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Haas et al.

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(54) **PORTABLE TESTER FOR DETECTION EXPLOSIVES, DRUGS AND CHEMICALS BASED ON CREATED COLOR BAR CODES FOR ANALYTES**

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G01N 21/84 (2006.01)
G01N 31/22 (2006.01)

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CPC ***G01N 21/8483*** (2013.01); *G01N 31/22* (2013.01)
USPC **422/402**; 422/403; 422/404; 422/420; 422/423

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CPC D06Q 1/10; D06Q 1/00; D06Q 1/06; D06Q 1/02; C11D 11/007; C11D 11/0058; C11D 3/37; C11D 3/3715; C11D 3/3726; C11D 3/3749; C11D 3/0031; C11D 3/40; B41M 7/00; B41M 7/009; B41M 7/0027; B41M 7/0072; B41M 7/0081; B41M 5/025; B41M 5/0256; B41M 5/03; B41M 5/04; B41M 5/0023; B41M 5/52; B01J 2219/00385; B01J 2219/00612; H01L 41/0805; H01L 41/18; H01L 41/314; G01N 29/0609; G01N 31/22
USPC 422/102.2
See application file for complete search history.

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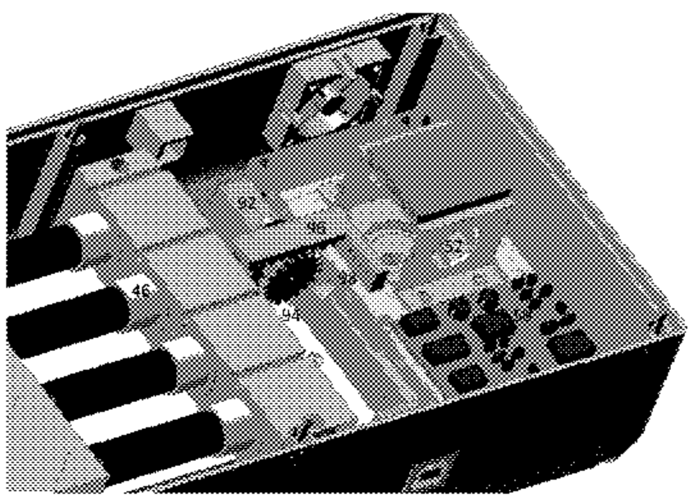
(57) **ABSTRACT**

A portable tester to detect one or more analytes from explosives, drugs, or household chemicals, comprising: a plurality of chemical disposable, detachable reagent reservoirs storing reagents to induce a series of color reactions, wherein developed color depends on sequences of applied reagents to respective pads on a support base, reaction times and temperatures on said pad to create one or more color bar codes for a specific analyte. The tester comprises a piezoelectric dispenser coupled to each respective reservoir to dispense a mist of reagent onto respective test pads to increase sensitivity and reduce reaction heat and time; wherein piezoelectric dispenser is processor controlled to control dispensing time and volume in each step. The tester also includes a programmable digital camera system for imaging and data collection at specific times, temperature, and applied reagents for analysis by the processor, and a processor to interpret resulting changes in color codes of the test pads throughout the analysis occurring at specific times, temperature, and applied reagent and to identify or characterize the type explosive or class of explosives, clandestine drugs, or household chemicals.

34 Claims, 10 Drawing Sheets



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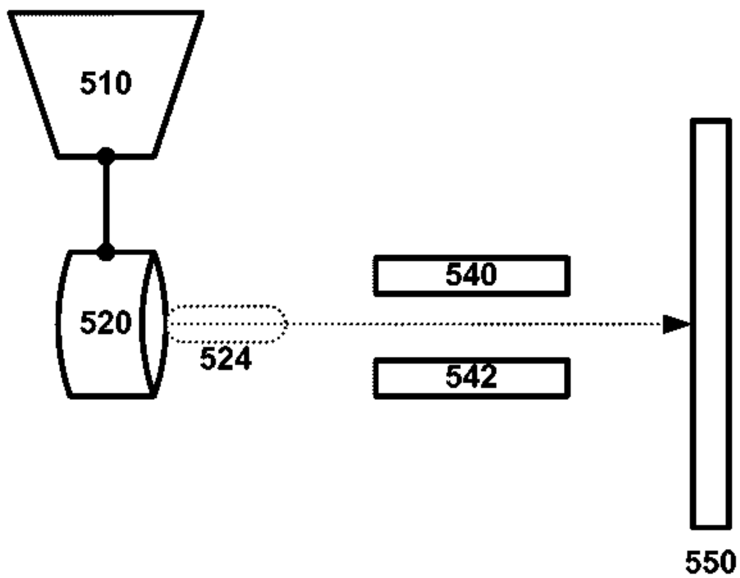


FIG. 1A

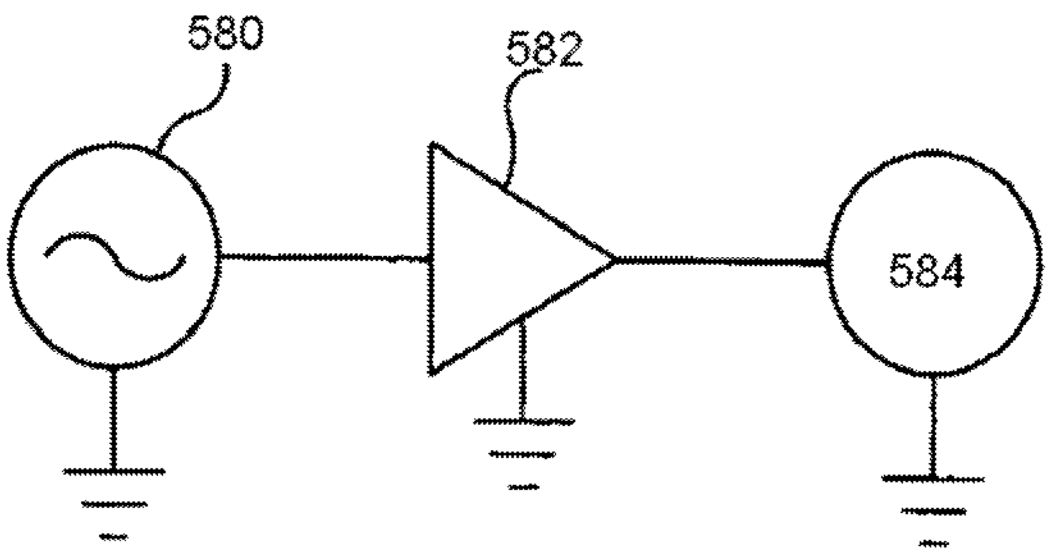
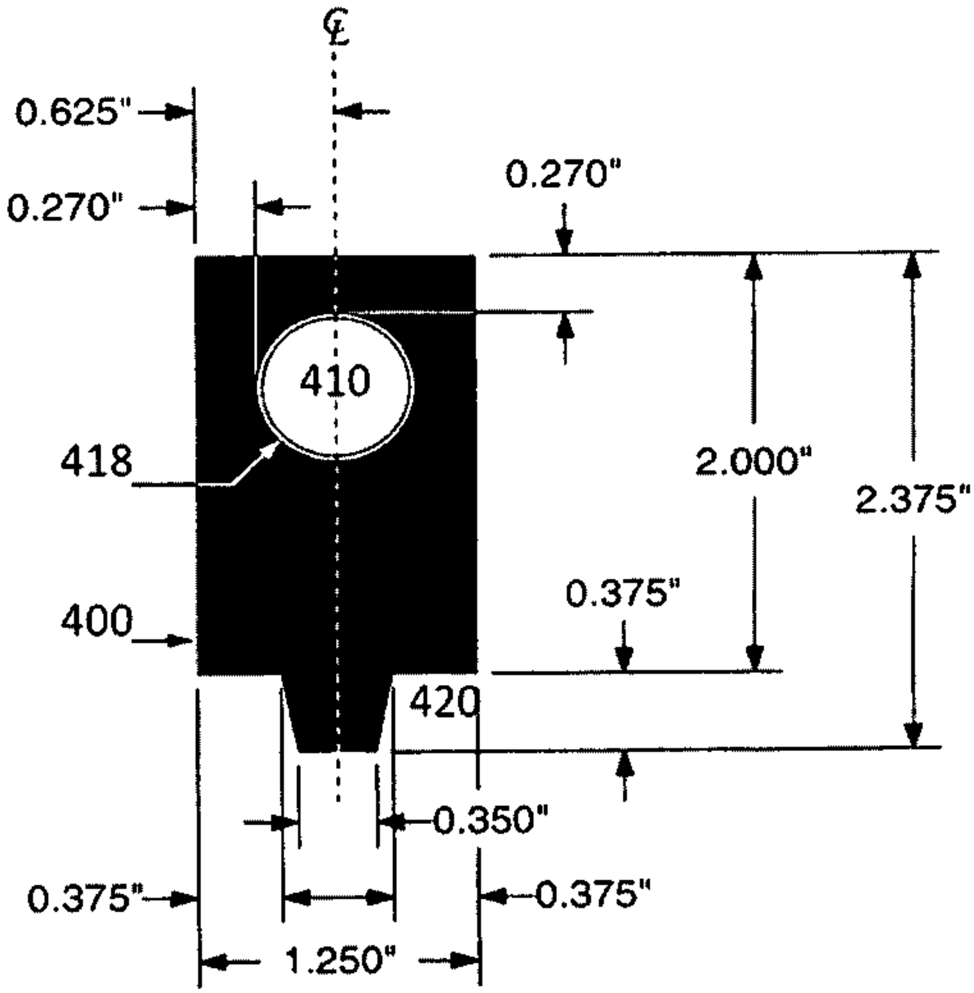


