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(54) Title: K-9 TRAINING AIDS MADE USING ADDITIVE MANUFACTURING AND EXPLOSIVES MIMIC FOR TESTING, TRAINING, AND MONITORING

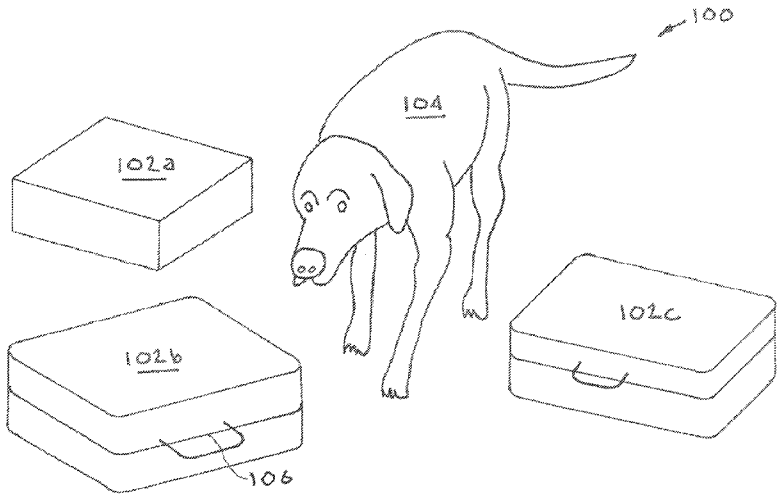

FIG. 1

(57) Abstract: Additive Manufacturing (AM) is used to make aids that target the training of K-9s to detect explosives and make mimics for explosives. The process uses mixtures of explosives and matrices commonly used in AM. The explosives are formulated into a mixture with the matrix and printed using AM techniques and equipment. The explosive concentrations are kept less than 10% by wt. of the mixture to conform to requirements of shipping and handling.

[Continued on next page]

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K-9 TRAINING AIDS MADE USING ADDITIVE MANUFACTURING AND EXPLOSIVES MIMIC FOR TESTING, TRAINING, AND MONITORING

[0001] This disclosure concerns chapters 1 and 2 entitled "K-9 TRAINING AIDS MADE USING ADDITIVE MANUFACTURING" and "EXPLOSIVES MIMIC FOR TESTING, TRAINING, AND MONITORING", respectively.

STATEMENT AS TO RIGHTS TO APPLICATIONS MADE UNDER FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT

[0002] The United States Government has rights in this application pursuant to Contract No. DE-AC52-07NA27344 between the United States Department of Energy and Lawrence Livermore National Security, LLC for the operation of Lawrence Livermore National Laboratory.

BACKGROUND FOR CHAPTER 1

Field of Endeavor

[0003] The present chapter relates to training aids and more particularly to making K-9 training aids using additive manufacturing.

State of Technology

[0004] This section provides background information related to the present disclosure which is not necessarily prior art.

[0005] United States Patent No. 9,108,890 for a process for producing non-detonable training aid materials for detecting explosives issued

August 18, 2015 provides the state of technology information reproduced below.

[0006] Example embodiments generally relate to producing non-detonable explosive samples and, more particularly, to producing such samples for use as training aids.

[0007] Non-detonable training aid materials have been developed for allowing training of explosives detection dogs (EDD), dolphins, or other living or non-living entities that can detect presence of explosives through emitted vapors. The training aid materials desirably exude the same odor as bulk quantities of real explosives, but lack the detonable properties of real explosives and are otherwise safe to handle. Furthermore, the training aid materials can preferably produce vapors that exude the odor for at least a specific period of time after opening the package (e.g., 2 hours). Such training aid materials have been developed for peroxide-based homemade explosives (HME) allowing for training EDDs to detect such explosives in various environments.

[0008] Some training aid materials are formed by coating materials with layers of the explosive molecules as dissolved in a solvent. These materials can similarly produce off-odors, however, due to addition of the solvent.

The article "The Education of a Bomb Dog" by Joshua Levine in the July 2013 issue of Smithsonian Magazine provides the state of technology information reproduced below.

[0010] Top training academy works double time to meet skyrocketing demand for canines who can sniff out danger.

[0011] Then I first meet a likable young Labrador named Merry, she is clearing her nostrils with nine or ten sharp snorts before she snuffles along a row of luggage pieces, all different makes and models. They're lined up against the back wall of a large hangar on a country road outside Hartford, Connecticut. This is where MSA Security trains what are known in the security trade as explosive detection canines, or EDCs. Most people call them bomb dogs.

[0012] Dogs are recognized as premier explosives detection systems. They are reliable, friendly, love to work, and are portable. Dogs have some intrinsic weaknesses such as sensory fatigue and limited detection lifespan, but still are preferred by law enforcement and the military for illicit substance detection. For example, the ATF have K-9s deployed for detection in over 13 different countries. Training K-9s is difficult because of limited targeted training aids and contamination (training on the impurity). In addition, shape recognition is not fully employed.

SUMMARY

[0013] Features and advantages of the disclosed apparatus, systems, and methods will become apparent from the following description. Applicant is providing this description, which includes drawings and examples of specific embodiments, to give a broad representation of the apparatus, systems, and methods. Various changes and modifications within the spirit and scope of the application will become apparent to those skilled in the art from this description and by practice of the apparatus, systems, and methods. The scope of the apparatus, systems, and methods is not intended to be limited to the

forms disclosed and the application covers all modifications, equivalents, and alternatives falling within the spirit and scope of the apparatus, systems, and methods as defined by the claims.

[0014] Additive Manufacturing (AM) is used to make aids that target the training of K-9s to detect explosives. The process uses mixtures of explosives and matrices commonly used in AM. The explosives are formulated into a mixture using AM techniques and equipment. The explosive concentrations are kept less than 10% by wt. of the mixture to conform to requirements of shipping and handling, although higher concentrations of explosives are viable. The matrices vary but the most desirable are those that have no volatile compound signatures after processing. The training aids are printed in a variety of form and shapes, consistent with meeting K-9 training protocols.

[0015] In general, the inventors' apparatus, systems, and methods utilizes the technology of AM printing to produce unusual materials with special properties. K-9 explosives training aids have to minimally meet the following requirements:) 1) low concentration of explosive or explosive mixture (this allows handling and transportation without special requirements); 2) non-volatile matrix (so the K-9 will not be trained on a false signature); 3) flexibility in form (so the aid can be used in various configurations and applications). Current technology meets some of these requirements. There are companies (few), such as NESTT and ScentLogic, that produce training aids that can be shipped and handled normally, but the list of explosives is somewhat limited, including no real improvised explosive mixtures. Matrices are available, but these are usually limited to silica and thick gel hydrocarbons. The flexibility of form is also limited as the current aids

are generally pastes or powders that must have secondary containment, such as a bag, or applied as a smear.

[0016] AM printed training aids have many advantages over current training aids. They can be printed in low concentrations to meet DOT requirements as non-hazardous, non-explosive materials. They can be printed in any shape, such as a dog bone, box or hand grenade. They can be printed with a large variety of matrices that are more realistic to actual threat environments, such as clays, ceramics, plastics. They can be printed then processes with little or no volatile backgrounds, for example, several printing formulations are water based. They can be printed with a large array of different explosive materials. The open porous structure allows ample access of inner concentrations of explosives. They can be printed as laminates with two components of an improvised explosive (oxidizer and fuel) without the components being mixed or co-mingled. They can be printed on-demand. With possible selection of printing equipment, they could be printed in the field. They could be printed with other illicit target materials so they could be used for K-9 training aids for drugs, chemical weapons, and environmental hazards.

[0017] The inventors' apparatus, systems, and methods have been described as addressing the need for a K-9 training aid when the target for the training aid is explosives. The technology can be extended to any material that could be a target in K-9 detection. If there is a desire to use K-9s to identify drugs being smuggled, these methods can be applied to produce K-9 drug training aids using manufacture methods comparable to these. If there is a desire to use K-9s to identify fugitive emissions from industrial equipment, these methods can be applied to produce K-9 training aids using manufacture methods comparable to

these. These manufacturing methods can be applied to produce training aids to almost any material targeted for detection by K-9s.

[0018] The apparatus, systems, and methods are susceptible to modifications and alternative forms. Specific embodiments are shown by way of example. It is to be understood that the apparatus, systems, and methods are not limited to the particular forms disclosed. The apparatus, systems, and methods cover all modifications, equivalents, and alternatives falling within the spirit and scope of the application as defined by the claims.

BACKGROUND FOR CHAPTER 2

Field of Endeavor

[0019] The present chapter relates to testing, training, and monitoring and more particularly to an explosives mimic for testing, training, and monitoring.

State of Technology

[0020] This section provides background information related to the present disclosure which is not necessarily prior art.

[0021] United States Patent No. 5,958,299 for explosive simulants for testing explosive detection systems issued September 28, 1999 provides the state of technology information reproduced below.

[0022] The Federal Aviation Administration (FAA) has used explosive simulants for many years to field test various automated explosive detection systems embedded within baggage inspection systems at airports, and to train the operators of this equipment. The FAA develops and validates training aids for baggage inspectors and hand-searchers to help them distinguish threats from false alarms. The best

explosive simulant is a physical model that imitates selected attributes of the more complex, real-world system. Simulators are particularly useful to hone, test, and evaluate the abilities of personnel and equipment when a real-world environment is too costly or not available.

[0023] United States Patent No. 9,108,890 for process for producing non-detonable training aid materials for detecting explosives issued August 18, 2015 provides the state of technology information reproduced below.

[0024] Non-detonable training aid materials have been developed for allowing training of explosives detection dogs (EDD), dolphins, or other living or non-living entities that can detect presence of explosives through emitted vapors. The training aid materials desirably exude the same odor as bulk quantities of real explosives, but lack the detonable properties of real explosives and are otherwise safe to handle. Furthermore, the training aid materials can preferably produce vapors that exude the odor for at least a specific period of time after opening the package (e.g., 2 hours). Such training aid materials have been developed for peroxide-based homemade explosives (HME) allowing for training EDDs to detect such explosives in various environments.

[0025] Some training aid materials are formed by coating materials with layers of the explosive molecules as dissolved in a solvent. These materials can similarly produce off-odors, however, due to addition of the solvent.

SUMMARY

[0026] Features and advantages of the disclosed apparatus, systems, and methods will become apparent from the following description.

Applicant is providing this description, which includes drawings and examples of specific embodiments, to give a broad representation of the apparatus, systems, and methods. Various changes and modifications within the spirit and scope of the application will become apparent to those skilled in the art from this description and by practice of the apparatus, systems, and methods. The scope of the apparatus, systems, and methods is not intended to be limited to the particular forms disclosed and the application covers all modifications, equivalents, and alternatives falling within the spirit and scope of the apparatus, systems, and methods as defined by the claims.

[0027] Additive Manufacturing (AM) is used to make an explosives mimic for testing, training, or monitoring. The process uses mixtures of explosives and matrices commonly used in AM. The explosives are formulated into a mixture using AM techniques and equipment. The explosive concentrations are kept less than 10% by wt. of the mixture to conform to requirements of shipping and handling, although higher concentrations of explosives are viable. The matrices vary but the most desirable are those that have no volatile compound signatures after processing. The explosives mimic for testing, training, or monitoring is printed in a variety of form and shapes, consistent with meeting K-9 training protocols.

[0028] In general, the inventors' apparatus, systems, and methods utilizes the technology of AM printing to produce unusual materials with special properties. Explosives mimics have to minimally meet the following requirements: 1) low concentration of explosive or explosive mixture (this allows handling and transportation without special requirements); 2) non-volatile matrix (so K-9s will not be trained on a false signature); 3) flexibility in form (so the aid can be used in various

configurations and applications). Current technology meets some of these requirements. There are companies (few), such as NESTT and ScentLogic, that produce mimic for explosives that can be shipped and handled normally, but the list of explosives is somewhat limited, including no real improvised explosive mixtures. Matrices are available, but these are usually limited to silica and thick gel hydrocarbons. The flexibility of form is also limited as the current aids are generally pastes or powders that must have secondary containment, such as a bag, or applied as a smear.

[0029] AM printed mimic for explosives have many advantages over current explosives mimics. They can be printed in low concentrations to meet DOT requirements as non-hazardous, non-explosive materials. They can be printed in any shape, such as a box or hand grenade. They can be printed with a large variety of matrices that are more realistic to actual threat environments, such as clays, ceramics, plastics. They can be printed then processed with little or no volatile backgrounds, for example, several printing formulations are water based. They can be printed with a large array of different explosive materials. The open porous structure allows ample access of inner concentrations of explosives. They can be printed as laminates with two components of an improvised explosive (oxidizer and fuel) without the components being mixed or co-mingled. They can be printed on-demand. With possible selection of printing equipment, they could be printed in the field. They could be printed with other illicit target materials so they could be used as mimics for testing, training, or monitoring for drugs, chemical weapons, and environmental hazards.

[0030] The apparatus, systems, and methods are susceptible to modifications and alternative forms. Specific embodiments are shown

by way of example. It is to be understood that the apparatus, systems, and methods are not limited to the particular forms disclosed. The apparatus, systems, and methods cover all modifications, equivalents, and alternatives falling within the spirit and scope of the application as defined by the claims.

