of mine clearance, since once the suspicious object is localized, the mine clearance operator may analyze it in a few seconds without having to evacuate the other mine clearance operators to a safe distance, nor to take some risk himself, nor to remove or add a complementary device to the probe.

Tests were made in the course of which the probe described above was used first as a mechanical mine clearance probe and then as a reconnaissance and neutralization probe or for the destruction of a pseudo-mine, possibly PVC cylindrical blocks (l: 40 mm; h: 55; t: 5 mm) buried under ten centimeters of sand.

The choice of sand as test medium is justified because of the strong likelihood of facing problems associated with possible reappearance of sands that could damage the probe.

After having detected an object, and having analyzed that a PVC block is at issue, the first element of tube
and the elements that are fixed thereto were removed and the destroying means 102 were then put in, and the laser can then be ignited and the behavior of the target can be observed.

[0107] The PVC blocks which are buried under ten centimeters of sand were successively irradiated after having placed the probe in contact therewith. The conditions of irradiation used are for a power supply transmitted by the fiber of 10 W (20 W during the injection) and for irradiation times of 40 seconds (first target) and 30 seconds (second target) in the form of a single impulse.

[0108] Already during the opening of the stop valve of the covering gas, sand was agitated above rod end 5a of the probe, a phenomenon that is comparable to the one used in “fluid beds”. After a few seconds of irradiation, black fumes produced by pyrolysis of PVC were released at the surface of the sand. The ashes emitted in this fume have rapidly become incandescent under the action of a sudden runaway of the PVC combustion.

[0109] This runaway of the combustion goes on to the extent of obtaining a phenomenon that is similar to a mini volcanic eruption by projecting many fragments and crystals of incandescent sand through a hole at the surface of the sand.

[0110] When the oxygen feed is stopped, combustion of residual PVC stops rapidly.

[0111] However, because of the strongly elevated combustion that is reached at the level of the buried target, and since sand constitutes in a way a heat insulating oven, nearly all the PVC, a material known as being strongly fire resistant even in free air, could be burnt under the sand after a few seconds of irradiation and a few minutes of combustion.

[0112] Many modifications could be brought about to the invention without departing from the domain of the invention. Thus rod end 6 could include more than three sectors, for example two or four, or even more. Moreover, a large number of techniques for analyzing a material may be associated with a probe according to the invention such as for example:

[0113] spectrometric analysis of the reflection spectrum in white light;

[0114] analysis of the reflection signal, so called “hyper spectral” in white light, with selection of spectral bands in the reflected signal by means of a spectroscopic system;

[0115] study of the fluorescence of the lighted surface induced by a blue or UV monochromatic lighting.

[0116] On the other hand, the means for positioning tube 24 may be of different shapes, such as those of FIG. 12 where the first or second hollow cylinders of the embodiment described previously have been replaced by a spring 110 which is disposed longitudinally with respect to axis XX' and which rests on one side on handle 8 and on the other side on tube 24 in which the rods 111, 112 which are unitary therewith, abut against one of the ends 113 of the oblong openings provided in tube 5. To allow for the spreading apart of the sectors 18a, 18b, and 18c, in order to give a tubular shape to the rod end, it is only necessary that the operator pulls the rods in the direction of the second end 114 of the openings and then releases the rods as soon as the analysis has been completed. In this embodiment, a contactor, disposed against the second end 114 and associated with the means for feeding the diodes, initiates the analysis of the material that constitutes the detected object.

[0117] According to another non illustrated embodiment, tube 24 may constitute with a single tube with tube 5, and tube 20 may be fixed to the handle by means of a spring longitudinally disposed and may include at least one rod which extends beyond an opening provided in tube 5. As when it is at rest, through this spring, the rod abuts against end 114 of the closest opening of handle 8, and its displacement by an operator in the direction of the rod end produces a forward displacement of the latter and a gap of a part of sectors 18a, 18b, and 18c, either through the pressure of a spring as shown on FIG. 4, or because of the resiliency of the material that constitutes the sectors. However, a prior retraction of the probe for a few millimeters is required in order to permit the advancement of rod end 6 in the direction of the object.

[0118] Moreover, means for injecting a gas, for example nitrogen, or even air, may be provided to clean the portion of the partition of the object, that is being analyzed. Moreover, the means for fixing the second element 5, of tube 5 to the first element 5, or to element 5, may consist of a simple fitting member or a clippable system or any equivalent system, the above systems operating only by translation to facilitate the mounting of the destroying means 99.