FIG. 1B


℄
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0.270"
0.270"
410
418
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2.375"
0.375"
400
420
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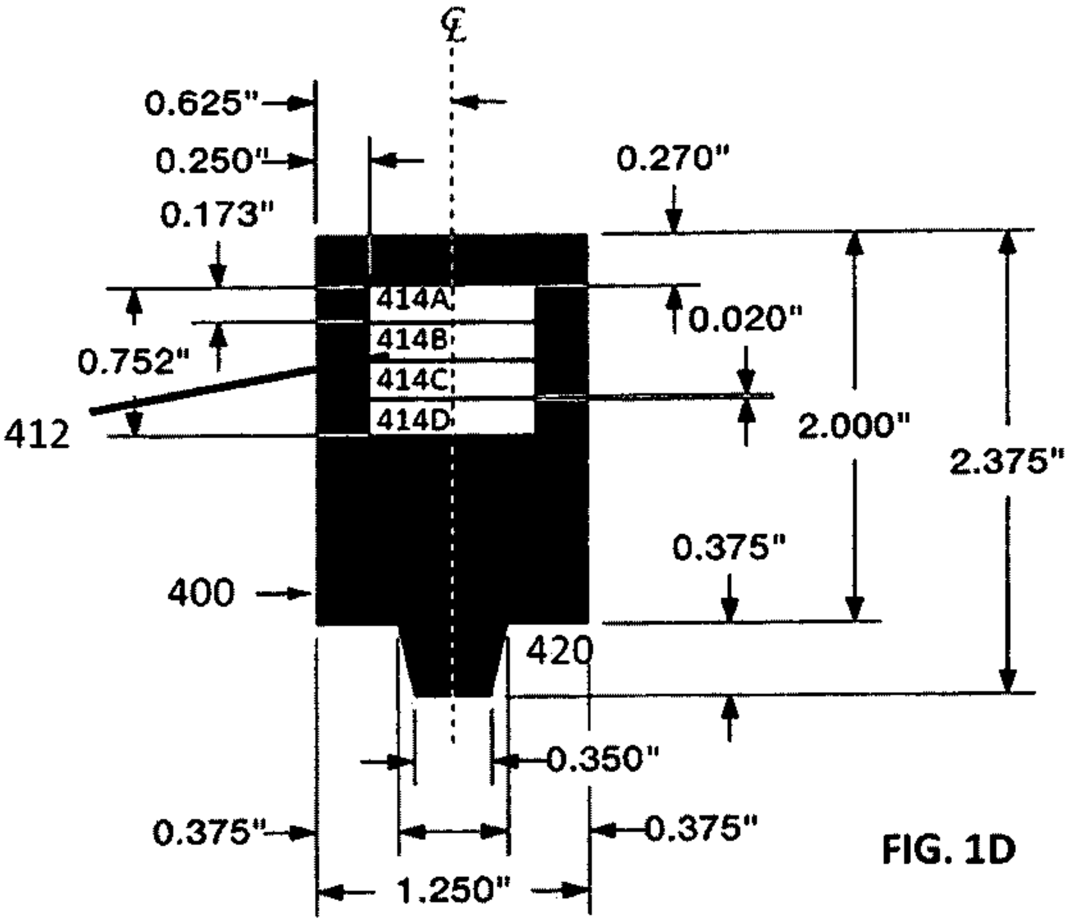
0.375"
1.250"

FIG. 1C



0.625"
0.250"
0.270"
0.173"
414A
414B
414C
414D
0.020"
0.752"
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2.375"
0.375"
400
420
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0.375"
0.375"
1.250"

FIG. 1D

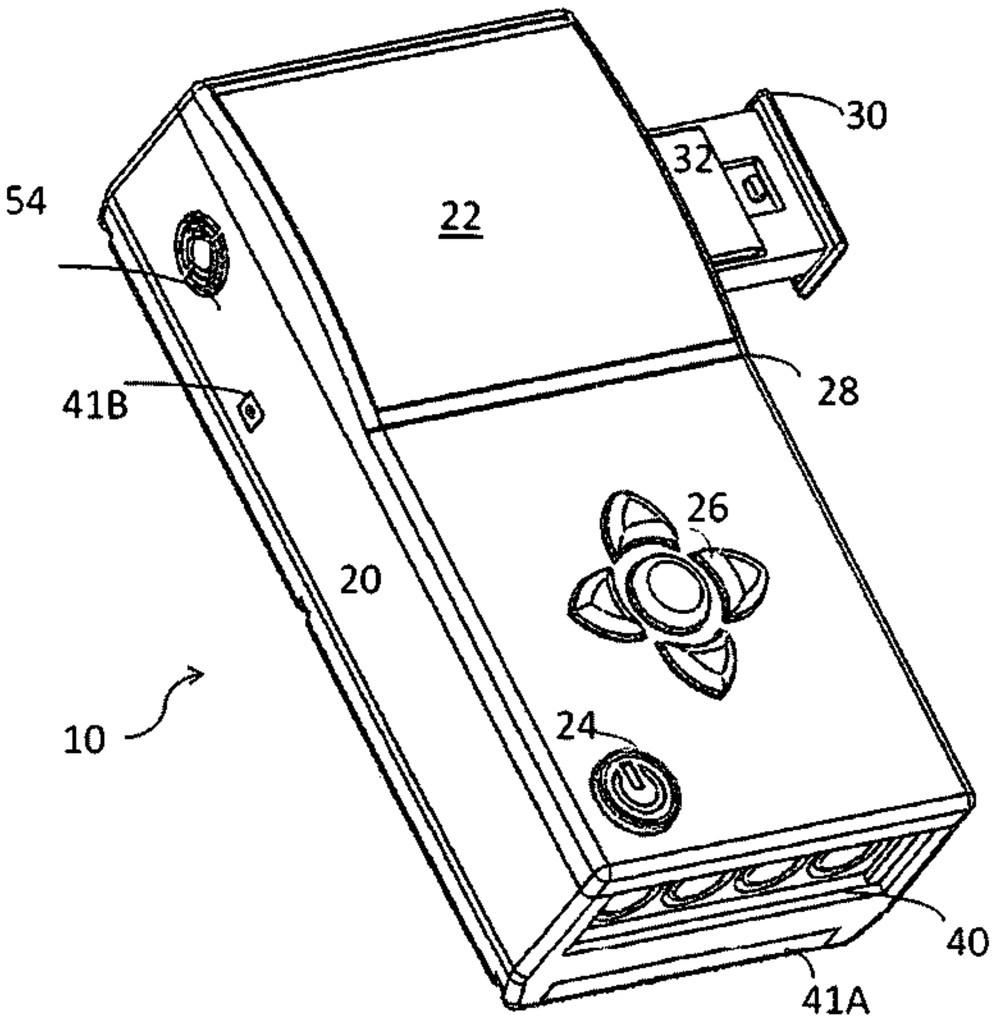
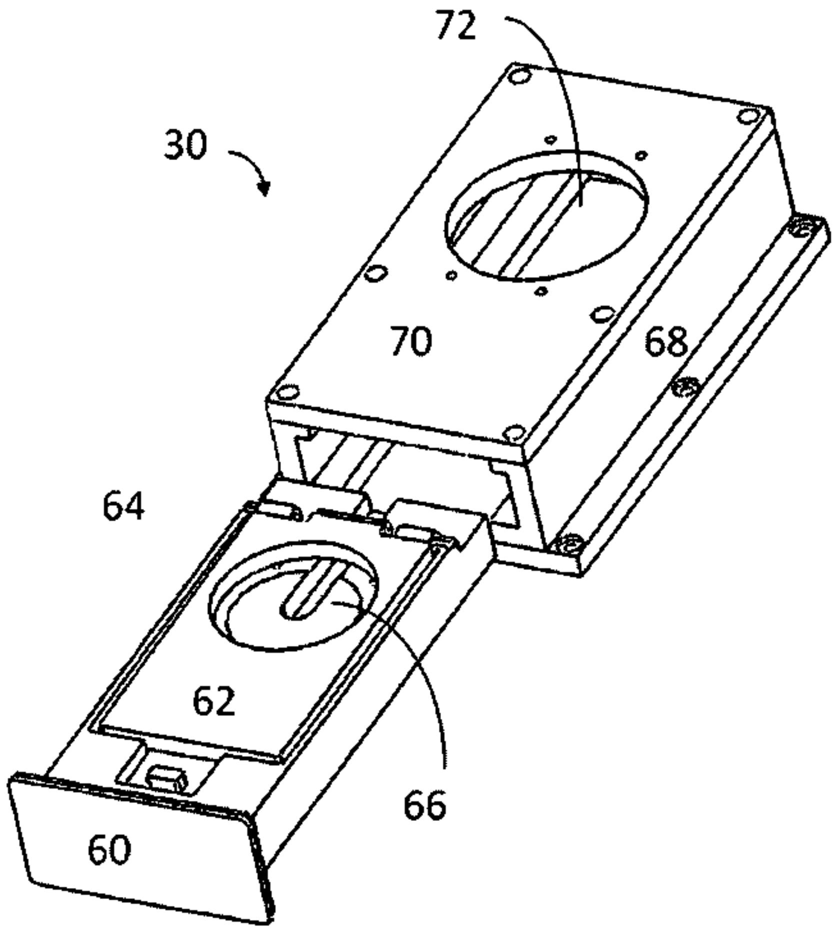