BRIEF DESCRIPTION OF THE DRAWINGS FOR CHAPTERS 1 AND 2

[0031] The accompanying drawings, which are incorporated into and constitute a part of the specification, illustrate specific embodiments of the apparatus, systems, and methods and, together with the general description given above, and the detailed description of the specific embodiments, serve to explain the principles of the apparatus, systems, and methods.

[0032] FIG. 1 shows a trained K-9 in an operation of actively detecting explosives or explosives residue in connection with a variety of pieces of luggage.

[0033] FIG. 2 is an example of the use of a K-9 training aid for teaching the dog to recognize a target.

[0034] FIG. 3 is an illustration showing one embodiment of the inventors' apparatus, systems, and methods using AM to make aids that used in the training of K-9s to detect explosives.

[0035] FIGS. 4A, 4B, and 4C illustrate another embodiment of the inventors' apparatus, systems, and methods using AM to make aids used in the training of K-9s to detect explosives.

[0036] FIG. 5 is an example of an Additive Manufactured K-9 training aid that can be used for teaching a dog to recognize a target.

[0037] FIG. 6 is a flow chart that illustrates another embodiment of the inventors' apparatus, systems, and methods of using AM to make aids that used in the training of K-9s to detect explosives.

[0038] FIG. 7 is a flow chart that illustrates another embodiment of the inventors' apparatus, systems, and methods of using AM to make aids that used in the training of K-9s to detect explosives.

[0039] FIG. 8 shows a view of a notebook computer that has been printed by AM using penta-erythritol as a surrogate for penta erythritol tetra nitrate (PETN).

[0040] FIG. 9 is an illustration showing another embodiment of the inventors' apparatus, systems, and methods using AM to make aids that used in the training of K-9s to detect explosives.

[0041] FIGS. 10A and 10B illustrate another embodiment of the inventors' apparatus, systems, and methods using AM to make aids used in the training of K-9s to detect explosives.

[0042] FIG. 11 illustrates one embodiment of the inventors' apparatus, systems, and methods using AM to make mimics of explosives.

[0043] FIG. 12 illustrates an example of an additive manufactured mimic of explosives that can be used in the testing, training, and monitoring of explosives.

[0044] FIGS. 13A and 13B provide more details of the mimic for explosives produced by the AM system illustrated in FIG. 11.

CHAPTER 1: K-9 TRAINING AIDS MADE USING ADDITIVE MANUFACTURING

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0045] Referring to the drawings, to the following detailed description, and to incorporated materials, detailed information about the apparatus, systems, and methods is provided including the description of specific embodiments. The detailed description serves to explain the principles of the apparatus, systems, and methods. The apparatus, systems, and methods are susceptible to modifications and alternative forms. The application is not limited to the particular forms disclosed. The application covers all modifications, equivalents, and alternatives falling within the spirit and scope of the apparatus, systems, and methods as defined by the claims.

[0046] The inventors have been involved in AM research technology for some time. Various research efforts have led the inventors to accumulate vast expertise in AM as adapted to security applications. Recently, the application of AM printing explosives has come to fruition. Developing safe handling and manufacturing methods and adapting formulation to include explosives has been recently successful. This technology is only possible because of the long history of the inventors working with explosives on many different levels, and knowledge of the safe handling and formulation of explosives in general. Combining AM with the safe guards of handling explosives was a natural extension to produce the training aid focus.

[0047] The increased threats of violence unsettle us all. Often times these threats are carefully hidden from human detection, but thanks to explosives detection K-9s, they can still be found. The explosives detection K-9 can be trained and conditioned to detect explosives, explosives residue, and post blast evidence. As a bonus, because of their conditioning to smokeless powder and other explosive fillers

explosives detection K-9s can detect firearms and ammunition hidden in containers and vehicles, on persons and buried underground.

[0048] As illustrated in FIG. 1, a trained K-9 is shown in an operation of actively detecting explosives or explosives residue in connection with a variety of pieces of luggage 102a, 102b and 102c. The operation is designated generally by the reference numeral 100. In the operation 100 a dog 104 is drawn to the suitcase 102b because it contains an explosive or explosives residue 106.

[0049] Dogs can be trained to accomplish many task including detecting materials such as explosives and drugs. Scent training is used to train a dog to recognize a target. Repeatedly having the dog find the target will give the dog the ability to detect the target when working in field. Successful detection of the target earns the dog a food and praise reward, which encourages repetition.

[0050] Referring to FIG. 2 an example of the use of a K-9 training aid for teaching the dog to recognize a target. This example is designated generally by the reference numeral 200. The training aid in this instance is a bone 202 that is used for early training. The bone 202 is something that the dog recognizes and has favorable attitudes towards.

[0051] The inventors have developed apparatus, systems, and methods using AM to make aids that are used in the training of K-9s to detect explosives. The inventors' process uses mixtures of explosives and matrices commonly used in AM. The explosives are formulated into a mixture with the matrix and printed using AM techniques and equipment. The explosive concentrations are kept less than 10% by wt. of the mixture to conform to requirements of shipping and handling, although higher concentrations of explosives are viable. The matrices vary but the most desirable are those that have no volatile compound

signatures after processing. The training aids are printed in a variety of forms and shapes, consistent with meeting K-9 training protocols.

[0052] Referring now to FIG. 3, an illustration shows one embodiment of the inventors' apparatus, systems, and methods using AM to make aids that used in the training of K-9s to detect explosives. The embodiment is designated generally by the reference numeral 300. The embodiment 300 uses AM in at least one step of a process to produce a K-9 training aid that can be used to train dogs to detect explosives.

[0053] The embodiment 300 provides an AM system for selectively processing feedstock materials in a layer-by-layer process to produce the K-9 training aid. Processing includes, but is not limited to, producing a computer-generated image 302 of the training aid to be produced, projecting a digital image 304 of the training aid, using a computer 306 to provide print head motion control 308 to a print head 310 that is moved as indicated by the arrows 316 to provide an extrusion 314 and build the training aid 324. Feed stocks of Material A 318 or Material B 320 or Material C 322 is fed to the print head 310 to produce the layers being printed. In other variations, the print head is fixed and the carriage is moved relative to the print head.

[0054] Initially a 3D model of the desired product (training aid 324) is designed by any suitable method, e.g., by bit mapping or by computer aided design (CAD) software at a PC/controller. The CAD model of the desired product (training aid 324) is electronically sliced into series of 2-dimensional data files, i.e. 2D layers, each defining a planar cross section through the model of the desired product. The sliced layer thickness can vary depending on the spatial resolution of layer printing. The digital images are used in the AM system 300 to produce the final product. The digital images provide a digital image projection

304 of each layer. The digital image projection 304 is fed to a computer that provides computer generated instructions 306. The computer-generated instructions 306 are fed to a print head motion control 308 that moves the print head 310. Layers of the feedstock (Material A 318 or Material B 320 or Material C 322) are printed sequentially onto a substrate in a layer by layer process to produce the final product (training aid 324).

[0055] FIGS. 4A, 4B and 4C illustrate another embodiment of the inventors' apparatus, systems, and methods using AM to make aids used in the training of K-9s to detect explosives. This embodiment is designated generally by the reference numeral 400. The embodiment 400 uses AM to produce a K-9 training aid that can be used to train dogs to detect explosives.

[0056] The embodiment 400 provides an AM system for selectively processing separate feedstock materials in a layer-by-layer process to produce a K-9 training aid. A digital image of the training aid to be produced is created using a computer. The digital image is used to control print head motion and provide an extrusion to build the training aid in a layer-by-layer process.

[0057] Referring now to FIG. 4A, the system 400 is illustrated in a first operation wherein the print head 402 is moved as indicated by the arrows 414 to provide and print stream 404 to build the first layer 406a of the object 406 (training aid) on the build platform 408. The first material 410a of the print material supply is fed to the print head 402 to produce the first layer 406a being printed. The computer controller 412 is directly or indirectly (i.e. by Blue Tooth) connected to all of the machine components and provides the instructions for producing the object 406.

[0058] Referring now to FIG. 4B, the system 400 is illustrated in a second operation wherein the print head 402 is moved as indicated by the arrows 414 to provide and print stream 404 to build the second layer 406b of the object 406 (training aid) on the build platform 408. The second material 410b of the print material supply is fed to the print head 402 to produce the second layer 406b being printed. The computer controller 412 is directly or indirectly (i.e. by Blue Tooth) connected to all of the machine components and provides the instructions for producing the object 406.

[0059] Referring now to FIG. 4C, the system 400 is illustrated in a third operation wherein the print head 402 is moved as indicated by the arrows 414 to provide and print stream 404 to build the third layer 406c of the object 406 (training aid) on the build platform 408. The third material 410c of the print material supply is fed to the print head 402 to produce the third layer 406b being printed. The computer controller 412 is directly or indirectly (i.e. by Blue Tooth) connected to all of the machine components and provides the instructions for producing the object 406.

[0060] Referring to FIG. 5 an example of an Additive Manufactured K-9 training aid that can be used for teaching a dog to recognize a target is illustrated. This example is designated generally by the reference numeral 500. Dogs can be trained to accomplish many task including detecting materials such as explosives and drugs. Scent training is used to train a dog to recognize a target. Repeatedly having the dog find the target will give the dog the ability to detect the target when working in field. Successful detection of the target earns the dog a food and praise reward, which encourages repetition.

[0061] The training aid 500 illustrated in FIG. 5 has many advantages over current training aids. The training aid 500 can be printed in low concentrations to meet DOT requirements as non-hazardous, non-explosive materials. The training aid 500 can be printed in any shape, such as a dog bone, box or hand grenade. The training aid 500 can be printed with a large variety of matrices that are more realistic to actual threat environments, such as clays, ceramics, plastics. The training aid 500 can be printed then processes with little or no volatile backgrounds, for example, several printing formulations are water based. The training aid 500 can be printed with a large array of different explosive materials. The training aid 500 can be printed as laminates with two components of an improvised explosive (oxidizer and fuel) without the components being mixed or co-mingled. The training aid 500 can be printed on-demand. With possible selection of printing equipment, the training aid 500 can be printed in the field. Also, the training aid 500 could be printed with other illicit target materials so they could be used for K-9 training aids for drugs, chemical weapons, and environmental hazards.

[0062] The training aid 500 illustrated in FIG. 5 has an inner inert layer 502a that separates an oxidizer layer 504 from a fuel layer 506. An upper inert layer 502b and a lower inert layer 502c covers and seals the oxidizer layer 504 and the fuel layer 506. The oxidizer layer 504 is less than 10% by weight and the fuel layer 506 is less than 10% by weight and the training aid 500 conforms to requirements of shipping and handling. The training aid 500 is classified as non-hazardous material.

[0063] The first layer 502b is be an inert separator material. The second layer 504, for example, can be an oxidizer. The third layer 502a is be an inert separator material. The fourth layer 506, for example, can be a

fuel. The fifth layer 502c is be an inert separator material. The printing process prints the second layer 504 and the fourth layer 506 separated by the third layer 502a made of an inert separator material. The second, third, and fourth layers are encased in inert separator materials layers 502b and 502c. Examples of the second oxidizer layer 504 and the fourth fuel layer 506 include those listed below.

Example 1
First Layer – Oxidizer 504 - Ammonium Nitrate
Fourth Layer - Fuel 506 - Fuel Oil

Example 2
First Layer – Oxidizer 504 – Potassium Perchlorate
Fourth Layer - Fuel 506 – Powdered Sugar

Example 3
First Layer – Oxidizer 504 – Potassium Nitrate
Fourth Layer - Fuel 506 - Sulfur

[0064] Referring now to FIG. 6, a flow chart illustrates another embodiment of the inventors' apparatus, systems, and methods of using AM to make aids that used in the training of K-9s to detect explosives. This additional embodiment is designated generally by the reference numeral 600. The embodiment 600 uses AM to produce a K-9 training aid that can be used to train dogs to detect explosives.

[0065] Step 602 comprises selecting the desired shape for finished product (i.e., cell phone, bone, hand Grenade etc.).

[0066] Step 604 comprises printing the first polymer layer containing traces of a first reactive material.

[0067] Step 606 comprises printing a second polymer barrier (safety) layer.

[0068] Step 608 comprises printing the third polymer layer containing traces of a second reactive material.

[0069] Step 610 comprise curing the printed green product to produce the final product.

[0070] Referring now to FIG. 7, a flow chart illustrates another embodiment of the inventors' apparatus, systems, and methods of using AM to make aids that used in the training of K-9s to detect explosives. This additional embodiment is designated generally by the reference numeral 700. The embodiment 700 uses AM to produce a K-9 training aid that can be used to train dogs to detect explosives.

[0071] Step 702 comprises selecting trace elements for mixing with a polymer of any material targeted for detection (explosives, drugs, fugitive industrial emissions).

[0072] Step 704 comprises creating a desired shape to be used for training purpose.

[0073] Step 706 comprises curing the printed part to produce the final product.

