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(54) **ADDITIVE MANUFACTURING OPTICAL INSPECTION SYSTEM**

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B33Y 50/02	(2015.01)
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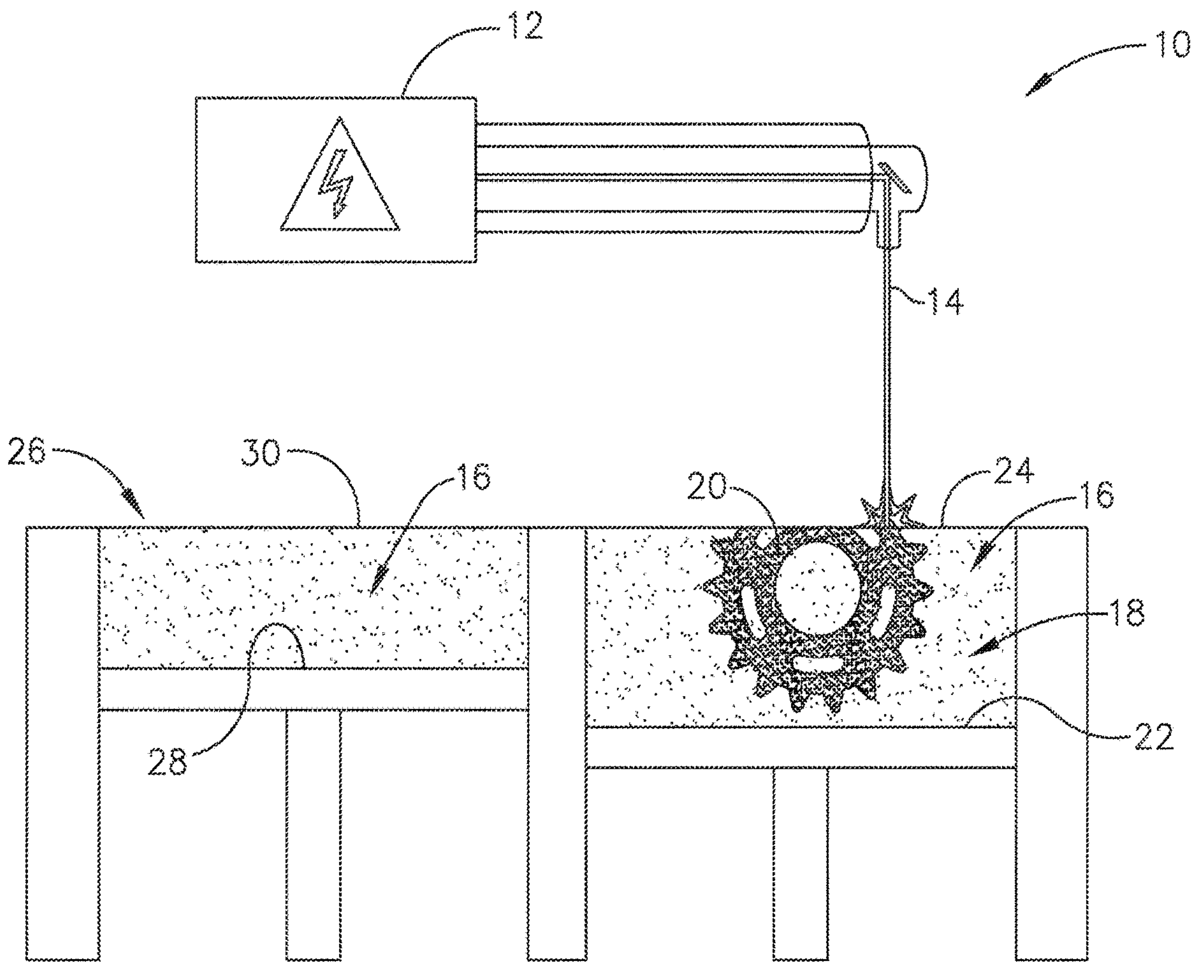
(57) **ABSTRACT**

A system for detecting a contaminant, which includes a light source directed to heat a layer of a material positioned in a location. The system further includes an infrared camera positioned aligned with the location to receive electromagnetic thermal radiation energy from the layer of the material in the location.