FIG. 2

FIG. 3



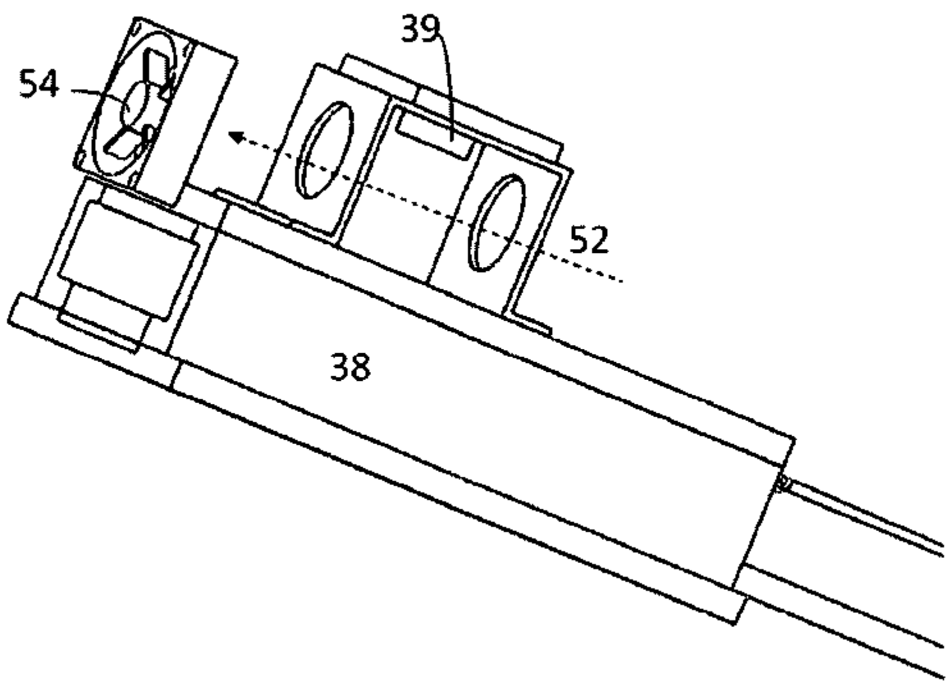


FIG. 4

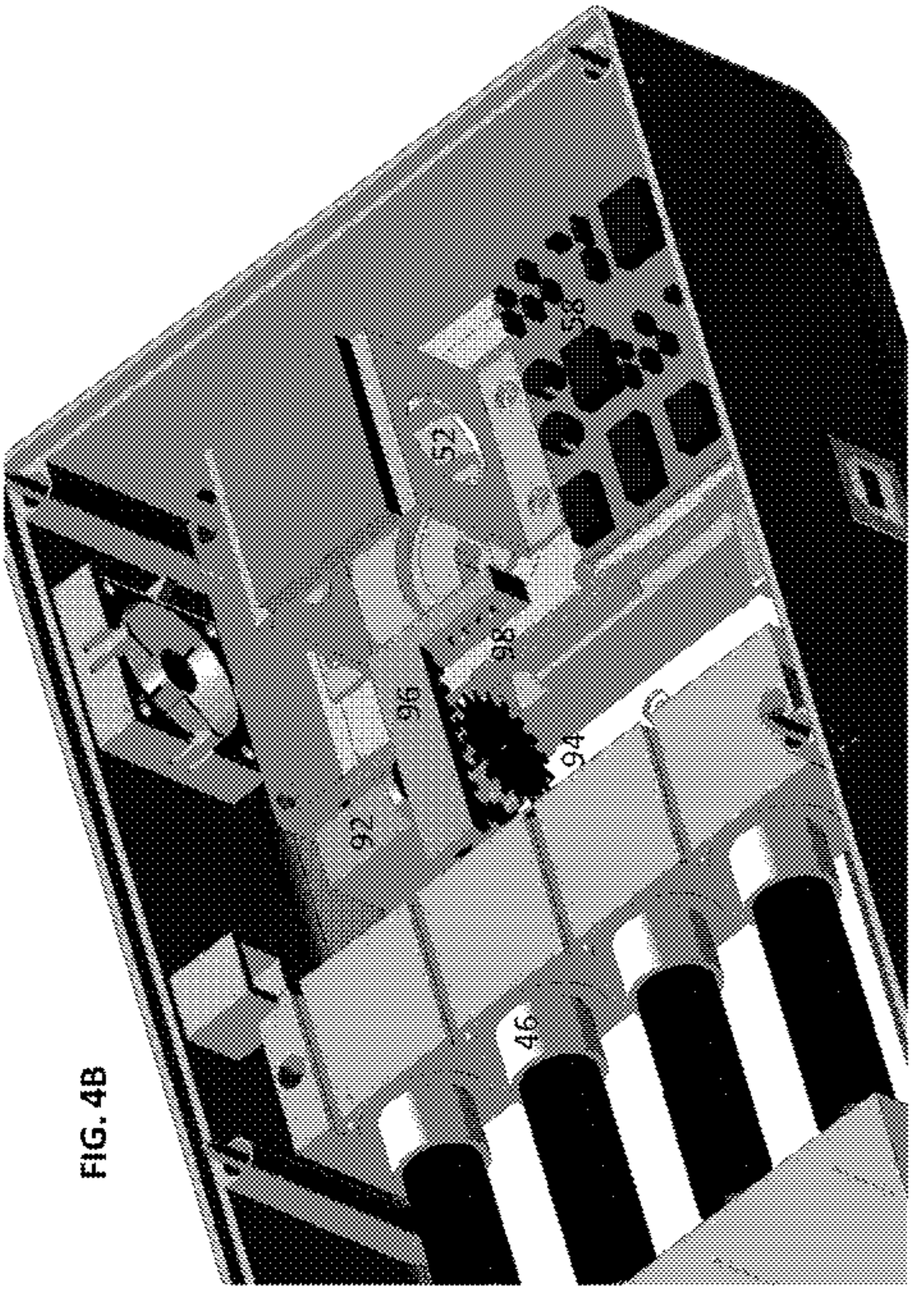
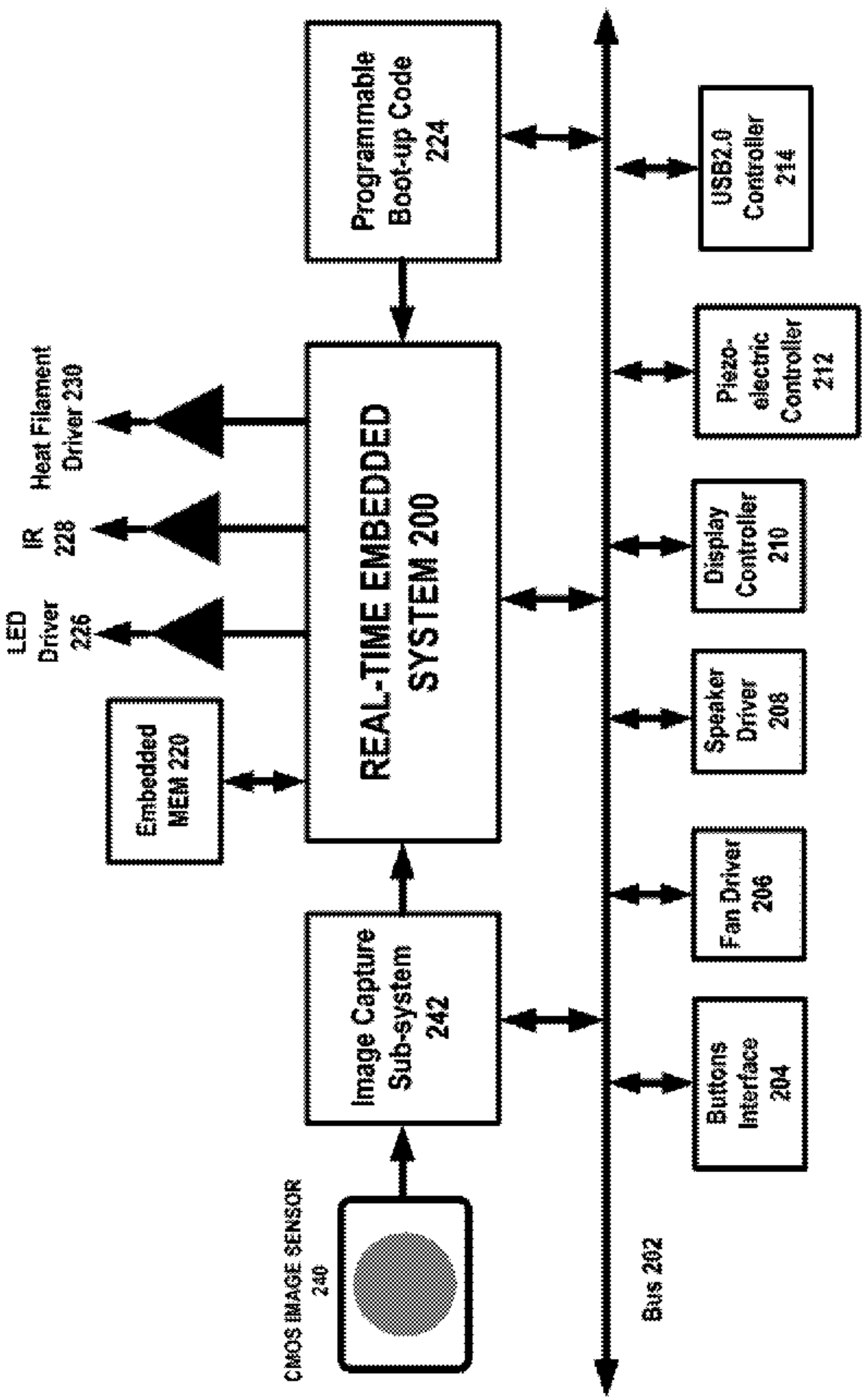


FIG. 4B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REAL-TIME EMBEDDED SYSTEM 200
Image Capture Sub-system 242
CMOS IMAGE SENSOR 240
Embedded MEM 220
LED Driver 226
IR 228
Heat Filament Driver 230
Bus 202
USB2.0 Controller 214
Piezo-electric Controller 212
Display Controller 210
Speaker Driver 208
Fan Driver 206
Buttons Interface 204