[0074] FIG. 8 shows a view of a notebook computer that has been printed using penta-erythritol as a surrogate for penta erythritol tetra nitrate (PETN). The penta-erythitol was added to the matrix at about 8 wt. %. The printing of the notebook computer demonstrates the ability of the AM process to produce objects that would be consider of interest to K-9 detection. These objects could be printed on-demand, depending upon the application, and provide a more sophisticated type of training aid that also represents object recognition.

[0075] FIG. 9 illustrates another embodiment of the inventors' apparatus, systems, and methods using AM to make aids used in the training of K-9s to detect explosives. This embodiment is designated

generally by the reference numeral 900 and focuses on the detection of standard commercial and military explosives.

[0076] The embodiment 900 provides an AM system for selectively processing separate explosive material feedstock and separator material feedstock in a layer-by-layer process to produce a K-9 training aid. A digital image of the training aid to be produced is created using a computer. The digital image is used to control print head motion and provide an extrusion to build the training aid in a layer-by-layer process.

[0077] The system 900 is illustrated in operation wherein a first print head 902 and a second print head 906 are moved to provide and print streams 904 and 908 to build the training aid 910 on the build platform 912. The material in the print head 902 is a separator material that produces the body portion of the training aid 910 being printed. The material in the print head 906 is explosive material. The print head 906 places separate allocates of the explosives separated from one another in the body portion of the training aid 910 being printed.

[0078] FIGS. 10A and 10B provide more details of the training aid produced by the AM system illustrated in FIG. 9. The training aid is designated generally by the reference numeral 1000.

[0079] FIG. 10A shows the training aid 1000 with the portion in the circle illustrated in greater detail in FIG. 10B. The material 1004 is a separator material that produces the body portion of the training aid 1000. The material 1002 is explosive material in the form of standard commercial and military explosives. The explosive material 1002 can include the following:

Military Explosives
C4

HMX
PETN
RDX
Semtex

Commercial Explosives
ANAL
ANFO
Black Powder
Dynamite
Nitroglycerin
Smokeless Powder
TNT
Urea Nitrate

[0080] The explosive material 1002 is positioned in separate allocates of the explosives separated from one another in the body portion of the training aid 1000. The explosive material 1002 constitutes less than 10% of the training aid 1000. The explosive concentration is kept less than 10% by wt. of the training aid to conform to requirements of shipping and handling. The training aid 1000 is printed in low concentrations to meet DOT requirements as non-hazardous, non-explosive materials. The explosives 1002 are isolated in the inert separator material 1002.

[0081] Then I first meet a likable young Labrador named Merry, she is clearing her nostrils with nine or ten sharp snorts before she snuffles along a row of luggage pieces, all different makes and models. They're lined up against the back wall of a large hangar on a country road outside Hartford, Connecticut. This is where MSA Security trains what are known in the security trade as explosive detection canines, or EDCs. Most people call them bomb dogs.

[0082] Although the description above contains many details and specifics, these should not be construed as limiting the scope of the application but as merely providing illustrations of some of the presently preferred embodiments of the apparatus, systems, and methods. Other implementations, enhancements and variations can be made based on what is described and illustrated in this patent document. The features of the embodiments described herein may be combined in all possible combinations of methods, apparatus, modules, systems, and computer program products. Certain features that are described in this patent document in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination. Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments.

[0083] Therefore, it will be appreciated that the scope of the present application fully encompasses other embodiments which may become

obvious to those skilled in the art. In the claims, reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural and functional equivalents to the elements of the above-described preferred embodiment that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device to address each and every problem sought to be solved by the present apparatus, systems, and methods, for it to be encompassed by the present claims. Furthermore, no element or component in the present disclosure is intended to be dedicated to the public regardless of whether the element or component is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112, sixth paragraph, unless the element is expressly recited using the phrase "means for."

[0084] While the apparatus, systems, and methods may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the application is not intended to be limited to the particular forms disclosed. Rather, the application is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the application as defined by the following appended claims.

CHAPTER 2: EXPLOSIVES MIMIC FOR TESTING, TRAINING, AND MONITORING

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0085] Referring to the drawings, to the following detailed description, and to incorporated materials, detailed information about the apparatus, systems, and methods is provided including the description of specific embodiments. The detailed description serves to explain the principles of the apparatus, systems, and methods. The apparatus, systems, and methods are susceptible to modifications and alternative forms. The application is not limited to the particular forms disclosed. The application covers all modifications, equivalents, and alternatives falling within the spirit and scope of the apparatus, systems, and methods as defined by the claims.

[0086] The inventors have been involved in AM research technology for some time. Various research efforts have led the inventors to accumulate vast expertise in AM as adapted to security applications. Recently, the application of AM printing explosives has come to fruition. Developing safe handling and manufacturing methods and adapting formulation to include explosives has been recently successful. This technology is only possible because of the long history of the inventors working with explosives on many different levels, and knowledge of the safe handling and formulation of explosives in general. Combining AM with the safe guards of handling explosives was a natural extension to produce the mimic for explosives focus.

[0087] Referring now to the drawings, and in particular to FIG. 11, an illustration shows one embodiment of the inventors' apparatus, systems, and methods using AM to make mimics of explosives that can be used in the testing, training, and monitoring of explosives by detection systems, including K-9 detection of explosives. The embodiment is designated generally by the reference numeral 2-100. The embodiment 2-100 uses AM in at least one step of a process to

produce a mimic of explosives. The embodiment 2-100 provides an AM system for selectively processing feedstock materials in a layer-by-layer process to produce the mimic of explosives. Processing includes, but is not limited to, producing a computer-generated image 2-102 of the mimic of explosives to be produced, projecting a digital image 2-104 of the mimic of explosives, using a computer 2-106 to provide print head motion control 2-108 to a print head 2-110 that is moved as indicated by the arrows 2-116 to provide an extrusion 2-112 and build the mimic of explosives 2-114. Feed stocks of Material A 2-118 or Material B 2-120 are fed to the print head 2-110 to produce the layers being printed. In other variations, the print head is fixed and the carriage is moved relative to the print head.

[0088] Initially a 3D model of the desired product (mimic of explosives 2-114) is designed by any suitable method, e.g., by bit mapping or by computer aided design (CAD) software at a PC/controller. The CAD model of the desired product (mimic of explosives 2-114) is electronically sliced into series of 2-dimensional data files, i.e. 2D layers, each defining a planar cross section through the model of the desired product. The sliced layer thickness can vary depending on the spatial resolution of layer printing. The digital images are used in the AM system 2-100 to produce the final product. The digital images provide a digital image projection 2-104 of each layer. The digital image projection 2-104 is fed to a computer that provides computer generated instructions 2-106. The computer-generated instructions 2-106 are fed to a print head motion control 2-108 that moves the print head 2-110. Layers of the feedstock (Material A 2-118 or Material B 2-120) are printed sequentially onto a substrate in a layer by layer process to produce the final product (mimic of explosives 2-114).

[0089] Referring to FIG. 12 an example of an additive manufactured mimic of explosives that can be used in the testing, training, and monitoring of explosives is illustrated. This example is designated generally by the reference numeral 2-200. The mimic of explosives illustrated in FIG. 12 has many advantages. It can be printed in low concentrations to meet DOT requirements as non-hazardous, non-explosive materials. It can be printed in any shape, such as a cell phone, box or hand grenade. It can be printed with a large variety of matrices that are more realistic to actual threat environments, such as clays, ceramics, plastics. It can be printed with a large array of different explosive materials. The mimic of explosives can be printed as laminates with two components of an improvised explosive (oxidizer and fuel) without the components being mixed or co-mingled. The mimic of explosives can be printed on-demand. With possible selection of printing equipment, the mimic of explosives can be printed in the field. Also, the mimic of explosives could be printed with other illicit target materials so they could be used drugs, chemical weapons, and environmental hazards.

[0090] The mimic for explosives 2-200 illustrated in FIG. 12 has an inner inert layer 2-202a that separates an oxidizer layer 2-204 from a fuel layer 2-206. An upper inert layer 2-202b and a lower inert layer 2-202c covers and seals the oxidizer layer 2-204 and the fuel layer 2-206. The oxidizer layer 2-204 and the fuel layer 2-206 can be varied in concentration to conform to requirements of shipping and handling. The mimic for explosives 2-200 is classified as non-hazardous material.

[0091] The first layer 2-202b is be an inert separator material. The second layer 2-204, for example, can be an oxidizer. The third layer 2-202a is be an inert separator material. The fourth layer 2-206, for

example, can be a fuel. The fifth layer 2-202c is an inert separator material. The printing process prints the second layer 2-204 and the fourth layer 2-206 separated by the third layer 2-202a made of an inert separator material. The second, third, and fourth layers are encased in inert separator materials layers 2-202b and 2-202c. Examples of the second oxidizer layer 2-204 and the fourth fuel layer 2-206 include those listed below. The explosive concentrations are kept less than 10% by wt. of the mixture to conform to requirements of shipping and handling.

Example 1
First Layer – Oxidizer 2-204 - Ammonium Nitrate
Fourth Layer - Fuel 2-206 - Fuel Oil

Example 2
First Layer – Oxidizer 2-204 – Potassium Perchlorate
Fourth Layer - Fuel 2-206 – Powdered Sugar

Example 3
First Layer – Oxidizer 2-204 – Potassium Nitrate
Fourth Layer - Fuel 2-206 - Sulfur

[0092] FIGS. 13A and 13B provide more details of the mimic for explosives produced by the AM system illustrated in FIG. 11. The mimic for explosives is designated generally by the reference numeral 2-300.

[0093] FIG. 13A shows the mimic for explosives 2-300 with the portion in the circle illustrated in greater detail in FIG. 13B. The material 2-304 is a separator material that produces the body portion of the mimic for explosives 2-300. The material 2-302 is explosive material in the form of standard commercial and military explosives. The explosive material 2-302 can include the following:

Military Explosives

C4
HMX
PETN
RDX
Semtex

Commercial Explosives
ANAL
ANFO
Black Powder
Dynamite
Nitroglycerin
Smokeless Powder
TNT
Urea Nitrate

[0094] The explosive material 2-302 is positioned in separate allocates of the explosives separated from one another in the body portion of the mimic for explosives 2-300. The explosive material 2-302 constitutes less than 10% of the mimic for explosives 2-300. The explosive concentration is kept less than 10% by wt. of the mimic for explosives to conform to requirements of shipping and handling. The mimic for explosives 2-300 is printed in low concentrations to meet DOT requirements as non-hazardous, non-explosive materials. The explosives 2-302 are isolated in the inert separator material 2-304.

[0095] Although the description above contains many details and specifics, these should not be construed as limiting the scope of the application but as merely providing illustrations of some of the presently preferred embodiments of the apparatus, systems, and methods. Other implementations, enhancements and variations can be made based on what is described and illustrated in this patent document. The features of the embodiments described herein may be combined in all possible combinations of methods, apparatus,

modules, systems, and computer program products. Certain features that are described in this patent document in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination. Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments.

[0096] Therefore, it will be appreciated that the scope of the present application fully encompasses other embodiments which may become obvious to those skilled in the art. In the claims, reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural and functional equivalents to the elements of the above-described preferred embodiment that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device to address each and every problem sought to be solved by the

present apparatus, systems, and methods, for it to be encompassed by the present claims. Furthermore, no element or component in the present disclosure is intended to be dedicated to the public regardless of whether the element or component is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112, sixth paragraph, unless the element is expressly recited using the phrase "means for."

[0097] While the apparatus, systems, and methods may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the application is not intended to be limited to the particular forms disclosed. Rather, the application is to cover all modifications, equivalents, and alternatives falling within the scope of the application as defined by the following appended claims.

[0098] This as presented in chapters 1 and 2 and otherwise also presents at least the following concepts.

Concept 1. An apparatus, comprising:

a K-9 training aid having multiple components,

an explosive material component comprising one of said components, and

a separator material component comprising another of said components.

Concept 2. The apparatus of concept 1 wherein said explosive material component comprising one of said components includes a layer made of an oxidizer material and a layer made of a fuel material.

Concept 3. The apparatus of concept 1 or 2 wherein said explosive material component comprising one of said components includes an additive manufactured layer made of an oxidizer material and an additive manufactured layer made of a fuel material.

Concept 4. The apparatus of concept 1, 2, or 3 wherein said additive manufactured layer made of an oxidizer material is less than ten percent of the apparatus by weight.

Concept 5. The apparatus of concept 1, 2, 3, or 4 wherein said additive manufactured layer made of a fuel material is less than ten percent of the apparatus by weight.

Concept 6. The apparatus of concept 1, 2, 3, 4, or 5 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Concept 7. The apparatus of concept 1, 2, 3, 4, 5, or 6 wherein said additive manufactured layer made of a fuel material comprises sulfur.

Concept 8. The apparatus of concept 1, 2, 3, 4, 5, 6, or 7 wherein said explosive material component comprising one of said components includes separate allocates of explosives located in said separator material component.

Concept 9. The apparatus of concept 1, 2, 3, 4, 5, 6, 7, or 8 wherein said explosive material component comprising one of said components includes

separate allocates of military explosives located in said separator material component.