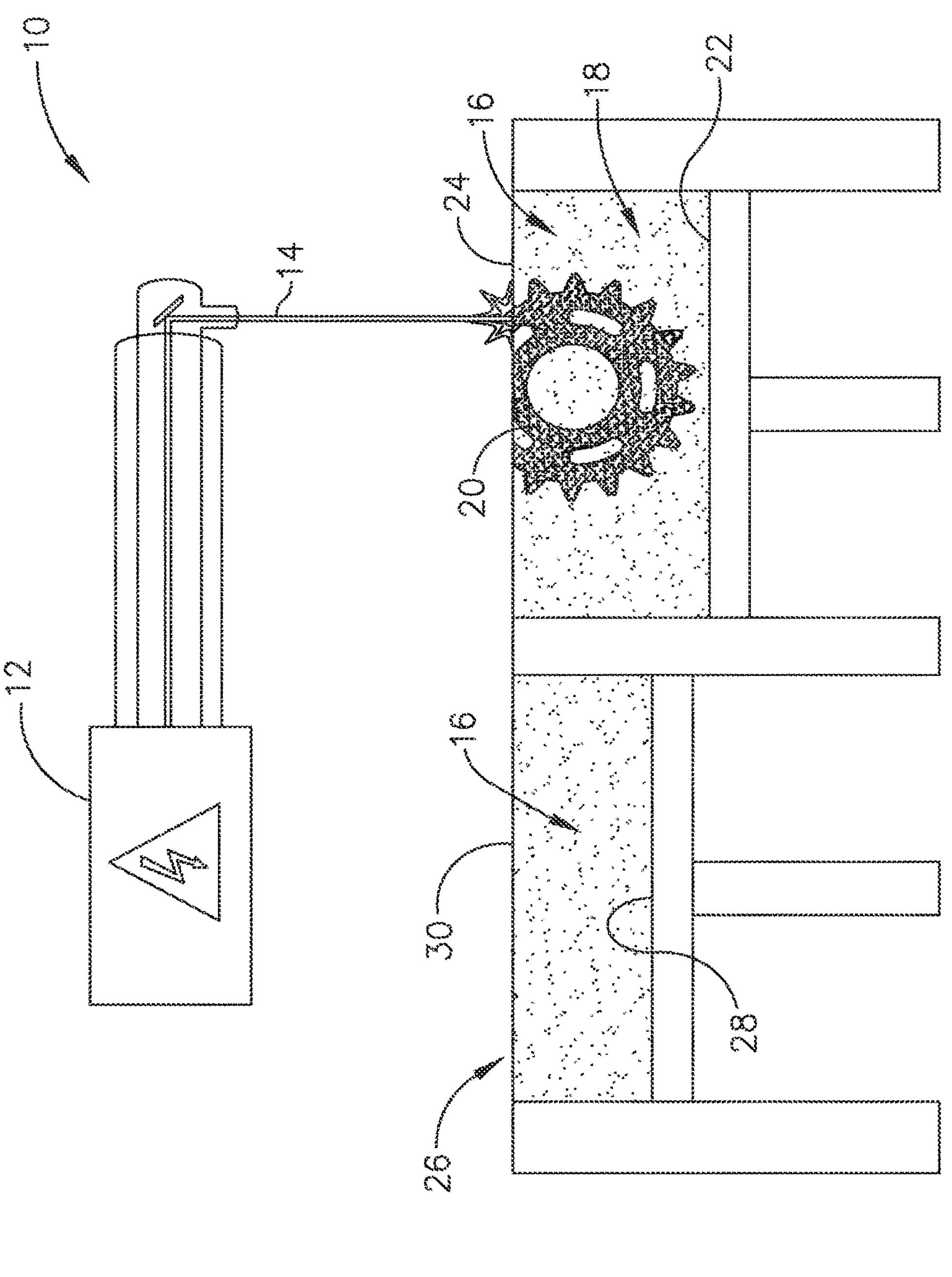


FIG. 1

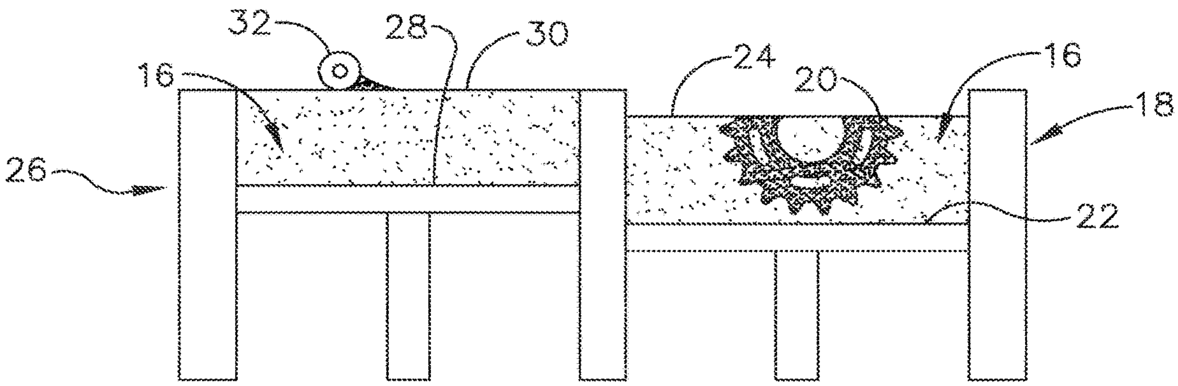


FIG. 2

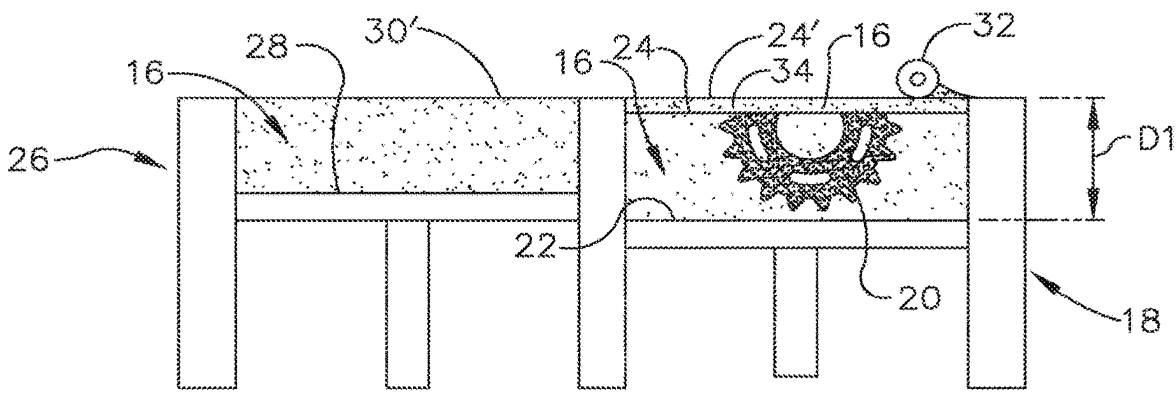