FIG. 5

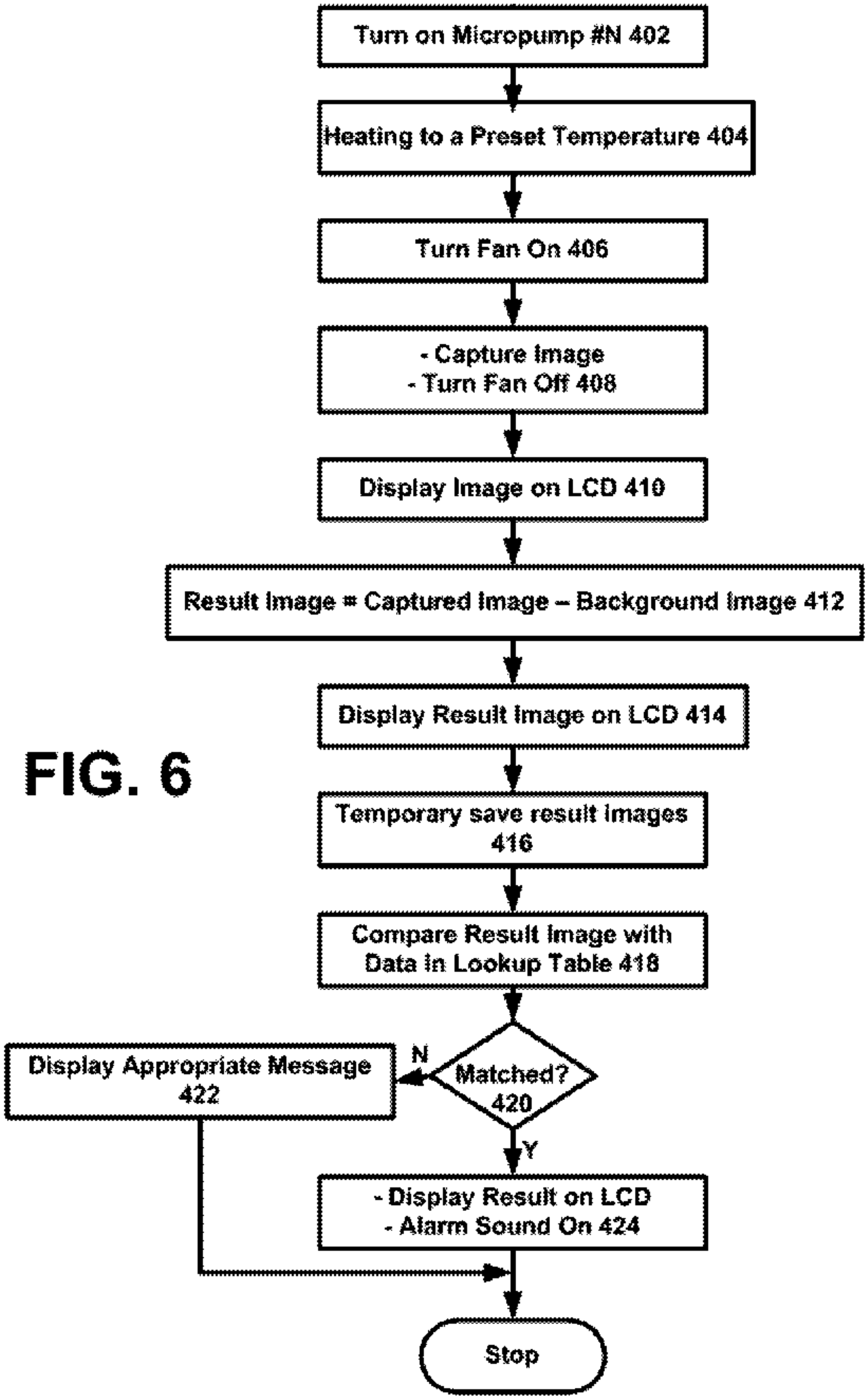
Turn on Micropump #N 402
Heating to a Preset Temperature 404
Turn Fan On 406
- Capture Image
- Turn Fan Off 408
Display Image on LCD 410
Result Image = Captured Image – Background Image 412
Display Result Image on LCD 414
Temporary save result images 416
Compare Result Image with Data in Lookup Table 418
Matched? 420
N
Y
Display Appropriate Message 422
- Display Result on LCD
- Alarm Sound On 424
Stop

FIG. 6

PORTABLE TESTER FOR DETECTION EXPLOSIVES, DRUGS AND CHEMICALS BASED ON CREATED COLOR BAR CODES FOR ANALYTES

BACKGROUND

This invention relates to systems for the detection of explosives and other controlled substances such as drugs or narcotics as well as other chemicals used in clandestine activities.

Recent terror attacks have changed the dynamics of the explosive detection systems across the globe. Terrorists, acting singly or in concert, instill immense fear and apprehension in civilians and governments alike with their technical knowledge about explosives. In parallel, the world has experienced an increase in the transportation of contraband substances such as drugs or narcotics.

With advances in explosives technology, such as the advent of the plastic explosives, which can be disguised as common items, it is becoming increasingly difficult to detect these substances. The problems that must be overcome in the detection of these substances as well as others, include low vapor pressure of the particular vapors escaping from the particular substance, the search time and the throughput of the various systems, the low concentration of vapor or particulate emissions from the particular substance, isolation of the particular substance with a high degree of reliability, and maintaining the integrity of the systems environment.

Various techniques for detecting substances such as explosives and drugs or narcotics have been developed, ranging from explosives/drug sniffing dogs to highly sophisticated vapor detection devices. Machine detection of the aforementioned substances can be accomplished through non-vapor detection or vapor detection. Non-vapor detection methods include x-ray detection, gamma-ray detection, neutron activation detection and nuclear magnetic resonance detection. These methods of detection are more applicable to the detection of the various substances when the substances are concealed and are carried or associated with non-living items such as baggage as these techniques might pose a threat to living items. Vapor detection methods include electron capture detection, gas chromatography detection, mass spectroscopy detection, plasma chromatography detection, bio-sensor detection and laser photo-acoustic detection. These methods of detection are more applicable to the detection of substances that are concealed and associated with living specimens.

Conventional systems tend to be large and immobile. Further, current systems can require users to manually apply toxic chemicals as testing agents. As a result, conventional systems are not mobile and hard to use. Hence, their adoption for field use has been limited.

SUMMARY

In one aspect, a tester includes a chemical reservoir; a piezoelectric dispenser coupled to the chemical reservoir to dispense a uniform thin layer mist of chemicals to increase sensitivity and reduce reaction times; and a test swipe adapted to receive the mist of chemicals, including a base; one or more chemically treated pads positioned above the base; and a tab attached to one side of the base.

Implementations of the above aspect may include one or more of the following. The chemically treated pad can be a substantially round shape. A sequence of one or more chemicals can be delivered to the pad to detect an explosive compound. Each chemical causes the pad to display a color

unique to the explosive compound. The sequence of chemicals are deposited onto the pad at predetermined times. The sequence of chemicals is deposited onto the pad at predetermined temperature range(s). The sequence of chemicals is deposited onto the pad at predetermined hold time(s) each at predetermined temperature range(s). Each chemical deposited under predetermined time and temperature conditions reacts to a specific explosive or class of explosives to yield a specific color unique to that explosive. The color is interpreted by the algorithms at specific times, temperature and chemistry to identify or characterize the explosive or class of explosives. The chemically treated pad can be a substantially round shape and adapted to receive a sequence of one or more chemicals to detect an explosive compound. The base can have a dull black color. The pad region can be a cloth with an ink free border.

The chemically treated pad can also be a substantially four-sided shape. One or more chemicals can be deposited onto their respective pads to detect one or more drug compounds. Each chemical causes the pad to display a color unique to the explosive compound. The sequence of chemicals are deposited onto their respective pads at predetermined times. The sequence of chemicals are deposited onto the pad at predetermined temperature range(s). The sequence of chemicals are deposited onto the pad at predetermined hold time(s) each at predetermined temperature range(s). Each chemical deposited under predetermined time and temperature conditions reacts to a specific explosive or class of explosives to yield a specific color unique to that explosive. The chemically treated pad can be a substantially four-sided shape and adapted to receive a sequence of one or more chemicals to detect a drug compound. The chemically treated area can have a plurality of test regions. A plurality of unique chemical solutions can be deposited on each test region generating a unique color of the respective pad. The pads collectively generate a unique color pattern or code for a particular drug or class of drugs. The chemical solutions can be deposited separately or at same time to the respective test regions on the swipe. The base can have a dull black color. The pad region can be a cloth positioned on a zone of the base that is white in color an inert ink free border.

In another aspect, a method to analyze a swiped sample to identify a chemical composition, includes clamping a test swipe under a camera and above a heater, the test swipe having a base; a chemically treated pad containing the swiped sample positioned above the base; and a tab attached to one side of the base; actuating a piezoelectric transducer that deposits a uniform, thin-film of a series of chemical solution agents into the swiped sample area without dripping so that the device may be held at any angle of position or orientation; heating the swiped sample to one or more predetermined temperatures at a controlled rate and hold times to optimize and accelerate the chemical reactions; capturing one or more images of the chemical reaction; sending the images to the a display screen for operator observation; and analyzing the images to identify the chemical composition based on a chemical reaction and sequence of occurrence and database.

In yet another aspect, a portable handheld chemical analytical apparatus that analyzes a test swipe for chemicals such as household, drug, and clandestine, and explosive chemicals is disclosed. The apparatus includes a heater to warm the test swipe to a predetermined temperature; a clamp to secure the test swipe to the heater; one or more piezoelectric actuators connected to a chemical reservoir to dispense one or more chemicals onto the test swipe; a fan to circulate chemical vapors rising from the test swipe; and a camera to capture an image of the test swipe for analysis.

In another aspect, a method to analyze a swiped sample to identify a chemical composition, includes piezoelectrically dispensing a series of chemical solution agents into the swiped sample; heating the swiped sample to one or more predetermined temperatures at a controlled rate to accelerate and optimize the chemical reactions or a series of chemical reactions reproducibly; capturing one or more images of the chemical reaction; sending the images to the a display screen for operator observation; and analyzing the images electronically to identify the chemical composition in an unbiased fashion based on a chemical reaction database.

Advantages of the system may include one or more of the following. The system tests the presence of chemical materials or compounds using a number of factors or parameters singly or in concert. The factors can include heat, volume, time, temperature, and vapor control, among others and sequences these factors over time. The sequences can be in unique intervals. As a result, the system is highly reliable color results from specific reaction chemistry under the controlled parameters and reduces "false positives" due to its multi-factor, multi-step diagnostic operations.

The piezoelectric dispenser is accurate, can operate in any orientation, requires low power, and small in size. The reaction chemistry fluid can be maintained at ambient pressure and the piezoelectric transducer is used to create micron sized droplets. The fluid source cannot be contaminated by the sample substrate, as is the potential with other transfer touching methods and also providing accurate and complete coverage dispensing of the entire surface area of the swipe. Further, the ability to free-fly micron sized droplets of the reacting chemistry over short distance allows fluids to be dispensed in a uniform, thin layer greatly increasing sensitivity for threat chemicals such as explosives, drugs, and other threat materials collected on the swipe by not diluting the threat material with a large volume of reacting chemical. Finally, the uniform thin layer deposited onto the swipe material greatly reduces analysis time since there is less reacting chemical to heat. The device significantly enhances the possibility of accurately and quickly screening personnel, equipment, and materials at security checkpoints, military operations, law enforcement, or other screening scenarios, and for detecting trace explosive materials, night or day, very high humidity and bad-weather conditions. The system allows users to precisely and quickly detect different explosive chemical agents.