Concept 10. The apparatus of concept 1, 2, 3, 4, 5, 6, 7, 8, or 9 wherein said explosive material component comprising one of said components includes separate allocates of commercial explosives located in said separator material component.

Concept 11. The apparatus of concept 1, 2, 3, 4, 5, 6, 7, 8, 9, or 10 wherein said explosive material component comprising one of said components is less than ten percent of the apparatus by weight.

Concept 12. A K-9 training aid apparatus, comprising:

an additive manufactured layer made of an oxidizer material,

an additive manufactured layer made of a fuel material, and

an additive manufactured layer made of an inert material that separates said layer made of an oxidizer material and said layer made of a fuel material.

Concept 13. The K-9 training aid apparatus of concept 12 wherein said additive manufactured layer made of an oxidizer material is less than 10% by weight.

Concept 14. The K-9 training aid apparatus of concept 12 or 13 wherein said additive manufactured layer made of a fuel material is less than 10% by weight.

Concept 15. The K-9 training aid apparatus of concept 12, 13, or 14 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Concept 16. The K-9 training aid apparatus of concept 12, 13, 14, or 15 wherein said additive manufactured layer made of a fuel material comprises sulfur.

Concept 17. A method of making a K-9 training aid, comprising the steps of:

printing a K-9 training aid having multiple components,

printing an explosive material component comprising one of said components, and

printing a separator material component comprising another of said components.

Concept 18. The method of making a K-9 training aid of concept 17 wherein said step of printing an explosive material component comprising printing an explosive material component that is less than ten percent of said K-9 training aid by weight.

Concept 19. An explosives mimic apparatus for testing, training, or monitoring; comprising:

an explosives mimic having multiple components,

an explosive material component comprising one of said components, and

a separator material component comprising another of said components.

Concept 20. The explosives mimic apparatus for testing, training, or monitoring of concept 19 wherein said explosive material component comprising one of said components includes a layer made of an oxidizer material and a layer made of a fuel material.

Concept 21. The explosives mimic apparatus for testing, training, or monitoring of concept 19 or 20 wherein said explosive material component comprising one of said components includes an additive manufactured layer made of an oxidizer material and an additive manufactured layer made of a fuel material.

Concept 22. The explosives mimic apparatus for testing, training, or monitoring of concept 19, 20, or 21 wherein said additive manufactured layer made of an oxidizer material is less than ten percent of the apparatus by weight.

Concept 23. The explosives mimic apparatus for testing, training, or monitoring of concept 19, 20, 21, or 22 wherein said additive manufactured layer made of a fuel material is less than ten percent of the apparatus by weight.

Concept 24. The explosives mimic apparatus for testing, training, or monitoring of concept 19, 20, 21, 22, or 23 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Concept 25. The explosives mimic apparatus for testing, training, or monitoring of concept 19, 20, 21, 22, 23, or 24 wherein said additive manufactured layer made of a fuel material comprises sulfur.

Concept 26. The explosives mimic apparatus for testing, training, or monitoring of concept 19, 20, 21, 22, 23, 24, or 25 wherein said explosive material component comprising one of said components includes separate allocates of explosives located in said separator material component.

Concept 27. The explosives mimic apparatus for testing, training, or monitoring of concept 19, 20, 21, 22, 23, 24, 25, or 26 wherein said explosive material component comprising one of said components includes separate allocates of military explosives located in said separator material component.

Concept 28. The explosives mimic apparatus for testing, training, or monitoring of concept 19, 20, 21, 22, 23, 24, 25, 26 or 27wherein said explosive material component comprising one of said components includes separate allocates of commercial explosives located in said separator material component.

Concept 29. The explosives mimic apparatus for testing, training, or monitoring of concept 19, 20, 21, 22, 23, 24, 25, 26, 27 or 28wherein said explosive material component comprising one of said components is less than ten percent of the apparatus by weight.

Concept 30. An explosives mimic apparatus for testing, training, or monitoring, comprising:

an additive manufactured layer made of an oxidizer material,

an additive manufactured layer made of a fuel material, and

an additive manufactured layer made of an inert material that separates said layer made of an oxidizer material and said layer made of a fuel material.

Concept 31. The explosives mimic apparatus for testing, training, or monitoring of concept 30 wherein said additive manufactured layer made of an oxidizer material is less than 10% by weight.

Concept 32. The explosives mimic apparatus for testing, training, or monitoring of concept 30 or 31wherein said additive manufactured layer made of a fuel material is less than 10% by weight.

Concept 33. The explosives mimic apparatus for testing, training, or monitoring of concept 30, 31, or 32wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Concept 34. The explosives mimic apparatus for testing, training, or monitoring of concept 30, 31, 32, or 33wherein said additive manufactured layer made of a fuel material comprises sulfur.

Concept 35. An explosives mimic apparatus for testing, training, or monitoring; comprising:

an additive manufactured layer made of an oxidizer material,

an additive manufactured layer made of a fuel material, and

an additive manufactured layer made of an inert material that separates said layer made of an oxidizer material and said layer made of a fuel material.

Concept 36. The explosives mimic apparatus for testing, training, or monitoring of concept 35 wherein said additive manufactured layer made of an oxidizer material is less than 10% by weight.

Concept 37. The explosives mimic apparatus for testing, training, or monitoring of concept 35 or 36 wherein said additive manufactured layer made of a fuel material is less than 10% by weight.

Concept 38. The explosives mimic apparatus for testing, training, or monitoring of concept 35, 36, or 37 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Concept 39. The explosives mimic apparatus for testing, training, or monitoring of concept 35, 36, 37, or 38wherein said additive manufactured layer made of a fuel material comprises sulfur.

Concept 40. An explosives mimic apparatus for testing, training, or monitoring comprising:

an additive manufactured layer made of an explosives material,

an additive manufactured layer made of a non-explosive material, and

an additive manufactured layer made of an inert material that separates said layer made of an explosives material and said layer made of a non-explosive material.

Concept 41. The explosives mimic apparatus for testing, training, or monitoring of concept 40 wherein said additive manufactured layer made of

an explosives material is less than 10% by weight of said additive manufactured layer made of an explosives material.

Concept 42. A method of making an explosives mimic apparatus for testing, training, or monitoring comprising the steps of:

printing a first layer made of an oxidizer material,

printing a second layer made of a fuel material, and

printing a third layer made of an inert material that separates said layer made of an oxidizer material and said layer made of a fuel material.

Concept 43. The method of making an explosives mimic apparatus for testing, training, or monitoring of concept 42 wherein said additive manufactured layer made of an oxidizer material is less than 10% by weight.

Concept 44. The method of making an explosives mimic apparatus for testing, training, or monitoring of concept 42 or 43 wherein said additive manufactured layer made of a fuel material is less than 10% by weight.

[0099] Broadly, this writing presents the following. Additive Manufacturing (AM) is used to make aids that target the training of K-9s to detect explosives and make mimics for explosives. The process uses mixtures of explosives and matrices commonly used in AM. The explosives are formulated into a mixture with the matrix and printed using AM techniques and equipment. The explosive concentrations are kept less than 10% by wt. of the mixture to conform to requirements of shipping and handling.

[00100] All elements, parts, and steps described herein are preferably included. It is to be understood that any of these elements,

parts, and steps may be replaced by other elements, parts, and steps or deleted altogether as will be obvious to those skilled in the art.

THE CLAIMS ARE:

Claim 1. An apparatus, comprising:

a K-9 training aid having multiple components;

an explosive material component comprising one of said components, wherein said explosive material component comprising one of said components includes a layer made of an oxidizer material and a layer made of a fuel material; and

a separator material component comprising another of said components.

Claim 2. The apparatus of claim 1 wherein said explosive material component comprising one of said components includes an additive manufactured layer made of an oxidizer material and an additive manufactured layer made of a fuel material.

Claim 3. The apparatus of claim 1 wherein said additive manufactured layer made of an oxidizer material is less than ten percent of the apparatus by weight.

Claim 4. The apparatus of claim 1 wherein said additive manufactured layer made of a fuel material is less than ten percent of the apparatus by weight.

Claim 5. The apparatus of claim 1 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Claim 6. The apparatus of claim 1 wherein said additive manufactured layer made of a fuel material comprises sulfur.

Claim 7. The apparatus of claim 1 wherein said explosive material component comprising one of said components includes separate allocates of explosives located in said separator material component.

Claim 8. The apparatus of claim 1 wherein said explosive material component comprising one of said components includes separate allocates of military explosives located in said separator material component.

Claim 9. The apparatus of claim 1 wherein said explosive material component comprising one of said components includes separate allocates of commercial explosives located in said separator material component.

Claim 10. The apparatus of claim 1 wherein said explosive material component comprising one of said components is less than ten percent of the apparatus by weight.

Claim 11. A K-9 training aid apparatus, comprising:

an additive manufactured layer made of an oxidizer material,

an additive manufactured layer made of a fuel material, and

an additive manufactured layer made of an inert material that separates said layer made of an oxidizer material and said layer made of a fuel material.

Claim 12. The K-9 training aid apparatus of claim 11 wherein said additive manufactured layer made of an oxidizer material is less than 10% by weight.

Claim 13. The K-9 training aid apparatus of claim 11 wherein said additive manufactured layer made of a fuel material is less than 10% by weight.

Claim 14. The K-9 training aid apparatus of claim 11 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Claim 15. The K-9 training aid apparatus of claim 11 wherein said additive manufactured layer made of a fuel material comprises sulfur.

Claim 16. A method of making a K-9 training aid, comprising the steps of:

printing a K-9 training aid having multiple components,

printing an explosive material component comprising one of said components, and

printing a separator material component comprising another of said components.

Claim 17. The method of making a K-9 training aid of claim 16 wherein said step of printing an explosive material component comprising printing an explosive material component that is less than ten percent of said K-9 training aid by weight.

Claim 18. An explosives mimic apparatus for testing, training, or monitoring; comprising:

an explosives mimic having multiple components;

an explosive material component comprising one of said components, wherein said explosive material component comprising one of said components includes a layer made of an oxidizer material and a layer made of a fuel material; and

a separator material component comprising another of said components.

Claim 19. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said layer made of an oxidizer material is an additive manufactured layer made of an oxidizer material and wherein said layer made of a fuel material is an additive manufactured layer made of a fuel material.

Claim 20. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said additive manufactured layer made of an oxidizer material is less than ten percent of the apparatus by weight.

Claim 21. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said additive manufactured layer made of a fuel material is less than ten percent of the apparatus by weight.

Claim 22. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Claim 23. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said additive manufactured layer made of a fuel material comprises sulfur.

Claim 24. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said explosive material component comprising one of said components includes separate allocates of explosives located in said separator material component.

Claim 25. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said explosive material component comprising one of said components includes separate allocates of military explosives located in said separator material component.

Claim 26. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said explosive material component comprising one of said components includes separate allocates of commercial explosives located in said separator material component.

Claim 27. The explosives mimic apparatus for testing, training, or monitoring of claim 18 wherein said explosive material component comprising one of said components is less than ten percent of the apparatus by weight.

Claim 28. An explosives mimic apparatus for testing, training, or monitoring, comprising:

an additive manufactured layer made of an oxidizer material,

an additive manufactured layer made of a fuel material, and

an additive manufactured layer made of an inert material that separates said layer made of an oxidizer material and said layer made of a fuel material.

Claim 29. The explosives mimic apparatus for testing, training, or monitoring of claim 28 wherein said additive manufactured layer made of an oxidizer material is less than 10% by weight.

Claim 30. The explosives mimic apparatus for testing, training, or monitoring of claim 28 wherein said additive manufactured layer made of a fuel material is less than 10% by weight.

Claim 31. The explosives mimic apparatus for testing, training, or monitoring of claim 28 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Claim 32. The explosives mimic apparatus for testing, training, or monitoring of claim 28 wherein said additive manufactured layer made of a fuel material comprises sulfur.

Claim 33. An explosives mimic apparatus for testing, training, or monitoring; comprising:

an additive manufactured layer made of an oxidizer material,

an additive manufactured layer made of a fuel material, and

an additive manufactured layer made of an inert material that separates said layer made of an oxidizer material and said layer made of a fuel material.

Claim 34. The explosives mimic apparatus for testing, training, or monitoring of claim 33 wherein said additive manufactured layer made of an oxidizer material is less than 10% by weight.

Claim 35. The explosives mimic apparatus for testing, training, or monitoring of claim 33 wherein said additive manufactured layer made of a fuel material is less than 10% by weight.

Claim 36. The explosives mimic apparatus for testing, training, or monitoring of claim 33 wherein said additive manufactured layer made of an oxidizer material comprises potassium nitrate.

Claim 37. The explosives mimic apparatus for testing, training, or monitoring of claim 33 wherein said additive manufactured layer made of a fuel material comprises sulfur.

Claim 38. An explosives mimic apparatus for testing, training, or monitoring comprising:

an additive manufactured layer made of an explosives material,

an additive manufactured layer made of a non-explosive material, and

an additive manufactured layer made of an inert material that separates said layer made of an explosives material and said layer made of a non-explosive material.