FIG. 3

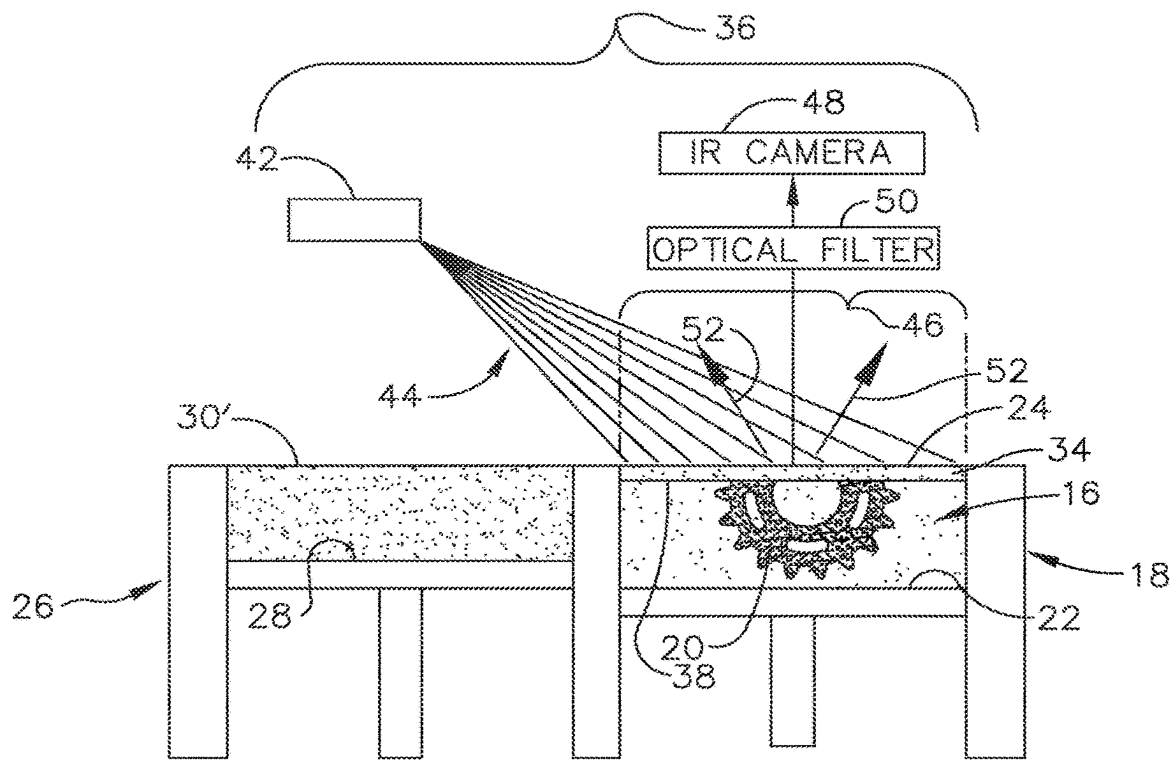

36
48
IR CAMERA
42
50
OPTICAL FILTER
52
46
52
44
24
30′
34
16
18
26
28
22
20
38

FIG. 4