The system operates in a real-time fashion. It automatically dispenses a precise volume of chemical solutions over time when requested. The system optionally allows users to manually control the sequence of the pumping and piezoelectric transducer dispensing process. The system provides users with pump controls for dispensing chemical solutions. Through the built-in heater, the system automatically heats up the swiped sample to predetermined temperatures over specific time parameters using an automatic ramped heating feedback control. The system automatically and continually performs self-check and monitors fluid levels, temperature and time. The system automatically chronologically stores data and arranges according to positive results versus negative results. The system automatically tells the operator to remove the analyzed swipe. The system delivers a unique sequence of precise chemical volumes under time, heat, and vapor parameters. The system has detachable and expendable chemical(s) in cartridge form for ease of replacement. The system uses a high-resolution digital camera for data collection and un-biased automated analysis.

By use of a wired or wireless transceiver, detected information can be easily transmitted to anywhere in the world. By replacing disposable swipes/pads/swabs and disposable chemical test reservoirs, the system can detect a wide range of explosives, clandestine material, drugs, and household products used to manufacture explosives, a range of controlled chemical agents, drugs, and narcotics etc. By allowing the user to swipe test materials and running computerized diagnostics, the user can easily and effectively change the system to meet what is considered to be the threat at that time. By having all components under program control and by arranging for a known input to the system such as a controlled injection of target material, the system can perform self-calibration and self-diagnostics.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features, and advantages of the present invention will be better understood from the following detailed descriptions taken in conjunction with the accompanying drawings, all of which are given by way of illustration only, and are not limitative of the present invention, in which:

FIG. **1**A shows a first embodiment of a piezoelectric mist generator.

FIG. **1**B shows a piezoelectric driver for the mist generator.

FIG. **1**C shows a first embodiment of the test swipe.

FIG. **1**D shows a second embodiment of the test swipe.

FIG. **2** shows an exemplary portable chemical detection device.

FIG. **3** shows in more details a swipe receiving port.

FIG. **4** shows an exemplary perspective view of a camera in a test chamber.

FIG. **4**B shows an exemplary perspective view of the interior of the test chamber.

FIG. **5** shows an exemplary block diagram of processing electronics for detecting drugs or explosives.

FIG. **6** shows an exemplary image analysis process executed by the system of FIG. **5**.

DESCRIPTION

The following detailed description of the invention is provided to aid those skilled in the art in practicing the present invention. Even so, the following detailed description of the invention should not be construed to unduly limit the present invention, as modifications and variations in the embodiments herein discussed may be made by those of ordinary skill in the art without departing from the spirit or scope of the present inventive discovery.

FIG. **1**A shows a first embodiment of a piezoelectric mist generator while FIG. **1**B shows a piezoelectric driver for the mist generator. Although a single piezoelectric mist generator is shown, a plurality of piezoelectric devices can be used to inject a plurality of test chemicals onto a test swipe such as the swipe of FIG. **1**D.

The operation of one piezoelectric device is described next. A chemical reservoir **510** contains a small quantity of test chemicals to be dispensed onto a test swipe **550** (FIG. **1**C or **1**D). A piezoelectric crystal **520** is located near the chemical reservoir **510** of each nozzle. The piezoelectric crystal **520** is driven by a driver circuit shown in FIG. **1**B. The driver circuit includes an oscillator **580** that is connected to an amplifier or driver **582**. The driver **582** in turn drives the piezoelectric crystal material **584**. In one embodiment, the oscillator **580** can be a digitally controllable pulse width modulation (PWM) circuit.

The crystal **520** receives a tiny electric charge that causes it to vibrate. When the crystal **520** vibrates inward, it forces a small amount of chemical **524** out of a nozzle. When it vibrates out, it pulls some more chemical into the reservoir to replace the chemical sprayed on the test swipe **550**. The piezoelectric crystal **520** has the property of deforming when high electric fields are applied across them. Two configurations can be used: piezoelectric rods which elongate under applied fields, or bimorphs which bend (in a geometry similar to a drum head). In either case, these materials are configured so that they deform one of the walls of the chemical channel leading to each nozzle. This deformation squeezes the channel, creating a pressure pulse and ejecting chemical(s) from the nozzle. An elastic diaphragm typically isolates the crystalline piezoelectric materials from the chemical. The electrical pulses which energize these piezoelectric elements are once again in the microsecond range. The chemical channels in a piezoelectric head can be formed using a variety of techniques, but one common method is lamination of a stack of metal plates, each of which includes precision microfabricated features of various shapes. In one embodiment, an inkjet printer head can be used.

The location of the chemical droplet up and down the test swipe **550** is controlled by electrostatic plates **540** and **542**, similar to the plates in a cathode ray tube. By charging the plates **540** and **542**, the angle of the droplet can be varied to hit specific spots on the swipe **550**. In another embodiment with a plurality of heads dispensing one chemical, the droplet deposition can be controlled by nozzle pitch which is manually calibrated.

In another embodiment, the head can perform liquid atomization. The purpose of liquid atomizing is to increase the surface area of droplets and thereby raise the reaction speed with the surrounding air and enhance the effects of the heat and mass transfer. Higher surface to volume ratio can lead to increase contact areas between droplets and ambient air, and thereby achieve better atomization. The process has no chemical waste, is non-contact preventing cross-contamination issues, no masks or screens are required; the deposition of reacting chemicals is data-driven. Ink-jet printing technology can dispense droplets of fluid with diameters in the range of 20-200 μm and at rates up to 25,000 per second.

FIG. **1**C shows a test swipe with a base **400**, a chemically treated pad positioned above the base **410**; and a tab **420** attached to one side of the base **400**. In the embodiment of FIG. **1**A, the chemically treated pad has a substantially round shape. A sequence of one or more chemicals can be delivered to the pad to detect an explosive compound. Each chemical or chemical sequence in tandem with temperature parameters over time causes the pad to display a color unique to the explosive compound. The sequence of chemicals are deposited onto the pad at predetermined times. The sequence of chemicals is deposited onto the pad at predetermined temperature range(s) achieved at a specific ramp rate. The sequence of chemicals is deposited onto the pad at predetermined hold time(s) each at predetermined temperature range(s). Each chemical deposited under predetermined time and temperature conditions reacts to a specific explosive or class of explosives to yield a specific color unique to that explosive. The chemically treated pad can be a substantially round shape of thickness less than 0.005 inches to achieve rapid, and even heating through the material layer, and adapted to receive a sequence of one or more chemicals to detect an explosive compounds. The base **400** can have a non reflective dull black color. The pad region **418** can be a cloth within a white zone on the base and an ink free border.

The round swipe of FIG. **1**C can be used for explosives in which a sequence of unique chemicals are deposited onto the same circular pad at specified times, temperature ramp rates, and hold times at a given temperature. Each chemical deposited under these time/temp conditions will react a specific explosive or class of explosives yielding a specific color unique to that explosive or class of explosives.

Turning now to FIG. **1**D, a chemically treated pad **412** can be a substantially four-sided shape. The chemically treated area **412** can have a plurality of test regions **414**A-**414**D. A plurality of unique chemical solutions can be deposited on each test region. The chemical solutions can be deposited separately or at same time to the respective test regions on the swipe. One or more chemicals can be deposited onto the pad to detect one or more drug compounds. Each chemical causes the pad to display a color unique to the explosive compound or class of explosives. The colors generated on each pad, in combination, subsequently generate a color bar code unique to the drug or class of drugs. The sequence of chemicals are deposited onto the pad at predetermined times. The sequence of chemicals is deposited onto the pad at predetermined temperature range(s). The sequence of chemicals is deposited onto the pad at predetermined hold time(s) each at predetermined temperature range(s). Each chemical deposited under predetermined time and temperature conditions reacts to a specific explosive or class of explosives, drug or class of drugs to yield a specific color unique to that explosive or drug. The chemically treated pad can be a substantially four-sided shape of thickness less than 0.005 inches to achieve rapid and even heating through the material layer, and adapted to receive a sequence of one or more chemicals to detect a drug compound.

The drug swipe embodiment of FIG. **1**D can have four different solutions deposited at same time to the respective rectangles on the swipe. The portable test device (FIG. **2**A) will read the "color bar code" results to determine certain drugs. Then, the swipe will be heated through one to several heat ramp cycles to invoke more color changes to each of the respective rectangles creating new color bar codes. Each color bar code at a specific temperature and time will indicate a specific drug or clandestine material sought. A sampler/applicator can be used to sample a suspect material; in a baggie for example; and wipes the collected drug sample onto the square swipe pad (made up of four rectangles **414**A-**414**D).

The swipe pad may be formed of material that may be resistant to chemical degradation during testing in the approximate pH range of 0.1 through 14 to avoid reacting or decomposing. The swipe pad may be white in color to aid test evaluation, may be heat resistant and chemically resistant at elevated temperatures up to approximately 150° C. and may have hydrophilic properties for wetting only when using fluid reagents in the test apparatus. The swipe pad may also be roughened, for example, by use of a woven material, to aid in retrieving test sample particles from the environment. The swipe pad may also be thick enough to resist damage such as tearing during sampling, yet not be too thick such that heating of the test sample is inhibited. A thickness less than 0.005 inches to achieve rapid, and even heating through the material layer.

The test swipe can be used to swipe a sample to identify a chemical composition. This can be done by clamping the test swipe under a camera and above a heater, the test swipe having a base; a chemically treated pad containing the swiped sample positioned above the base in a white zone; and a tab attached to one side of the base; automatically pumping a series of chemical solution agents into the swiped sample without dripping so that the device may be held in any orientation; heating the swiped sample to one or more accurate predetermined temperatures and hold times to optimize and accelerate the chemical reactions; evacuation of vapors generated, capturing one or more images of the chemical reaction; sending the images to the a display screen for operator observation; and analyzing the images to identify the chemical composition based on a chemical reaction and sequence of occurrence and database.