Claim 39. The explosives mimic apparatus for testing, training, or monitoring of claim 38 wherein said additive manufactured layer made of an

explosives material is less than 10% by weight of said additive manufactured layer made of an explosives material.

Claim 40. A method of making an explosives mimic apparatus for testing, training, or monitoring comprising the steps of:

printing a first layer made of an oxidizer material,

printing a second layer made of a fuel material, and

printing a third layer made of an inert material that separates said layer made of an oxidizer material and said layer made of a fuel material.

Claim 41. The method of making an explosives mimic apparatus for testing, training, or monitoring of claim 40 wherein said additive manufactured layer made of an oxidizer material is less than 10% by weight.

Claim 42. The method of making an explosives mimic apparatus for testing, training, or monitoring of claim 40 wherein said additive manufactured layer made of a fuel material is less than 10% by weight.

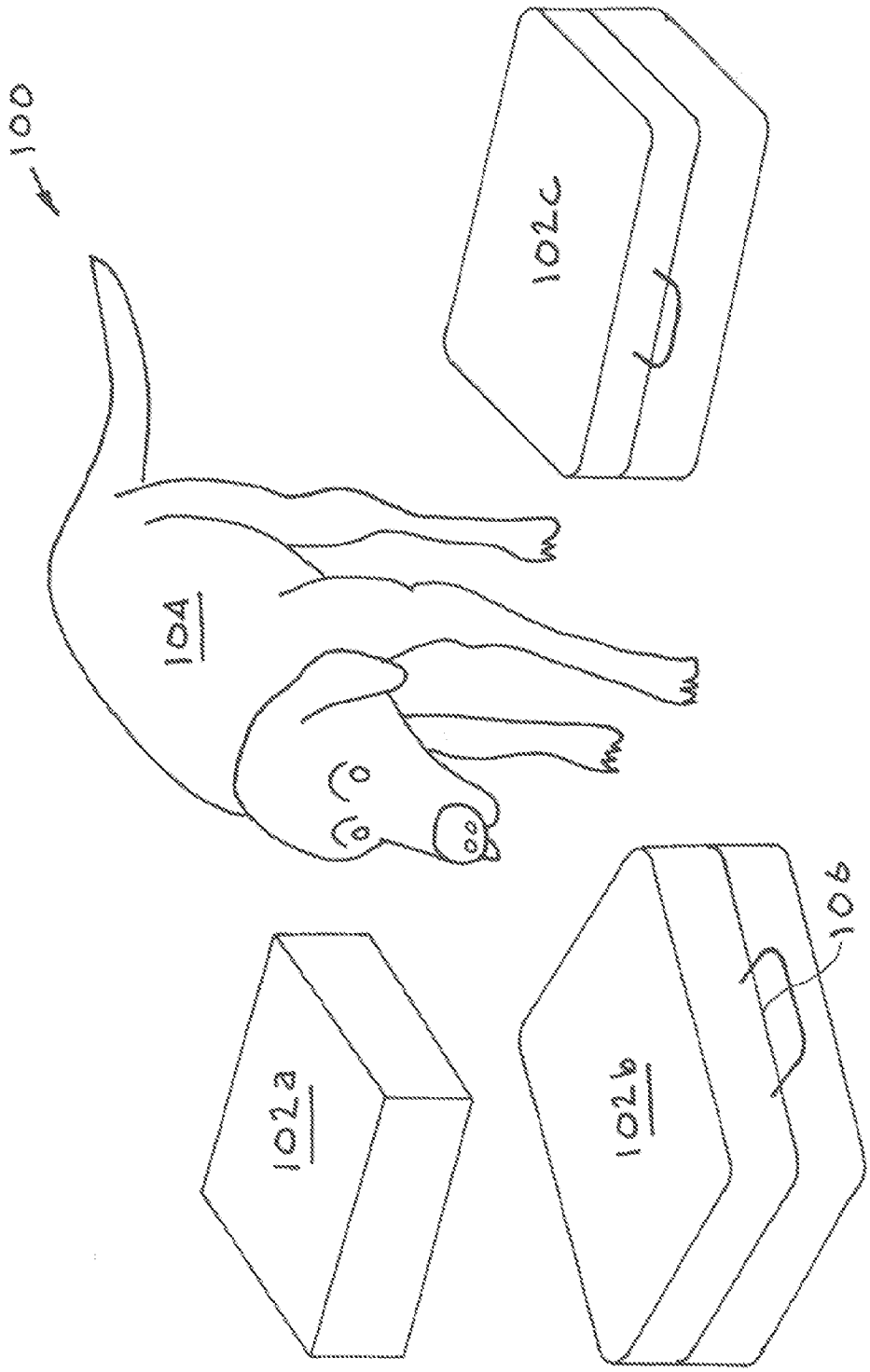


FIG. 1

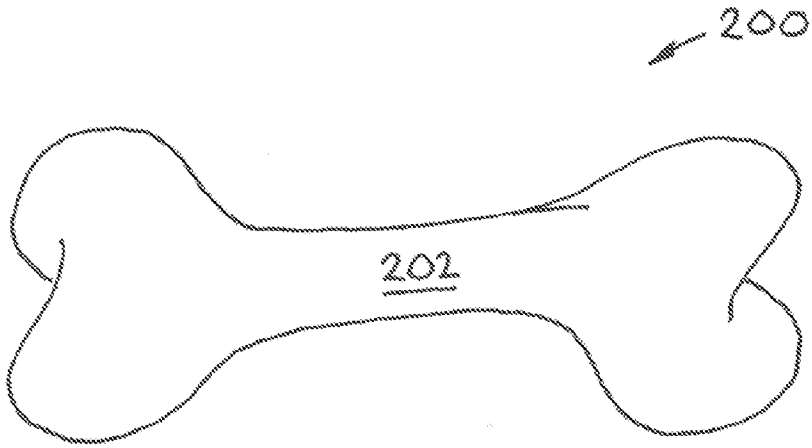


FIG. 2

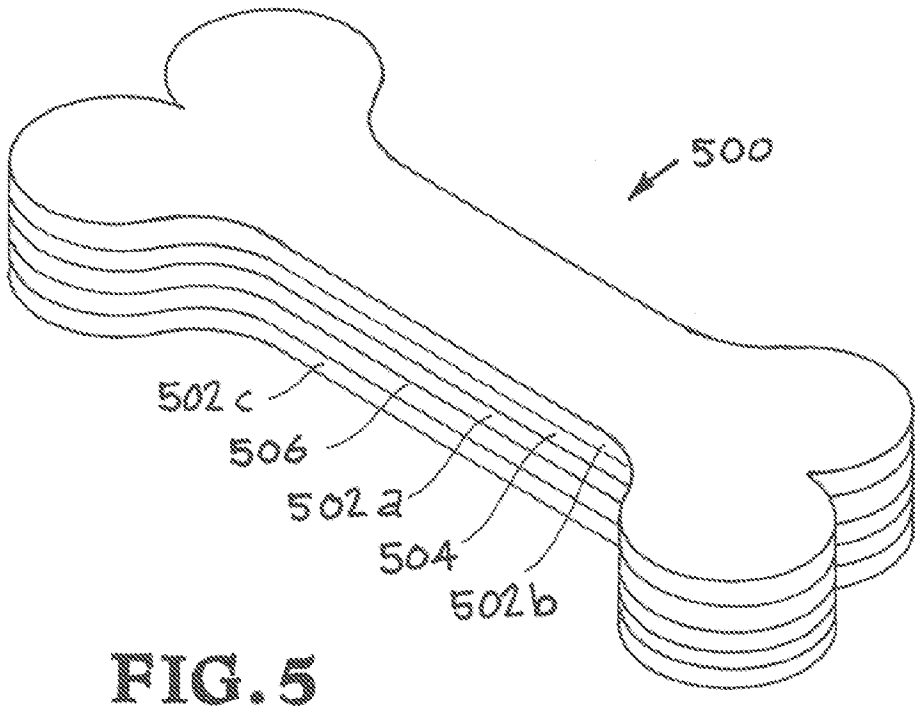
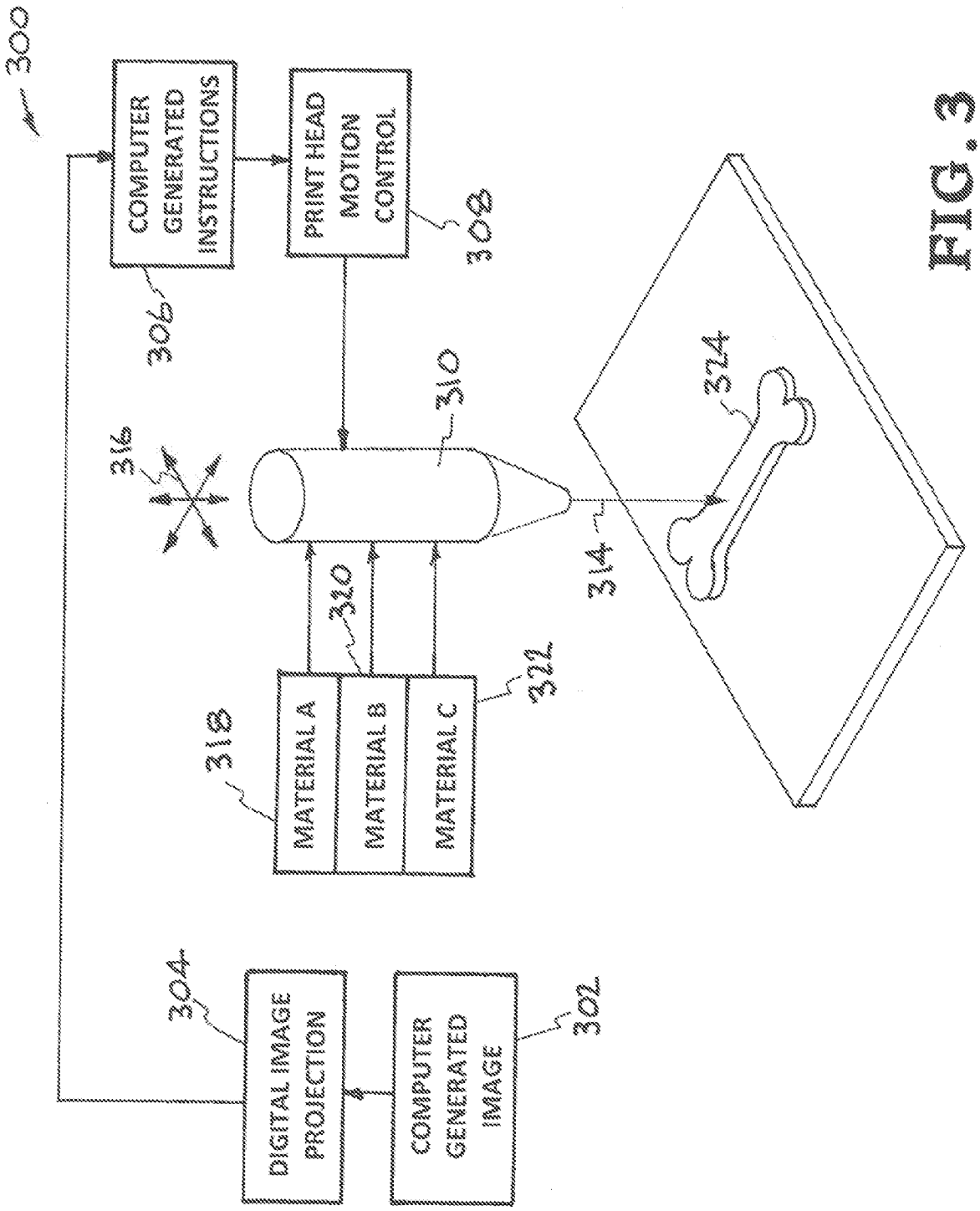


FIG. 5


300
COMPUTER GENERATED INSTRUCTIONS
306
PRINT HEAD MOTION CONTROL
308
310
316
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314
324
318
MATERIAL A
MATERIAL B
MATERIAL C
322
304
DIGITAL IMAGE PROJECTION
COMPUTER GENERATED IMAGE
302