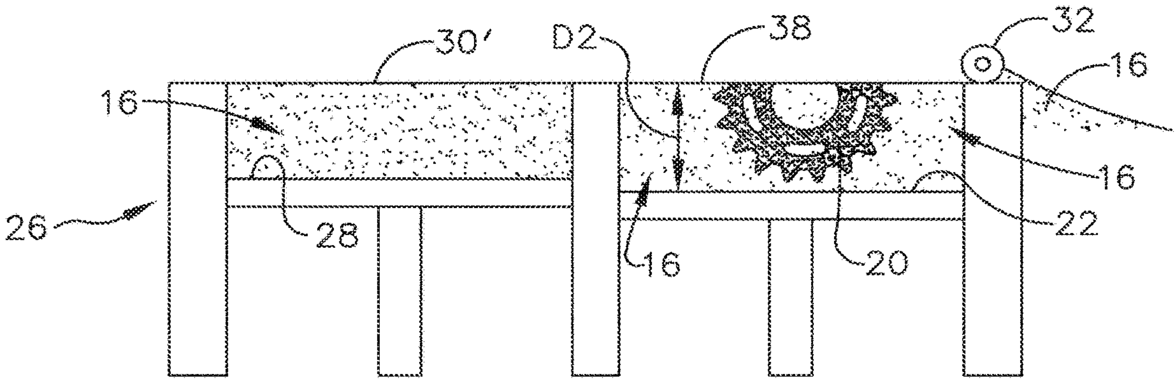

30′
D2
38
32
16
16
16
26
28
16
20
22

FIG. 5

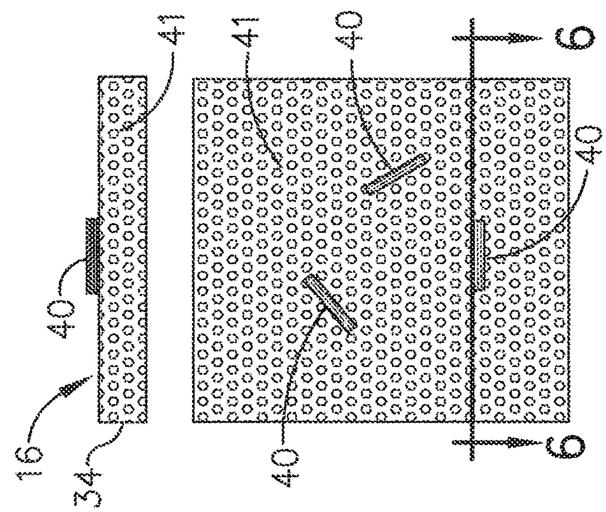


FIG. 6

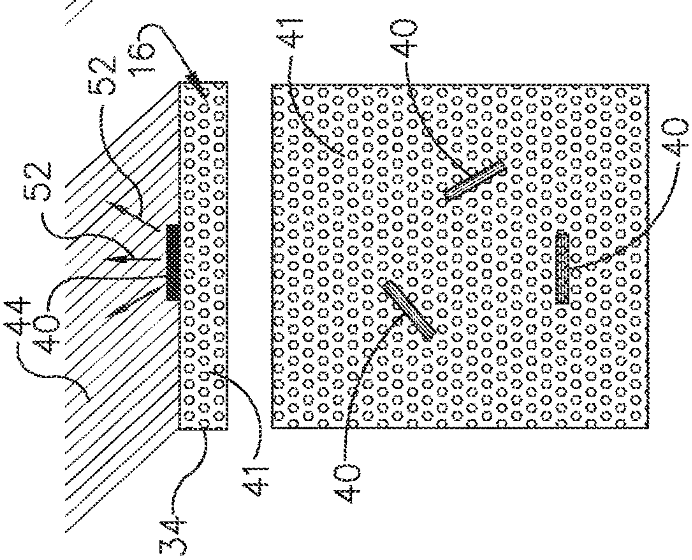