The chemical solution agents are described next. A Tetrabutylammonium hydroxide formulation may be used in a reagent test to impart a color to nitroaromatic compounds that may otherwise not be detected by other bases, such as, sodium hydroxide or potassium hydroxide regardless of their respective concentrations. The tetrabutylammonium hydroxide may also be strong enough to create nitrite salts for other types of explosives that may be in the test sample in preparation for testing with a second type reagent. Use of tetrabutylammonium hydroxide may be difficult due to limited shelf life and its reaction to environmental carbon dioxide that may degrade the necessary color chemistry with nitroaromatics. To develop a solvent system mixable with water to inhibit degradation and reduce hazardous effects to a user, an ethanol and water mixture may be used to inhibit tetrabutylammonium hydroxide degradation with the ethanol ratio such as not to be flammable. The ethanol and water may also have minimum nitrite content to avoid reaction to a second type reagent test that may give false positive results. The tetrabutylammonium hydroxide may also be of a concentration in the ethanol water mixture so as not to interfere chemically with subsequent formulations added to the swipe. For example, if a 10 nanogram detection threshold may be used, any nitrite content in the solutions may be less than 0.2 nanograms per microliter of fluid to minimize corruption of test results or false detection.

The first reagent test may use a first reagent fluid that may have an optimum detection performance range with the fluid having a tetrabutylammonium hydroxide in a water solution in the approximate range of 65-850 percent and an ethanol as approximately 20-35 percent of the water solution. Test results may be obtained using a wider tolerance of elements in the first reagent fluid, but there may be reduced detection sensitively. The tetrabutylammonium hydroxide in water solution may be in the approximate range of 0.1 to 1.6 Molar and the ethanol as approximately 5 to 95 percent of the water solution. Also, other alcohols or blends of alcohols may be used in place of ethanol; however, for example, methanol may be toxic to the user and isopropyl may be less toxic, but may have poorer detection sensitivity results and cause shorter shelf life for the reagent fluid.

A second reagent test may be a Griess reagent test. The Griess reagent may cause a highly colored azo dye to be created in a reaction with nitrite salts generated from the first reaction or present as residue from firearms. The acid that may be used in the formulation of the second reagent may be phosphoric acid that reduces hazardous effects to a user that may become a buffer during the reaction thereby buffering against itself to inhibit creation of too much acid on the swipe pad **42**. Other types of acids that may be used in the Griess test may react too violently with other bases, may be toxic or hazardous, or may create a strong odor.

The phosphoric acid may be mixed with sulfanilic acid and N-(1-naphthyl) ethylenediamine dihydrochloride. The sulfanilic acid may be water soluble with reduced toxicity in combination with and it may impart a deep magenta or fuchsia color to the test sample for ease of detection of explosives. N-(1-naphthyl)ethylenediamine dihydrochloride may be water soluble and not carcinogenic as with other salts, and may impart an effective color reaction from the test sample. The second reagent solution may use deionized water that may have minimum nitrite content to reduce false positive test results. For example, if a 10 nanogram detection threshold may be used any nitrite content in the solutions may be less than 0.2 nanograms per microliter of fluid to minimize corruption of test results or false detection.

The second reagent test may use a second reagent fluid that may have an optimum detection performance range with the fluid having a phosphoric acid in a water solution in the approximate range of 1.3 to 1.7 Molar; and a sulfanilic acid of approximately 8 grams with a N-(1-naphthyl)ethylenediamine dihydrochloride of approximately 5 grams per 1000 milliliters of the phosphoric acid in water solution. Test results may be obtained using a wider tolerance of elements in the second reagent fluid, but there may be reduced detection sensitivity. The phosphoric acid in water solution may be in the approximate range of 0.1 to 7.35 Molar, the sulfanilic acid may be in the approximate range of 5 to 8 grams, and the N-(1-naphthyl) ethylenediamine dihydrochloride may be in the approximate range of 5 to 9 grams. Other acids, acid combinations, or acid concentrations may be used, but may produce less than optimal testing sensitivity results. Other solutions may have increased acidity and be hazardous to the user as well as have a detrimental effect on the testing device. Other solutions may not be acidic enough for a detection reaction to occur or may be toxic. Other salts may be used, but they may reduce the explosives detection sensitivity.

FIG. **2** shows an exemplary portable chemical detection device **10** that uses the test swipe of FIG. **1**C or **1**D. The device **10** has a housing **20** that supports a display **22** and input devices such as an on-off button **24** and navigation/selection buttons **26**. In one embodiment, the system has six buttons. The first button is the On/Off button. This button allows user to turn the unit on or off. The remaining five buttons (Left, Right, Down, Up, and Enter) allows user to interact with a Graphical User Interface (GUI) of the system. The GUI is flexible, efficient and user friendly.

The device **10** also has an input/output port **28** such as a USB port or Firewire port to communicate with a remote computer, and AC power port, among others. In one embodiment, the I/O port **28** is a weather proof PC interface. The PC interface can set up operation parameters and recover analyzed data. In another embodiment, the I/O port **28** can include a flash memory card interface.

The device **10** also includes two ports **30** and **40** to receive user replaceable media and chemical. The device **10** also includes a port **41**A to receive user replaceable DC battery cartridge. Port **30** receives a test swipe of FIGS. **1**A and **1**B. The port **40** receives a chemical cartridge, which can house one or more chemical containers. An electronic controller **58** (shown in FIGS. **2**A AND **2**B) receives inputs from the buttons or keys and controls the display **22** and other electronics in the device **10**. The system can work with different power sources including battery port **41**A port and/or a DC input port **41**B such as a car jack or an AC/DC adaptor.

The system of FIG. **2** is preferably a hand-held unit, which can most preferably be operated easily in real time by one operator. Moreover, the operation of such detectors should preferably be simple so that non-technical persons can operate the instrument properly, efficiently, and easily.

To test a contaminate collection swipe, a user opens the port **30** and places a test swipe such as the swipe of FIG. **1**C or **1**D into a swipe holder. The swipe holder moves along sliding rails when the user closes the port **30** to place the test swipe under a test chamber. The test chamber includes a chamber with two openings that face a variable speed fan **54** to draw air across the test swab or test swipe while under test. The test chamber also includes a heating element **56** connected to a PID loop that can warm up the test swab to multiple predetermined temperature settings during test. The test chamber also contains a camera **39** (FIGS. **2**B and **5**A).

FIG. **3** shows in more detail port **30** that receives the test swipe in the swipe holder **64**. The swipe holder **64** includes a door **60** by which a user can press against to open or close the port **30**. The swipe holder **64** also includes an open face press-fit clamp **62** that secures the swipe against a heating element (not shown) under the swipe upon closure. The swipe holder **64** is attached to rails **66** that slide within rails **68** to enable the swipe holder **64** carrying the test swab of FIG. **1**C or **1**D to move in and out of the device **10**. An enclosure for the swipe holder **64** is formed by positioning a lid **70** with an opening **72** between the sliding rails **68**. The opening **72** allows movable tubes from the piezoelectric pumps **46** to dispense test chemicals onto the swipe. The opening **72** also allows a camera **39** (FIG. **5**A) to capture images of the test results for automatic real-time analysis of the test. A white-light source such as one or more LEDs are positioned near the camera that can be turned on to provide lighting if needed and turned off when not used to conserve power. In one embodiment, the camera output is shown on the display **22** so that the user or operator can visually determine the test result(s) while the automated determination is in progress. The opening **72** also allows a variable speed fan **54** to gently move vapor away from the camera lens to avoid fogging the lens (anti-fogging).

FIGS. **4** and **4**B show an exemplary perspective view of a camera **39** in conjunction with the test chamber **38**. The chamber **38** includes a motor **92** driving a gear **94**. The gear **94** cooperates with a moveable arm **96** that moves test tubing fixture back and forth over the test swab or swipe during testing. The test tubing fixture moves very closely to the swipe for chemical deposit onto the swipe when the device **10** is held in any orientation. The arm includes a plurality of piezoelectric pumps **46**. The arm **96** also moves the fixture out of the way for the camera **39** to capture changes on the test swipe during testing. The camera images are then analyzed, and the result can then be displayed on the display **22**. In one embodiment, the camera **39** can capture raw images with 65,536 colors. The camera is protected with an anti-fog feature using the adjustable speed fan **54**. The image data can be shown continuously throughout the entire process on a flip-up display **22** with high fidelity. In one embodiment, the system provides a software JPEG (or alternatively bitmap) encoder and decoder for storing and viewing previous results and images. The system also includes white light LEDs (not shown) located within the test chamber **38** that provides even, shadow free, and uniform lighting during camera **39**'s operation with a programmable white light intensity. The LEDs minimize shadows in the camera viewing area.

The swipe holder **34** moves along rugged sliding rails **66** when the user closes the port **30** to place the test swipe of FIG. **1**A or **1**B under the test chamber **38**. The test chamber **38** includes a chamber with two openings **52** that face the fan **54** to draw air across the test swipe while under test. The test chamber also includes a heating element **56** that can warm up the test swipe to a predetermined temperature during test.

FIG. **5** shows an exemplary block diagram of processing electronics for the system of FIG. **2**. A processor **200** controls all tasks done by the system. The processor **200** communicates over a bus **202** to various devices, including buttons interface **204**, fan driver **206**, speaker driver **208**, display controller **210**, micro-pump driver **212**, and USB controller **214**. The processor **200** also communicates with embedded memory **220** and a programmable ROM **224** that contains boot code as well as application code. The processor **200** also drives buffers **226**, **228** and **230** which controls the LED(s), infrared sensor that informs the operator if a swipe has been loaded into the test chamber **38**, and heat filament, respectively. The infrared sensor is positioned under the swipe and acts as a proximity sensor to detect the presence or absence of a swipe by the amount of light reflected back. The processor **200** or controller actuates the motor to drive a solution delivery manifold to the center of the swipe and in close proximity to the swipe to dispense the solution without dripping, regardless orientation. The controller can monitor fluid levels within each reservoir contained in the disposable cartridge. This is done by decrementing available volume each time the pump is actuated and when the count reaches a low threshold, the controller can indicate that the reservoir is out of chemical.