[0119] FIGS. 13, 14a and 14b give an example of another embodiment of the invention in which tube 5 is fixed to body 200a, 200b of handle 201. A first movable tube 202 is inserted inside tube 5 and a second movable tube 203, in which there is provided an optical fiber, is inserted inside tube 202. Inside handle 201, the first and second movable tubes 202 and 203 are respectively fixed to a first and second cylinder 204, 205, the axes of these cylinders being co-linear with the axes of the movable tubes, elements 203, 202 and 204 being disposed concentrically. Each of these cylinders include a thread, respectively 206, 207 on their outer surface and each is associated with a threaded ring 208, 209 in which the thread corresponds to that of the cylinder that is associated thereto. The pitch of thread 207 of the second cylinder 205 to which the second tube 203 is fixed is greater than that of the first cylinder 204 to which the first tube 202 is fixed.

[0120] These rings 208, 209 are fixed together for example by gluing or screwing, so that when one of them is displaced, the other is also displaced.

[0121] The displacement by translation of these rings is limited on the one side by the body 200a of handle 201 and on the other side by a counter ring 210 that is screwed inside body 200b of handle 201.

[0122] The lateral surface 211 of the body of the handle includes an opening giving access to at least one part of the rings 208, 209 and thus allowing them to be set into rotation. On the other hand, a rod 212 passes through a portion of body 200a of handle 201, cylinders 204, 205 and counter ring 210, according to an off centered axis. Its aim is to force the cylinders to be displaced in translation when the rings are set in rotation.

[0123] For a question of clarity, the analyzing means described above are not illustrated in this figure.
FIGS. 14a and 14b show the evolution of movable tubes 202 and 203 and of the rod end of the probe before and after the threaded rings 208, 209 are set in rotation.

A rod end 213 is fixedly mounted at the end of the first movable tube 202. This rod end includes a second tubular part 214 which flares and is fixed to the first movable tube 202, and a first part 215 that is conically shaped, is hollow, is longer that the second part and is fixed to the latter. The rod is terminated by a tip 216. The first part 215 of rod end 213 includes four slots 217 that are regularly distributed thereby delineating four sectors 219. At the level of its extremity, on the side of rod end 213 and interiorly thereof, tube member 5 includes a bevelled part along its entire circumference thereby defining a truncated surface 226 that is adapted to follow the surface of the second part 214 of the rod end.

As shown on FIG. 14a, in so called rest position, the end of the probe shows a continuity between the external surface of tube 5 and the first part 215 of rod end 213, while, as shown on FIG. 14b, the setting up in rotation of the threaded rings 208, 209 has caused a displacement in translation of the cylinders 204, 205 and therefore of the ends of the first and second movable tubes 202, 203 with respect to fixed tube 5. Bearing in mind the difference in pitch of the threads 206 and 207, cylinder 205 and the second tube 203 that is fixed thereto, are displaced in translation on a distance d+1 which is greater than the distance of displacement d of the first cylinder 204, the associated tube 202 and the rod end 213. Thus, on the one hand the distance of displacement d of rod end 21 is sufficient to release its second part 214 from the end of tube 5, and on the other hand, the distance of displacement d+1 of the second movable tube 203 is sufficient to cause a displacement of the ends 218 of sectors 219 of rod end 213 along a direction that is perpendicular to that of the displacement of the second movable tube 203. Obviously, the movement of the first and second movable tubes is reversible by simple setting up in rotation of the threaded rings 208, 209 in reverse direction. As explained in the embodiment above described, a spectral analysis may be carried out when the ends 218 of sectors 219 of rod end 213 are spread apart as shown on FIG. 14b.

Although the present invention has been described by way of an illustrative embodiment and example thereof, it should be noted that it will be apparent to persons skilled in the art that modifications may be applied to the present particular embodiment without departing from the scope of the present invention.

What is claimed is:

1. An optical mine clearance probe comprising: a handle that is extended through a rod having a geometrical axis and adapted to be driven into a soil to search through it and including a first tubular part, a second part consisting of a movable rod end part including slots adapted to constitute at least two sectors and a mechanism for displacement of the movable rod end between two extreme positions, one of which being one where a part of the rod end constitutes an extremity of the probe, the at least two sectors being adjacent one another in pairs and defining a conical member ending with a tip, and the other position being one in which extremities of the at least two sectors are spread apart from one another, the rod end then being of tubular shape, wherein the mechanism is capable of displacing at least a part of at least one of the sectors in a direction that is different from that of the geometrical axis of the rod while maintaining the part of rod end at the end of the rod so that it always constitutes the extremity of the probe.