FIG. 7

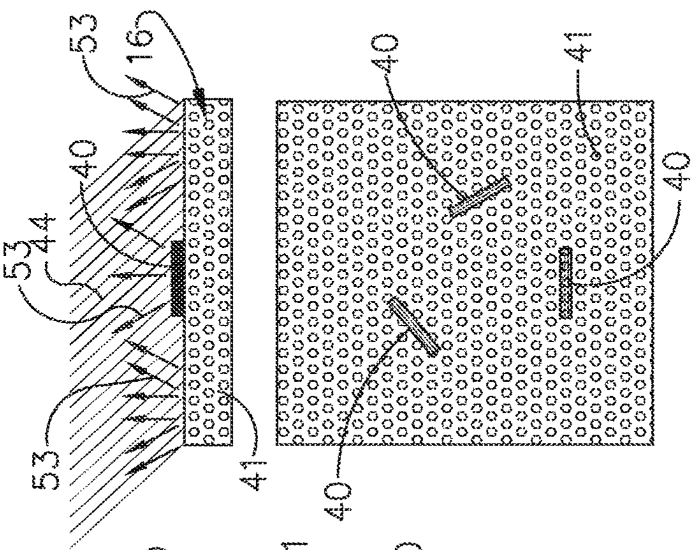


FIG. 8

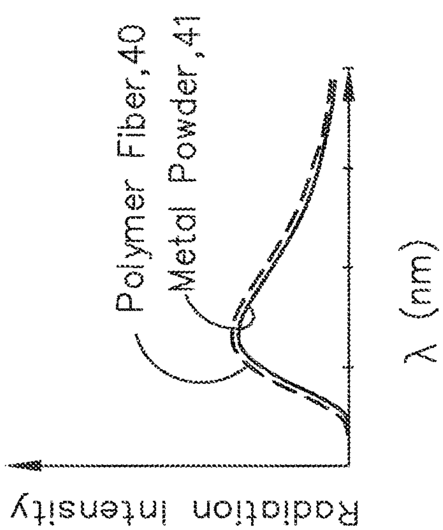


FIG. 9