FIG. 3

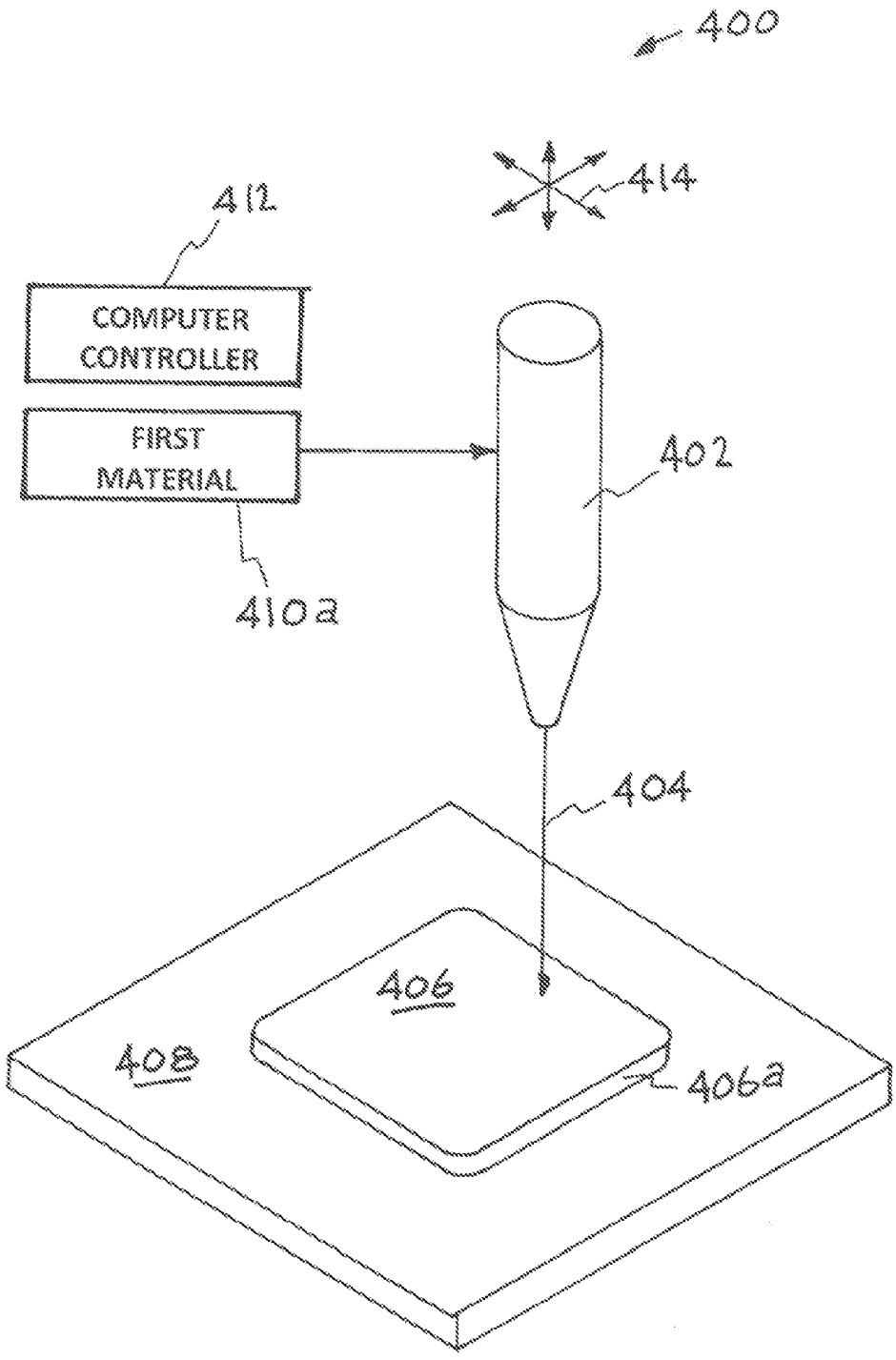
400
414
412
COMPUTER CONTROLLER
FIRST MATERIAL
410a
402
404
406
406a
408

FIG. 4A

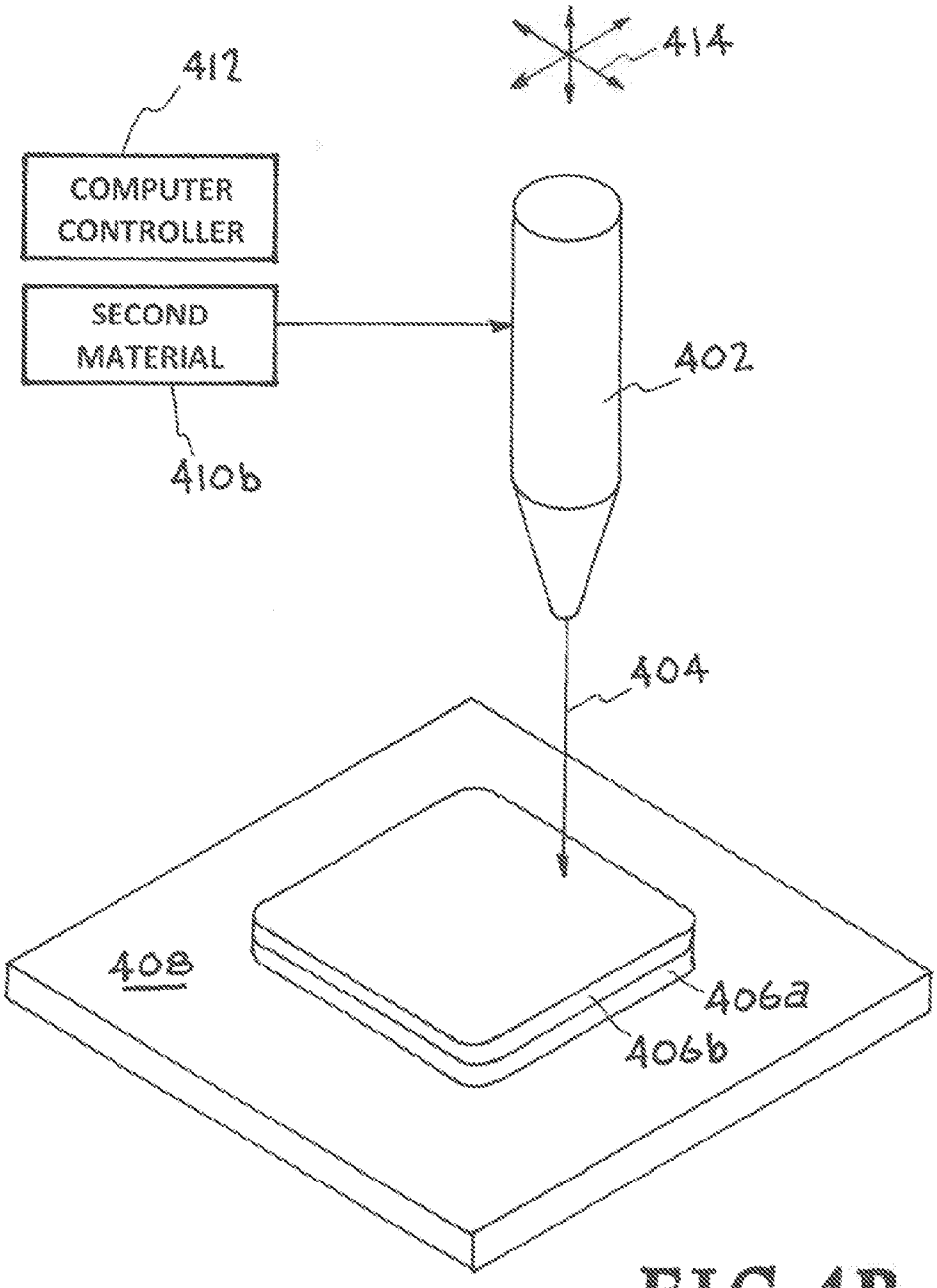
412
414
COMPUTER CONTROLLER
SECOND MATERIAL
410b
402
404
408
406a
406b

FIG. 4B

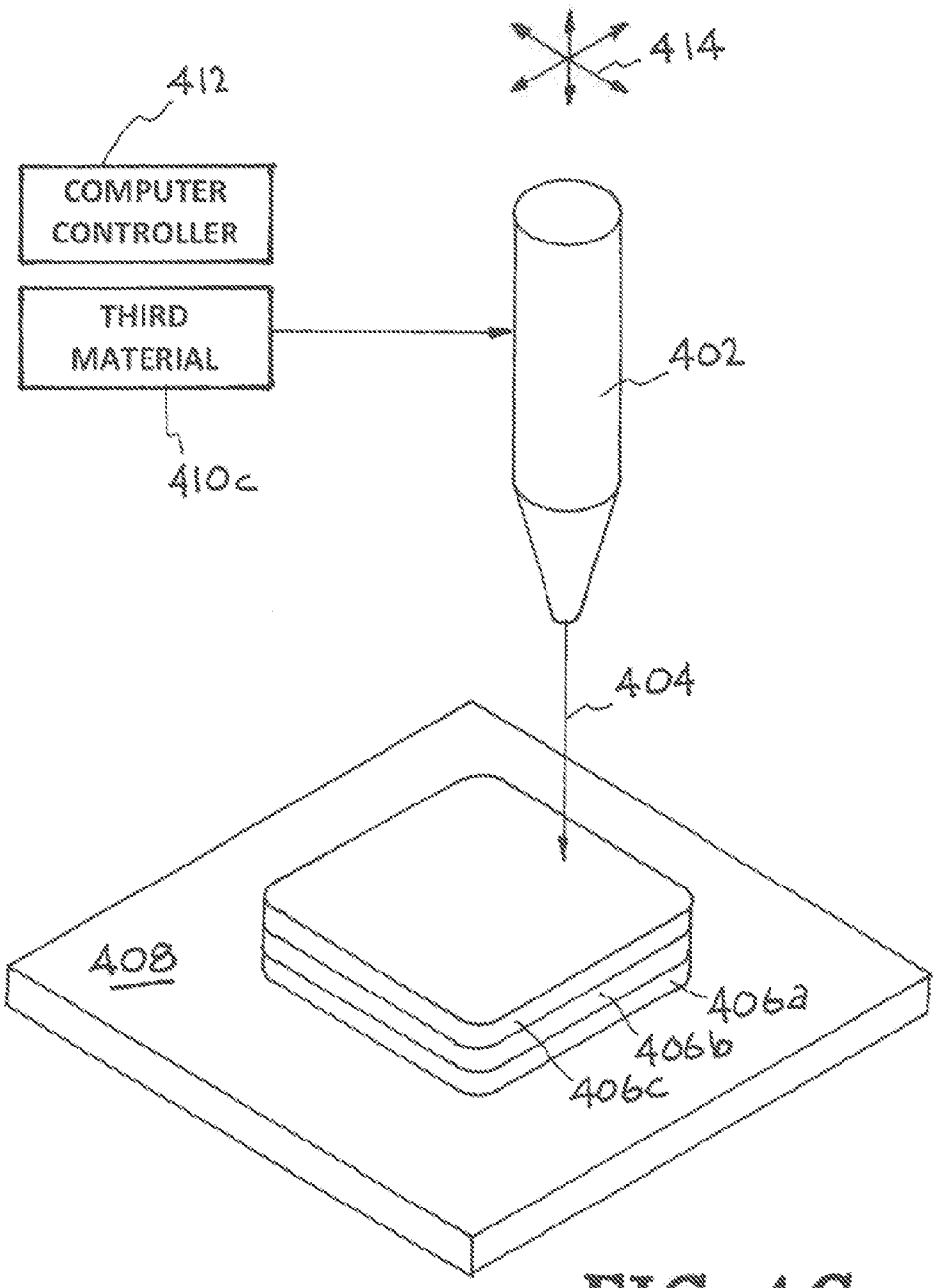
414
412
COMPUTER CONTROLLER
THIRD MATERIAL
410c
402
404
408
406a
406b
406c

FIG. 4C

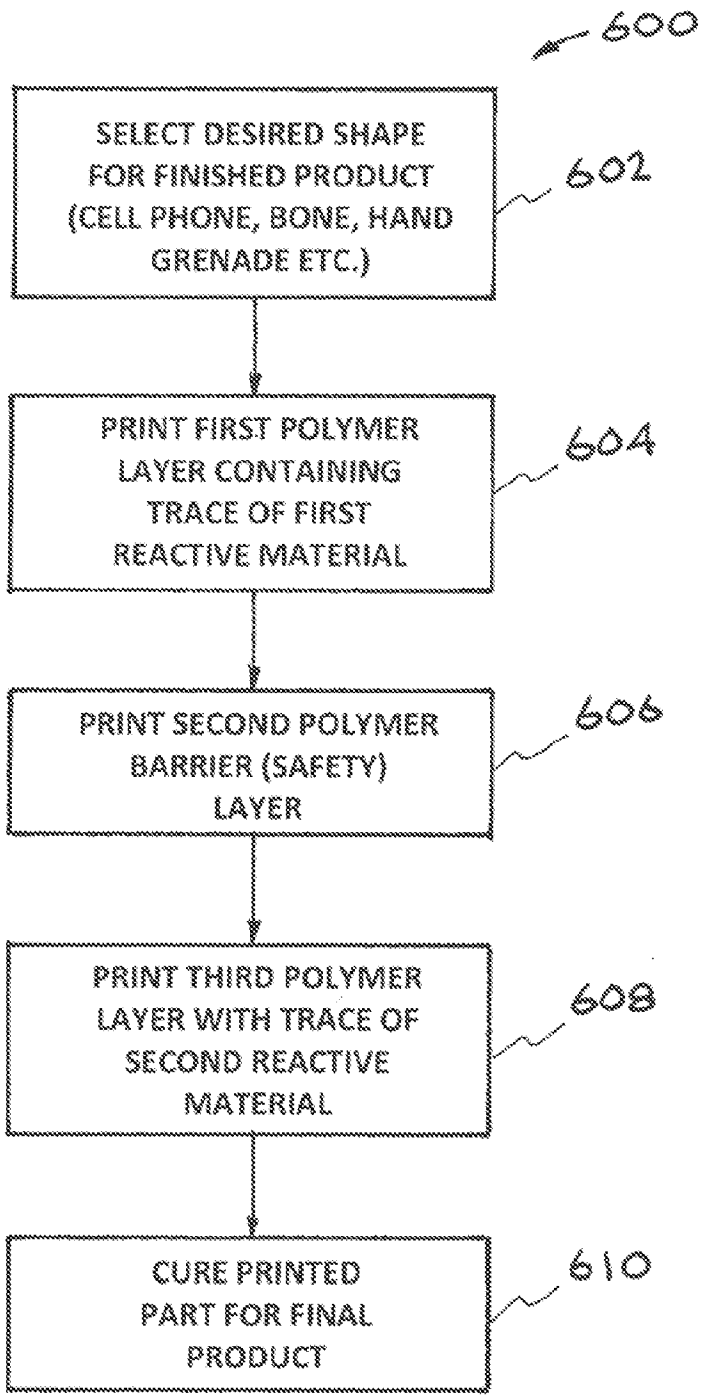
600
SELECT DESIRED SHAPE FOR FINISHED PRODUCT (CELL PHONE, BONE, HAND GRENADE ETC.)
602
PRINT FIRST POLYMER LAYER CONTAINING TRACE OF FIRST REACTIVE MATERIAL
604
PRINT SECOND POLYMER BARRIER (SAFETY) LAYER
606
PRINT THIRD POLYMER LAYER WITH TRACE OF SECOND REACTIVE MATERIAL
608
CURE PRINTED PART FOR FINAL PRODUCT
610