2. A mine clearance probe according to claim 1, wherein the rod end includes, while in its first position, at least one first part of conical shape ending with a tip and a second part of truncated shape widening in the direction of the first part and the mechanism includes a tubular member whose end includes, in an interior part thereof, a bevelled part along its entire circumference so as to constitute a truncated surface capable of following that of the second part of the rod end.

3. A mine clearance probe according to claim 2, wherein the rod includes an exterior hollow tube member and a second hollow tube member disposed between the exterior tube member and the rod end and including at one of its extremities and in an inner part thereof, a bevelled part that extends along its entire circumference so as to form a truncated surface that is capable of engaging with the second part of the rod end.

4. A mine clearance probe according to claim 3, wherein the second tube member is movable in translation along the geometrical axis of the rod.

5. A mine clearance probe according to claim 1, wherein the mechanism includes a first tube member that is unitary, at one of its ends, with the rod end and, at the other end, with a cylinder whose peripheral surface includes a first thread adapted to cooperate with that of a first threaded ring and to which are associated a first guide member for guiding the first cylinder in translation, the first guide member being adapted to force the first cylinder into a translation displacement when the first threaded ring is set into rotation.

6. A mine clearance probe according to claim 5, wherein the first guide member is a rod.

7. A mine clearance probe according to claim 5, comprising a second tube member, disposed inside the first tube member, that is unitary at one of its ends, with the rod end and at the other end with a second cylinder whose peripheral external surface includes a second thread adapted to cooperate with that of a second threaded ring and to which are also associated a second guide member for guiding the second cylinder in translation, the second guide member being adapted to force this cylinder into a translation displacement when the second threaded ring is set into rotation.

8. A mine clearance probe according to claim 7, wherein the second guide member is a rod.

9. A mine clearance probe according to claim 7, wherein the first and second guide members consist of a single rod.

10. A mine clearance probe according to claim 7, wherein the first and second rings are integral with one another.

11. A mine clearance probe according to claim 7, wherein the pitch of the second thread is larger than that of the first thread.

12. A mine clearance probe according to claim 12, comprising at least one optical fiber that extends at least in part through the rod end.

13. A mine clearance probe according to claim 1, wherein the at least one optical fiber is selected from a group consisting of a multifilaming optical fiber, an optical fiber with a capillary disposed, at least in part, around it and an optical fiber with at least one additional optical fiber disposed, at least in part, around it.
A mine clearance probe according to claim 13, comprising a generator of at least two pulsed radiations of different wave lengths and different and non harmonic pulse frequencies.

A mine clearance probe according to claim 13, wherein the generator includes diodes.

A mine clearance probe according to claim 14, comprising an analyzer of a radiation.

A mine clearance probe according to claim 16, wherein the analyzer includes a photodiode.

A mine clearance probe according to claim 1, comprising display means.

A method for the identification of a material for use with a probe according to claim 1, the method comprising: emitting at least two pulsed radiations of different wave lengths and of different and non harmonic pulse frequencies in the direction of the material, in order to irradiate same.

A method according to claim 19, comprising collecting part of the radiation that is reflected or emitted by the material following its irradiation with the at least two radiations and analyzing the reflected or emitted radiation.

A method according to claim 20, comprising calculating a ratio between an intensity of the reflected or emitted radiation that is associated with one the at least two radiations and an intensity of the reflected or emitted radiation that is associated with the other of the at least two radiations.

A method according to claim 21, comprising associating a name of a material with the value of the ratio.

A method according to claim 21, comprising associating a symbol of a material with the value of the ratio.

A method according to claim 24, comprising displaying an information that is representative of the ratio.

A method according to claim 24, wherein the information is selected from a group consisting of the ratio itself, a name of a material and a symbol of a material.

An optical mine clearance probe comprising: a handle that is extended through a rod having a geometrical axis and adapted to be driven into a soil to search through it and including a first tubular part, a second part consisting of a movable rod end part including slots adapted to constitute at least two sectors and means capable of displacing the movable rod end between two extreme positions, one of which being one where a part of the rod end constitutes the extremity of the probe, the sectors being adjacent one another in pairs and defining a conical member ending with a tip, and the other position being one in which the extremities of the at least two sectors are spread apart from one another, the rod end then being of tubular shape, wherein the means are capable of displacing at least a part of at least one of the sectors in a direction that is different from that of the geometrical axis of the rod while maintaining the part of the rod end at the end of the rod so that it always constitutes the extremity of the probe.

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