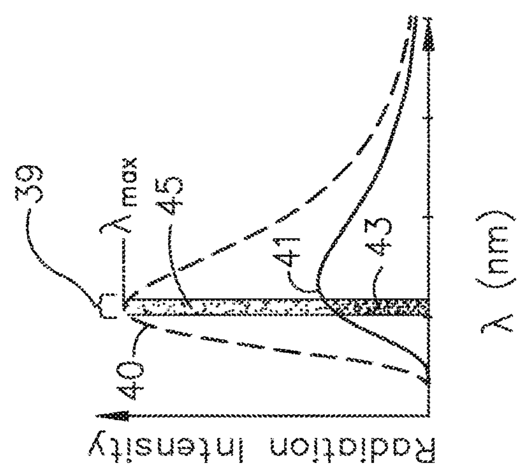


FIG. 10

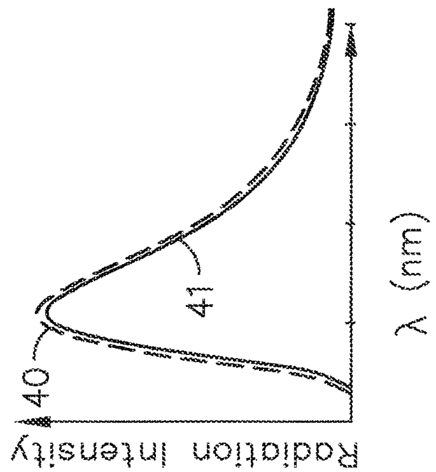


FIG. 11

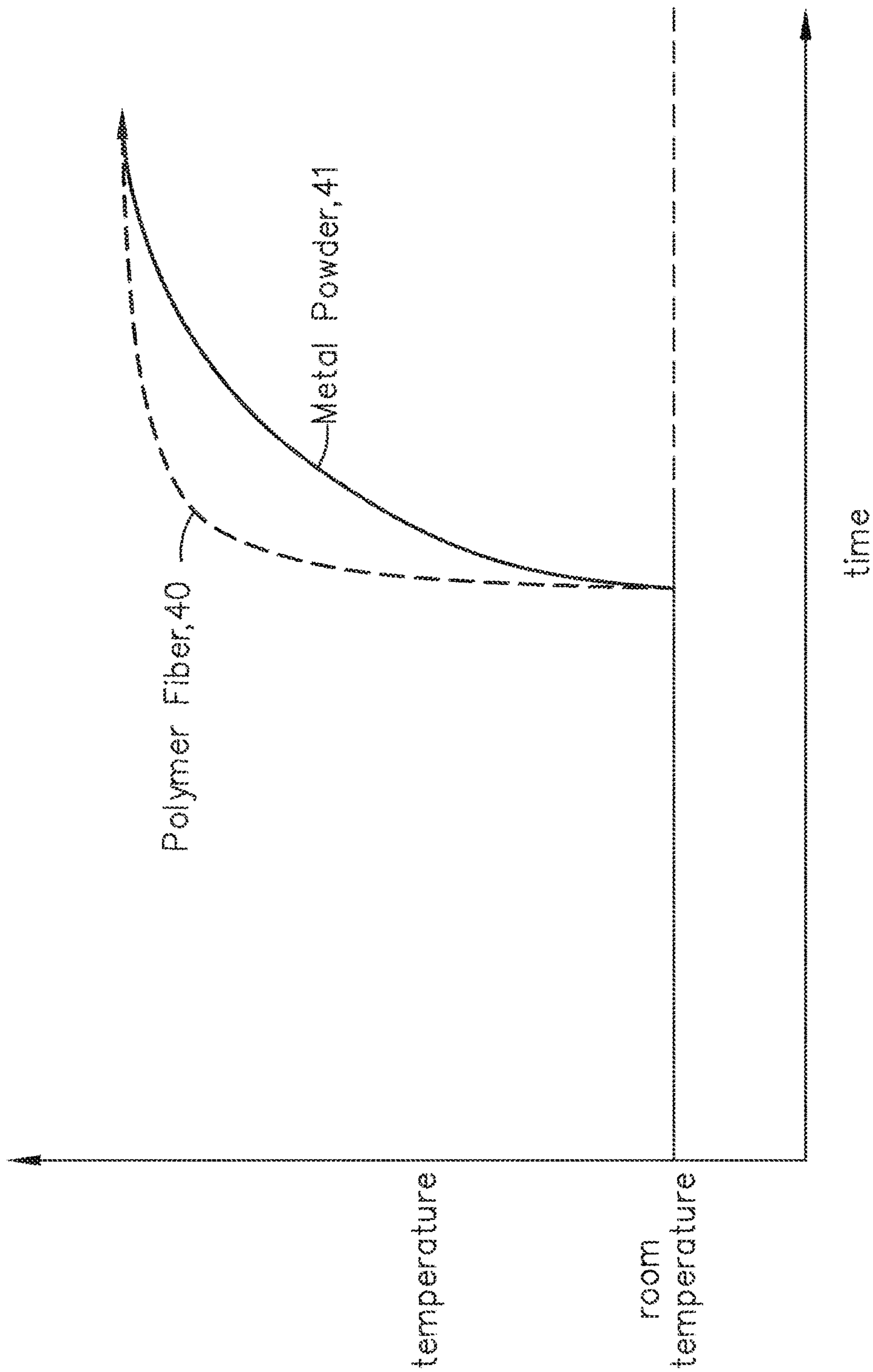

Metal Powder, 41