The system is powered by a 12-volt DC source, which can be generated from an AC/DC converter, a car outlet or from eight 1.5-volt batteries in series. The highest prioritized energy source is from an AC/DC converter followed by the one from a car outlet, then the energy from batteries. The 12-volt DC power source will supply current to the heater and the pump. It is also connected to the low drop voltage regulator to generate different voltage levels such as 5 V, 2.8 V and 3.3 V, which are necessary for the processor and for other peripherals as well.

One example of the of a sequence involving chemistry time, temperature ramp rates and hold times to optimize each of the results for explosives, drugs, or other threat chemicals within a chemical reaction sequence. The system always adjusts the start temperature prior to running a particular sequence to a predetermined temperature value. An example of this may be 35° C. whereby the swipe retaining a wet or dry sample is adequately held and in intimate contact with the elements of the swipe holder. Not mentioned in this section are the specific parameter controls for fan speed, LED lighting, pumping increments, GUI, camera, speaker, or display.

The background image of the swipe at this temperature is taken so as to subtract out any colors that may be present on the swipe prior to analysis. A selected chemical reactant from one of the reservoirs is then pumped onto the swipe in a non-drip fashion and in a volume of 20-30 μL, most favorable being 25 μL. The system takes second image of the chemically reacted sample on the swipe and immediately processes this image from subtracted background for color indicating peroxides. The second image then becomes the new background image whether peroxides are present or not for the next analyte sought hexamethylene triperoxide diamine HMTD.

Further reacting sample material on the swipe, the heater element begins rapidly heating only the sample area on the swipe with temperature setting ramp rates of 10-20° C. per minute to 115° C., most favorable being 15° C. per minute. During the ramp, a third image is taken between 5-15 seconds, 12 seconds being most favorable, to analyze for color indicating HMTD. The system takes third image of the chemically reacted sample on the swipe and immediately processes this image from second background for presence of HMTD. Once the heater element reaches 115° C., it then holds a for 20-40 seconds, 30 seconds being most favorable. The third image then becomes the new background image whether HMTD was present or not for the next analyte sought triacetone triperoxide TATP.

During the hold time, a fourth image is taken of the chemically reacted sample on the swipe at 25 to 30 seconds, 28 seconds being most favorable, and immediately processes this image from third background for presence of the color indicating TATP. The fourth image then becomes the new background image whether TATP was present or not for the next analyte sought chlorates.

During the same hold time, a fifth image is taken of the chemically reacted sample on the swipe at 25 to 35 seconds, 30 seconds being most favorable, and immediately processes this image from fourth background for presence of the color indicating chlorates. The fifth image then becomes the new background image whether chlorates were present or not for the next analyte sought TNT.

The heater element begins rapidly heating only the sample area on the swipe with temperature setting ramp rates of 10-20° C. per minute to 140° C., most favorable being 15° C. per minute. Simultaneously, a second selected chemical reactant from one of the reservoirs is then pumped to the piezoelectric transducer and deposited onto the swipe in a non-drip fashion and in a volume of 20-30 μL, most favorable being 25 μL. Once the heater element reaches 140° C., it then holds for 10-20 seconds, 10 seconds being most favorable. During the second temperature ramp, a sixth image is taken between 5-15 seconds, 8 seconds being most favorable, to analyze for color indicating TNT. The sixth image then becomes the new background image whether TNT was present or not for the next analytes sought all high explosives.

The heater element begins rapidly heating only the sample area on the swipe with temperature setting ramp rates of 10-20° C. per minute to 155° C., most favorable being 15° C. per minute. Simultaneously, a third selected chemical reactant from one of the reservoirs is then pumped onto the swipe in a non-drip fashion and in a volume of 20-30 μL, most favorable being 25 μL. Once the heater element reaches 155° C., it then holds for 10-20 seconds, 20 seconds being most favorable. During the third temperature ramp, a seventh image is taken between 5-15 seconds, 5 seconds being most favorable, to analyze for colors indicating all high explosives. The seventh image then becomes the new background image whether high explosives were present or not for the next analytes sought all nitrates.

The heater element continues to hold at 155° C. and from 10-20 seconds, an eighth image is taken between 10-20 seconds, 15 seconds being most favorable, to analyze for colors indicating all nitrates. The heater element immediately cools down for the next sample run.

Another example of a single test involving chemistry time, and temperature settings and hold times to optimize results for a chemical reaction involves depositing one or more of the chemical reactants from their respective reservoirs onto the swipe in a non-drip fashion. This is to impart a single spot test or multiple spot tests for a single drug or drugs, a single explosive or explosives, or other threat chemicals at ambient or preset temperature conditions that results in a single color or an array of colors unique to that material under the temperature settings and reagents applied.

In one embodiment as a Portable Explosive Trace Detector (PETD), the system of FIG. **6** significantly enhances the detection of the explosive materials as well as speeding up the screening and detecting procedures at security checkpoints. First, the PETD automatically pumps a series of chemical solution agents into the swiped sample and heats up to specific temperature to accelerate the chemical reactions. Second, an internal CMOS camera captures the chemical reaction images at its highest resolution, raw data for better image analysis. Third it then sends these raw images data to the LCD (Liquid Crystal Display) screen for the purpose of observation. Moreover, the JPEG codec is capable storing and replaying image functions. The LCD screen provides a high quality image for human viewing. In another embodiment, in place of JPEG, a bitmap image or an MPEG video or any suitable imaging storage format can be used. The LCD can analyze the image to identify explosive materials based on the provided chemical reaction database. Last but not least, the PC interfaces can be used to update software and firmware as well as to backup the data.

In one implementation, to start the analysis process, the system turns the micro-pump(s) N (i.e., N=1, 2, 3 . . . or a combination thereof) to disperse the chemical solution into the Swiped Sample. The pumping rate is set to 2 Hz. After dispersing chemical solution, the system starts heating the sample to excite the chemical reactions under controlled vapor, time, temperature, and chemical volume conditions specific to a particular analyte or group of analytes. A current of about one ampere is applied to heat up the heating filament. During the heating process, the fluctuation of the temperature is controlled by a feedback circuit with a thermistor.

When the temperature of the sample swipe reaches a predefined value, the system turns the heater off, the white light LED on and the fan on. The speed of the fan is adjustable using pulse width modulation control in one embodiment.

Before commanding the camera's CMOS image sensor to capture an image, the system waits for the chemical reaction to complete for around 1 ms. The captured image is then displayed on the LCD.

The system creates a result image by subtracting the captured image from the background one. Then the result image is compared with the color patterns in the lookup table stored in the system. If the results image matches some color pattern, the result probability will be displayed and an optional audible alarm is given or not. Otherwise, an appropriate message is displayed on the LCD.

During the process of writing to the memory, (e.g., saving results or updating database), the system is able to detect the memory capacity and give the user a warning of full memory. In such a case, the user needs to clear the memory by deleting certain files before commanding the system to continue its work.

In one embodiment, the system executes a prime pump procedure to clear up air and chemical bubbles in the tubes of minimized length and diameter once the system has been idled for more than 12 hours. If the system has not been used for the past 12 hours then the system prompts the user to place an empty swipe sample into a clamp holder. Once a swipe sample is secured on the clamp holder, the system prompts user to do the prime pump procedure by pumping chemical solutions onto swipe sample. During the prime pumps, the camera captures the image from the swipe and displays it on the LCD screen. During the prime pumps, no heat is applied to the swipe.

In one embodiment, in the main menu, user can see the date, the time and current status of the system. The system can generate a warning alarm once battery, chemical level and memory reach their minimal levels. The menu also contains three (3) software programmable buttons, namely New Analysis, Previous Results, and Settings. User can interact with these soft buttons by using the five hard buttons. The New Analysis option is highlighted as default. The usage of these soft buttons is as follows:

New Analysis: allows user to perform a new test.

Previous Results: allows user to trace back the data tested in the past.

Settings: allows user to set parameters such as date, time, to test the system reliability, or to connect to PC for firmware and/or database update.

The user can see the images taken by the camera. The system status is also displayed. In addition, three (3) soft buttons (Start, Stop, and Status) are provided. The Start option is highlighted as default.

FIG. **6** shows an exemplary image analysis process executed by the real-time embedded system processor **200** to detect chemical agents automatically. To start the analysis process, the system turns the micro-pump(s) N (i.e., N=1, 2, 3 . . . or a combination thereof) to disperse the chemical solution into the swiped sample. The pumping rate is set to 0.250 Hz. After dispersing chemical solution, the system starts heating the sample to excite the chemical reactions. A current of about 1 Ampere is required to heat up the heater filament. When the temperature of the sample reaches a predefined value, the system turns the heater off, the LED and the fan on. In one embodiment, before commanding the CMOS image sensor to capture an image, the system waits for the chemical reaction under optimized: time, temperature, volume dispensed, and vapor to complete for around 1 millisec. The captured image is then displayed on the LCD. The system creates a result image by subtracting the captured image from the background one. Then the result image is compared with the color patterns in the lookup table stored in the memory. If the results image matches some pattern, the result will be displayed and an audible alarm is given. Otherwise, an appropriate message is displayed on the LCD.

Due to the automated, reproducible analysis, the system provides an objective indication of potential threats with more accurate, un-biased results at night, high humidity, or bad weather conditions, and therefore, more convenient.

The invention may be implemented in hardware, firmware or software, or a combination of the three. Preferably the invention is implemented in a computer program executed on a programmable computer having a processor, a data storage system, volatile and non-volatile memory and/or storage elements, at least one input device and at least one output device.

By way of example, a block diagram of a computer to support the system is discussed next. The computer preferably includes a processor, random access memory (RAM), a program memory (preferably a writable read-only memory (ROM) such as a flash ROM) and an input/output (I/O) controller coupled by a CPU bus. The computer may optionally include a hard drive controller which is coupled to a hard disk and CPU bus. Hard disk may be used for storing application programs, such as the present invention, and data. Alternatively, application programs may be stored in RAM or ROM. I/O controller is coupled by means of an I/O bus to an I/O interface. I/O interface receives and transmits data in analog or digital form over communication links such as a serial link, local area network, wireless link, and parallel link. Optionally, a display, a keyboard and a pointing device (mouse) may also be connected to I/O bus. Alternatively, separate connections (separate buses) may be used for I/O interface, display, keyboard and pointing device. Programmable processing system may be preprogrammed or it may be programmed (and reprogrammed) by downloading a program from another source (e.g., a floppy disk, CD-ROM, or another computer).