FIG. 6

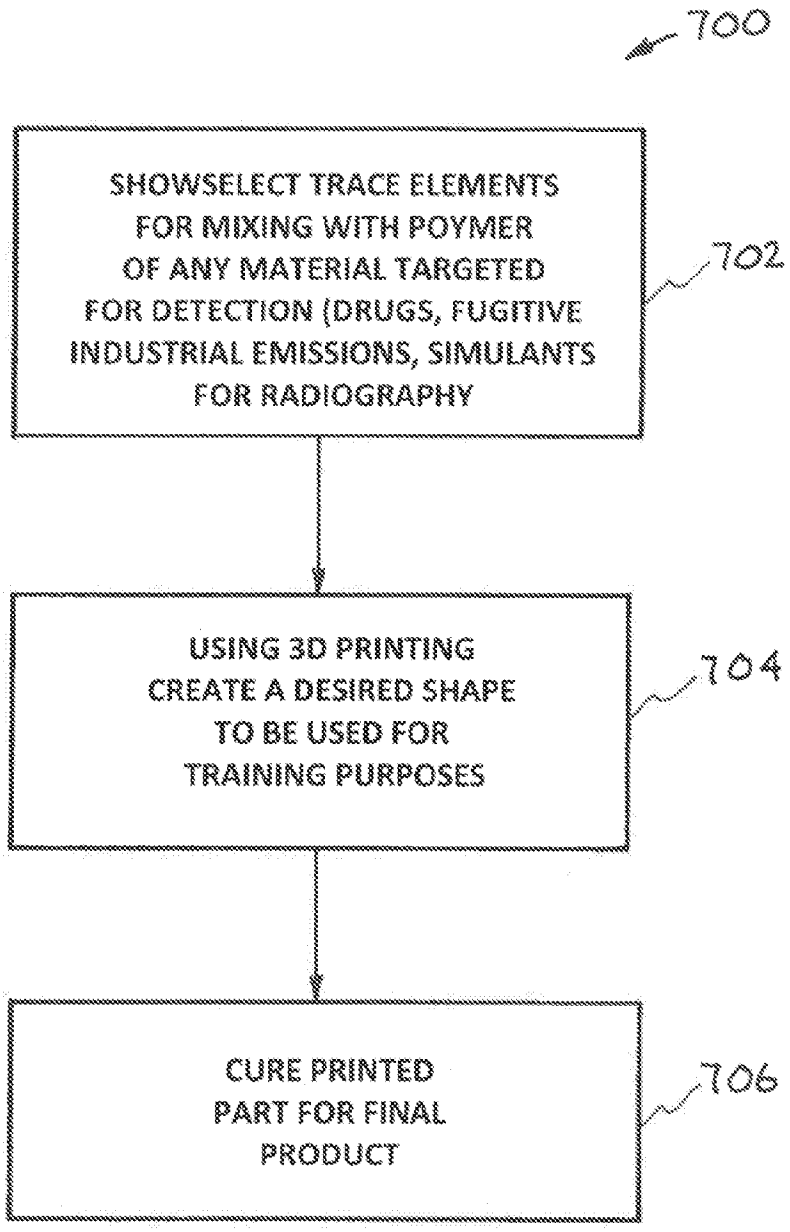
700
SHOWSELECT TRACE ELEMENTS FOR MIXING WITH POYMER OF ANY MATERIAL TARGETED FOR DETECTION (DRUGS, FUGITIVE INDUSTRIAL EMISSIONS, SIMULANTS FOR RADIOGRAPHY
702
USING 3D PRINTING CREATE A DESIRED SHAPE TO BE USED FOR TRAINING PURPOSES
704
CURE PRINTED PART FOR FINAL PRODUCT
706