Each computer program is tangibly stored in a machine-readable, removable storage media or device (e.g., program memory or magnetic disk) readable by a general or special purpose programmable computer, for configuring and controlling operation of a computer when the storage media or device is read by the computer to perform the procedures described herein. The inventive system may also be considered to be embodied in a computer-readable storage medium, configured with a computer program, where the storage medium so configured causes a computer to operate in a specific and predefined manner to perform the functions described herein.

The invention has been described herein in considerable detail in order to comply with the patent Statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct and use such specialized components as are required. However, it is to be understood that the invention can be carried out by specifically different equipment and devices, and that various modifications, both as to the equipment details and operating procedures, can be accomplished without departing from the scope of the invention itself.

Although specific embodiments of the present invention have been illustrated in the accompanying drawings and described in the foregoing detailed description, it will be understood that the invention is not limited to the particular embodiments described herein, but is capable of numerous rearrangements, modifications, and substitutions without departing from the scope of the invention. The following claims are intended to encompass all such modifications.

What is claimed is:

1. A portable tester to detect

one or more analytes from explosives, drugs, or household chemicals, comprising:

a plurality of disposable, detachable reagent reservoirs storing reagents to induce a series of color reactions, wherein developed color depends on sequences of applied reagents to respective pads on a support base, reaction times and temperatures on said pad to create one or more color bar codes for a specific analyte;

a piezoelectric dispenser coupled to each respective reservoir to dispense a mist of reagent onto respective test pads to increase sensitivity and reduce reaction heat and time; wherein piezoelectric dispenser is processor controlled to control dispensing time and volume in each step,

a disposable, chemically inert, and heat resistant swipe for sample collection composed of one or more test pads on a support to be analyzed containing one or more analytes

a durable, disposable support base that is chemically inert, heat resistant, and non reflective, for imaging purposes, to retain the test pads and protect the thin-film heaters

a plurality of chemically inert and heat resistant test pads to retain the sample to be analyzed with one or more analytes; wherein pads are positioned to receive the pumping and piezoelectric reagent dispensing, wherein each pad is positioned and attached to a nonreactive, heat resistant support base;

and

wherein each pad is positioned above individually programmable heaters for temperature ramps and hold times and wherein the heaters to generate heating ramps and hold time profiles unique to the respective test pad to evoke a sequence of color reactions of piezoelectric dispensed reagents and analytes and the heater rapidly returning to a start temperature for a new sample analysis,

a fan to circulate and exhaust vapors rising from the test swipe during reaction times;

a programmable digital camera system for imaging and data collection at specific times, temperature, and applied reagents for analysis by the processor; and

a processor to interpret resulting changing color codes of the test pads throughout the analysis occurring at specific times, temperature, and applied reagent and to identify or characterize the type explosive or class of explosives, clandestine drugs, or household chemicals.

2. The tester of claim **1**, wherein the pads to be chemically treated and positioned on the non reflective base comprises a substantially round shape.

3. The tester of claim **1**, comprising a sequence of one or more chemicals delivered to the test pad in a timed sequence as a directed, thin-layer, fine mist to the pad to color react with one or more drugs, explosives, or household chemicals over a time and heat profile to increase sensitivity and intensify color reaction and reduce reaction times and heat.

4. The tester of claim **3**, wherein each chemical causes the pad to display a color unique to the explosive, drug, or household compound.

5. The tester of claim **3**, wherein the plurality of piezoelectric dispensers deposit a sequence of chemicals onto the pad at predetermined time sequences under control of the processor.

6. The tester of claim **3**, wherein the plurality of piezoelectric dispensers deposit a sequence of chemicals from selected reservoirs onto the pad at predetermined temperature range(s) produced from a thin-film heat filament.

7. The tester of claim **3**, wherein the plurality of piezoelectric dispensers deposit a sequence of chemicals from-selected reservoirs onto the pad at predetermined hold time(s) each at predetermined temperature range(s) produced from a thin-film heat filament.

8. The tester of claim **3**, wherein the plurality of piezoelectric dispensers deposit a sequence of chemicals from selected reservoirs under predetermined time and temperature conditions, wherein each chemical reacts to a specific explosive or class of explosives, drug or class of drugs, or household chemicals, to yield a specific color or a sequence of colors unique to that explosive, drug, or household chemical.

9. The tester of claim **1**, wherein the pads to be chemically treated and positioned on the non reflective base comprises a substantially round shape to receive a sequence of one or more chemicals to detect an explosive, drug, or household chemical compound.

10. The tester of claim **1**, wherein the pads to be chemically treated and positioned on the non reflective comprises a substantially four-sided shape for the plurality of pads to receive specific chemical(s) per pad to detect drug compounds.

11. The tester of claim **1**, comprising chemicals dispensed by piezoelectric dispensers to react with and detect one or more drug compounds.

12. The tester of claim **11**, wherein each chemical causes each pad to display a color unique to a drug compound.

13. The tester of claim **11**, wherein the piezoelectric dispensers deposit chemicals onto the individual pads at controlled times under control of a processor.

14. The tester of claim **11**, wherein the piezoelectric dispensers deposit chemicals onto the individual pad at a predetermined temperature range(s) produced from a thin-film heat filament.

15. The tester of claim **11**, wherein the piezoelectric dispensers deposit chemicals onto the individual pad at predetermined hold time(s) each at predetermined temperature range(s) produced from a thin-film heat filament.

16. The tester of claim **11**, wherein the piezoelectric dispensers deposit chemicals under predetermined time(s) and temperature conditions and the chemicals react to a specific drug or class of drugs to yield a specific color unique to that drug.

17. The tester of claim **1**, wherein the pads to be chemically treated and positioned on the non reflective comprises a substantially four-sided shape for a plurality of pads to receive a sequence of one or more chemicals to detect a drug compound.

18. The tester of claim **1**, wherein the pads to be chemically treated comprises a plurality of test regions.

19. The tester of claim **1**, comprising a plurality of different chemical solutions deposited on each test region.

20. The tester of claim **18**, comprising chemical solutions deposited at same time to the respective test regions on the swipe to impart a collective color code of pads unique to a class of drugs.

21. The tester of claim **1**, wherein the base comprises a dull black color.

22. The tester of claim **1**, comprising a pad region having a cloth within a white zone on the base and an ink free border.

23. The tester of claim **1**, wherein the one or more pads to be chemically treated are positioned in a white zone.

24. The tester of claim **1**, wherein the base comprises an area approximately 1.25 inch by 2 inches.

25. The tester of claim **1**, wherein the pads are spaced at least approximately 0.25 inch from the base perimeter.

26. The tester of claim **1**, wherein the pads are spaced apart by approximately 0.02 inch.

27. The tester of claim **1**, wherein the base comprises a black color.

28. The tester of claim **1**, comprising a plurality of piezoelectric dispensers.

29. The tester of claim **1**, wherein the tab comprises a side measuring approximately 0.35 inch and a second side parallel to the first side measuring approximately 0.375 inch.

30. The tester of claim **1**, wherein the pad is circular and spaced at least approximately 0.27 inch from the base perimeter.

31. The tester of claim **1**, wherein the base comprises an area approximately 1.25 inch by 2 inches, the pads are spaced at least approximately 0.25 inch from the base perimeter, and the tab comprises a side measuring approximately 0.35 inch and a second side parallel to the first side measuring approximately 0.375 inch.

32. The tester of claim **1**, wherein the chemical dispensed by the piezoelectric dispenser comprises at least one of: a water based and alcohol formulation of tetrabutylammonium hydroxide and a water based and alcohol formulation of a Griess reagent.

33. A system to analyze a swiped sample to identify a chemical composition, comprising:

- a clamp to hold a test swipe under a camera and above a heater, the test swipe having a durable, disposable support base that is chemically inert, heat resistant; a chemically inert and heat resistant test pad positioned on the base; and a handling tab on one side of the non-reflective base; a base, and non reflective, for imaging purposes, to retain the test pads and protect the heaters;
- a piezoelectric dispenser to deliver a series of chemical solutions onto the swiped sample without dripping and allowing the system to be held at any angle;
- a thin-film heater to heat the swiped sample to one or more predetermined temperatures and hold times to optimize, uniform coverage, sensitivity, and reproducibly accelerate the chemical reactions;
- a programmable digital camera to capture one or more color images of the chemical reaction at specific times, temperature, and applied reagents;
- a display to show images for operator observation; and
- a color analyzer interpreting resulting changing color codes of the test pads throughout the analysis occurring at specific times, temperature, and applied reagent and to identify or characterize the type explosive or class of explosives, clandestine drugs, or household chemicals.

34. A portable tester, comprising:

- a plurality of disposable, detachable reagent reservoirs storing reagents to induce a series of color reactions, wherein developed color depends on sequences of applied reagents to respective pads on a support base, reaction times and temperatures on said pad to create one or more color bar codes for a specific analyte;

a piezoelectric dispenser coupled to each respective reservoir to dispense a mist of reagent onto respective test pads to increase sensitivity and reduce reaction heat and time, wherein piezoelectric dispenser is processor controlled to control dispensing time and volume in each step;

a support base that is chemically inert, heat resistant, and non reflective, for imaging purposes, to retain test pads that retain a sample to be analyzed with one or more analytes, the support base supporting one or more test pads to form a disposable, chemically inert, and heat resistant swipe for sample collection, wherein the pads are positioned to the pumping and piezoelectric reagent dispensing, wherein each pad is positioned above individually programmable heaters for temperature ramps and hold times and wherein heaters are used to generate heating ramps and hold time profiles unique to the respective test pad to evoke a sequence of color reactions of piezoelectric dispensed reagents and analytes; and

means for imaging and data collection at specific times, temperature, and applied reagents and interpreting changing color codes of the test pads throughout the analysis occurring at specific times, temperature, and applied reagent to identify or characterize explosive, drugs, or household chemicals.

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