FIG. 7

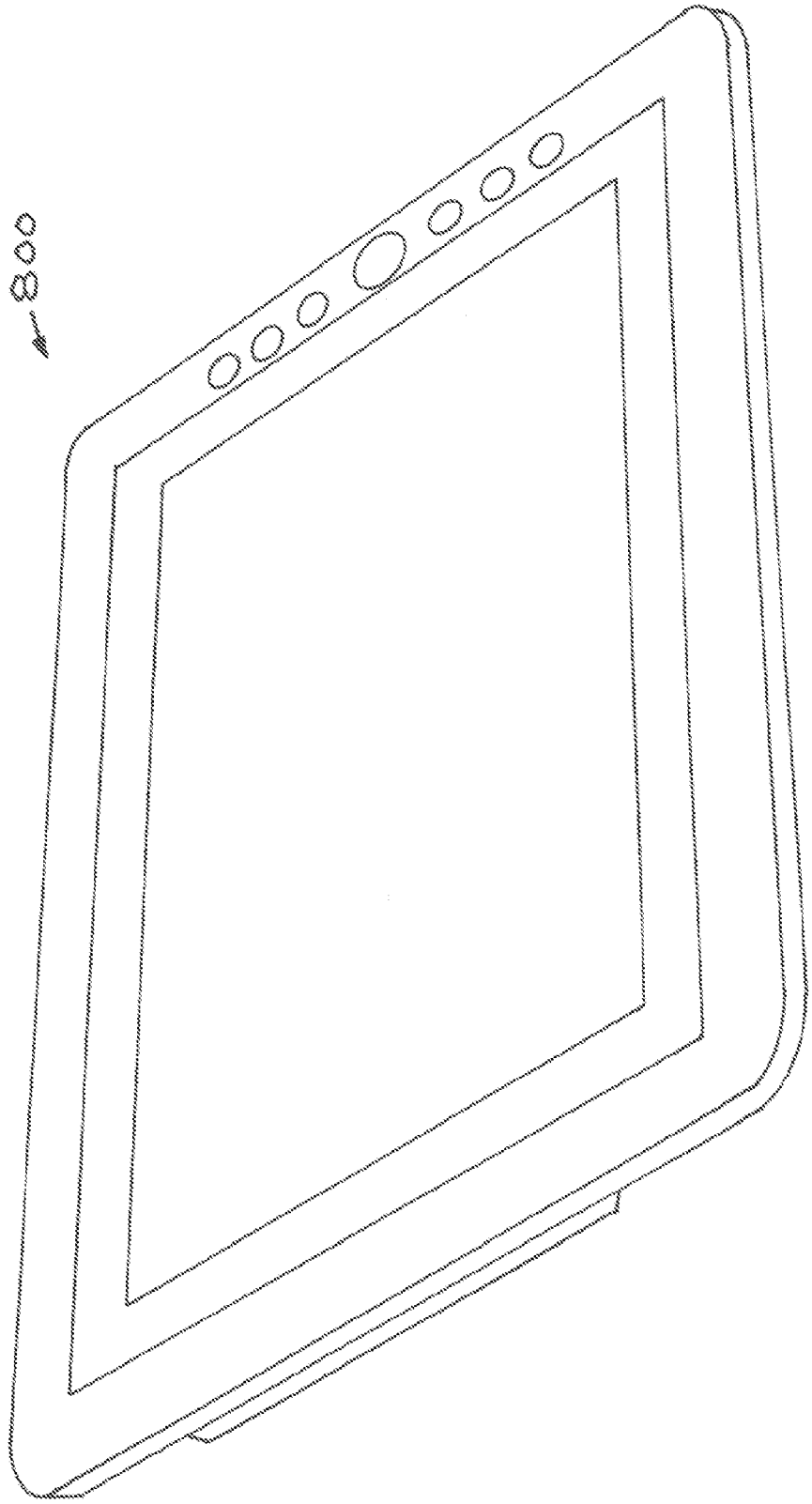

FIG. 8

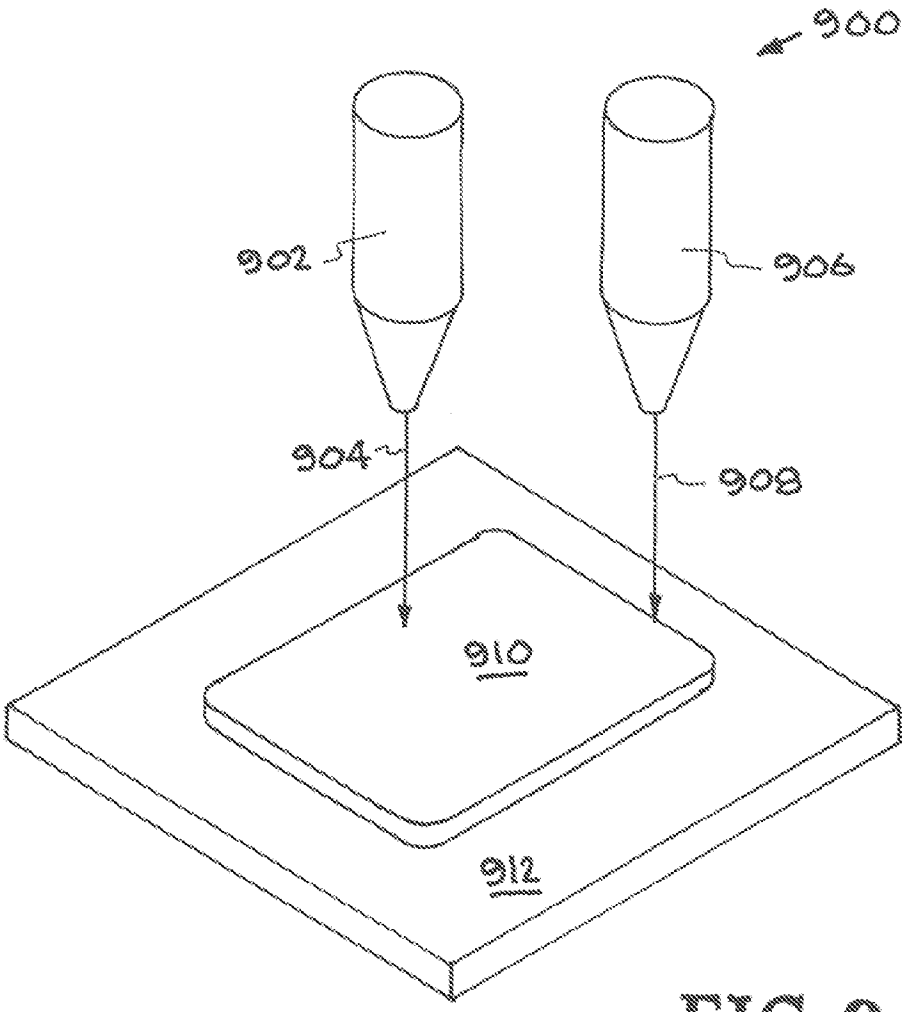

FIG. 9

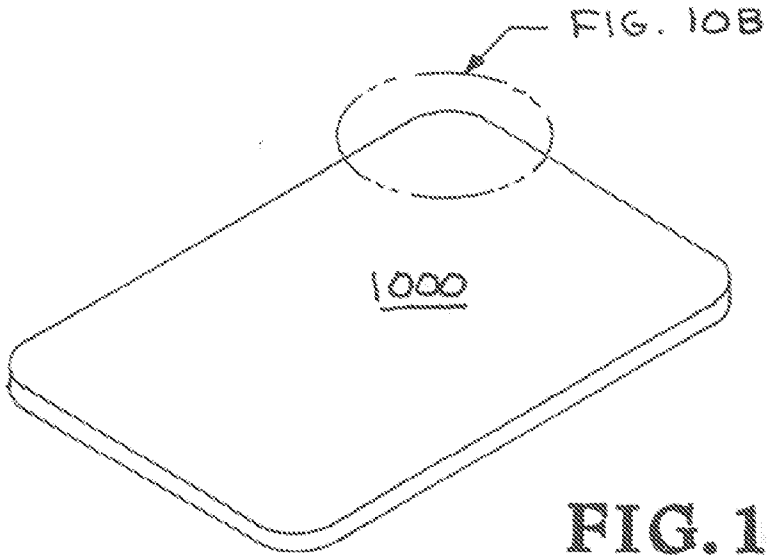

FIG. 10A

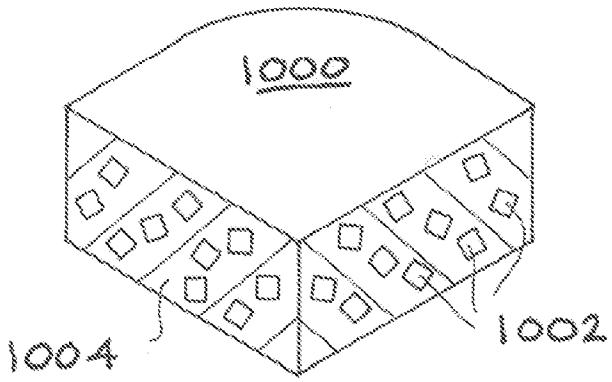

FIG. 10B

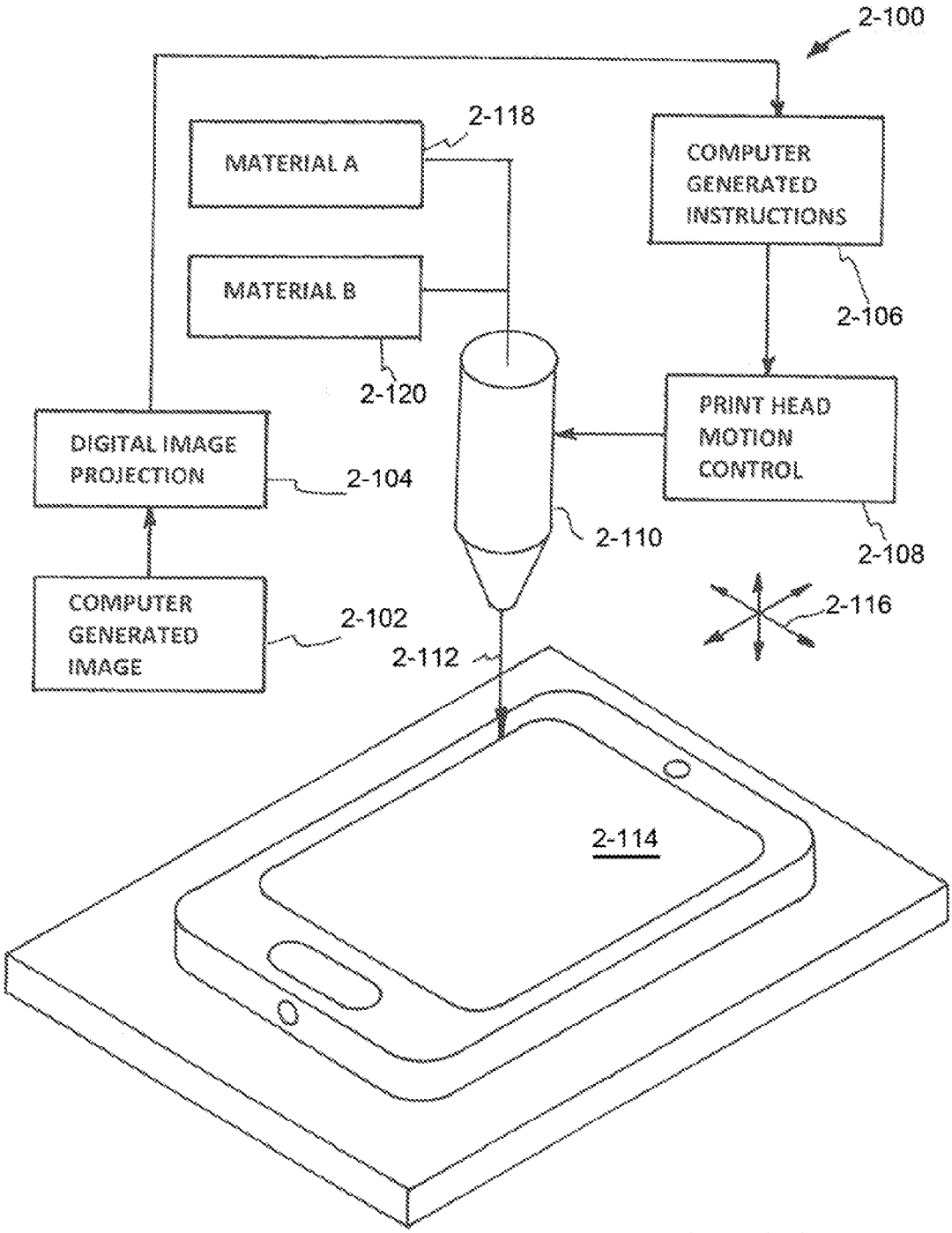
2-100
2-118
MATERIAL A
MATERIAL B
2-120
COMPUTER GENERATED INSTRUCTIONS
2-106
PRINT HEAD MOTION CONTROL
2-108
DIGITAL IMAGE PROJECTION
2-104
2-110
COMPUTER GENERATED IMAGE
2-102
2-112
2-116
2-114

FIG. 11

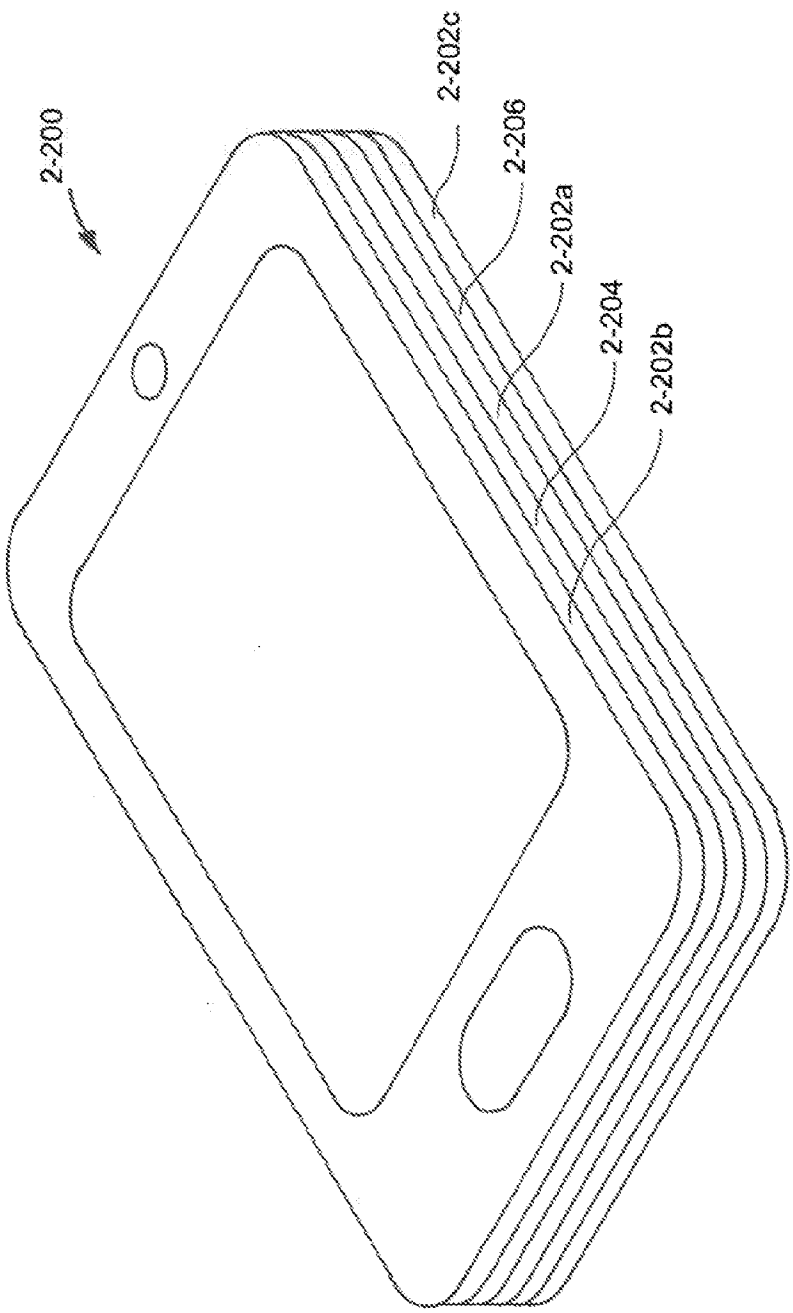

FIG. 12

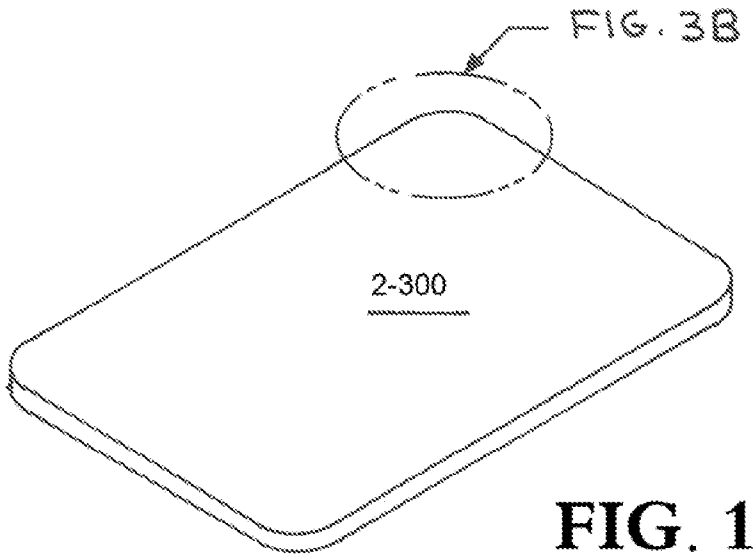

FIG. 13A

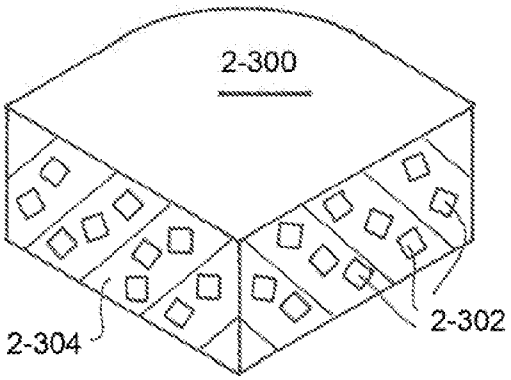

FIG. 13B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2018/025584

A. CLASSIFICATION OF SUBJECT MATTER

F41H 11/132(2011.01)i, A01K 15/02(2006.01)i, B33Y 10/00(2015.01)i, B33Y 80/00(2015.01)i, C06B 45/14(2006.01)i, B33Y 70/00(2015.01)i, C06B 31/02(2006.01)i, F41H 11/12(2011.01)i, G09B 9/00(2006.01)i, G09B 19/00(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F41H 11/132; F24F 7/04; F42B 8/28; F42B 4/18; A01K 15/02; G01N 31/00; C06B 21/00; C06B 43/00; B33Y 10/00; B33Y 80/00; C06B 45/14; B33Y 70/00; C06B 31/02; F41H 11/12; G09B 9/00; G09B 19/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: K-9 training aid, explosive material, oxdizer, fuel, separator material, additive manufactured layer, printing

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014-0097551 A1 (THE JOHNS HOPKINS UNIVERSITY) 10 April 2014 See paragraphs [0004], [0022] and claims 1-3.	38-39
A		1-37,40-42
A	US 2016-0341530 A1 (HUPP, MARK) 24 November 2016 See paragraph [0033].	1-42
A	US 2006-0037509 A1 (KNEISL, PHILLIP) 23 February 2006 See paragraph [0030].	1-42
A	US 2015-0056913 A1 (FOAT et al.) 26 February 2015 See abstract and claim 15.	1-42
A	US 2007-0221087 A1 (ADEBIMPE et al.) 27 September 2007 See abstract and paragraphs [0012]-[0013].	1-42

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

☒ See patent family annex.

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 July 2018 (11.07.2018)	**11 July 2018 (11.07.2018)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
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HWANG, Chan Yoon
Telephone No. +82-42-481-3347

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2018/025584

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014-0097551 A1	10/04/2014	US 9108890 B2	18/08/2015
US 2016-0341530 A1	24/11/2016	US 2017-0261293 A1	14/09/2017
		US 9658039 B2	23/05/2017
US 2006-0037509 A1	23/02/2006	None	
US 2015-0056913 A1	26/02/2015	EP 2751559 A1	09/07/2014
		GB 2494284 A	06/03/2013
		GB 2494284 B	01/10/2014
		US 9807979 B2	07/11/2017
		WO 2013-030525 A1	07/03/2013
US 2007-0221087 A1	27/09/2007	US 7694628 B2	13/04/2010