Polymer Fiber, 40
temperature
room temperature
time

FIG. 12

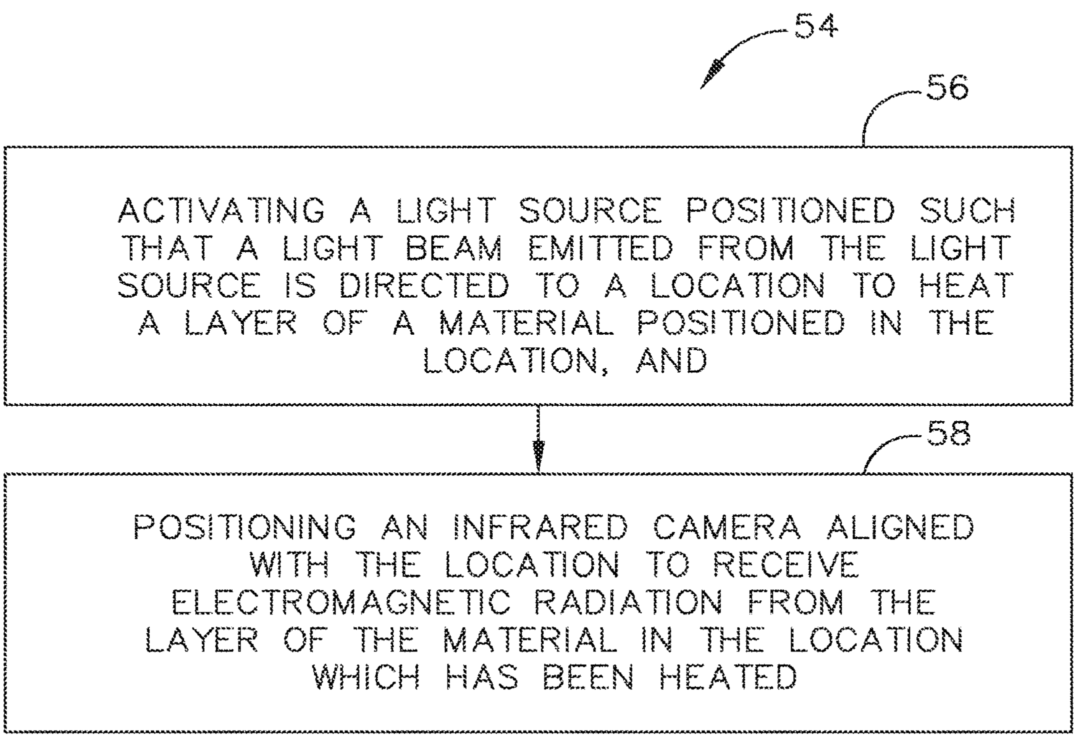
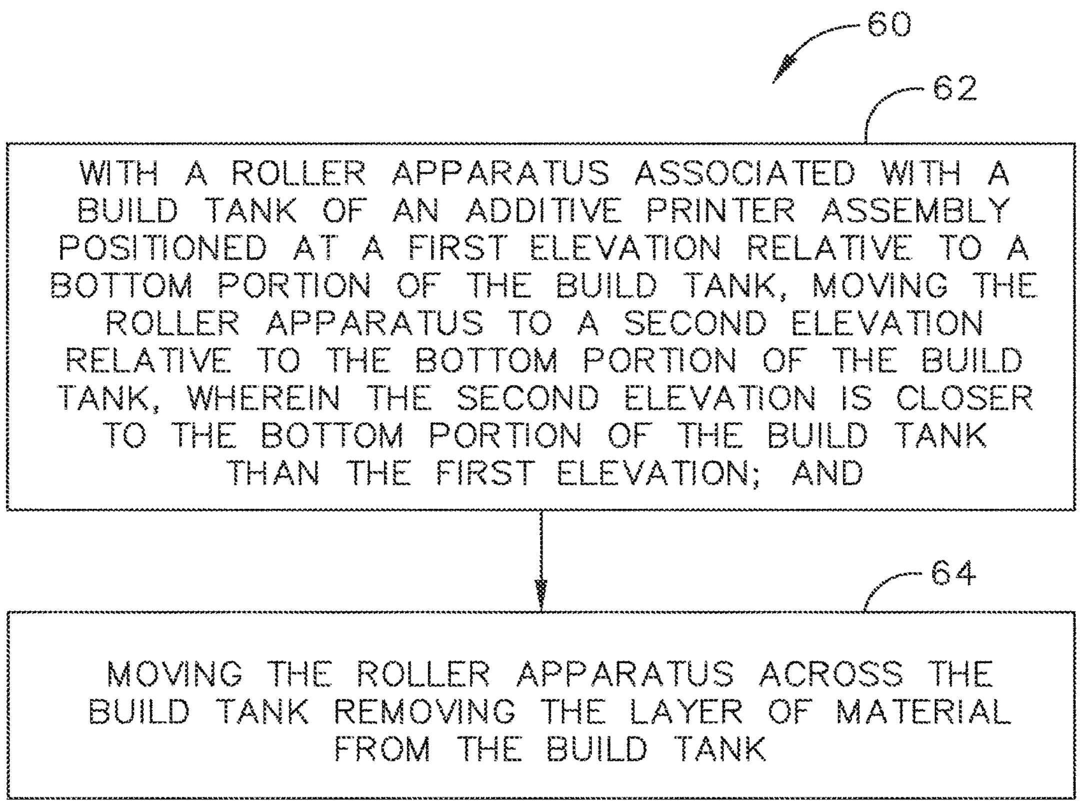

54
56
ACTIVATING A LIGHT SOURCE POSITIONED SUCH THAT A LIGHT BEAM EMITTED FROM THE LIGHT SOURCE IS DIRECTED TO A LOCATION TO HEAT A LAYER OF A MATERIAL POSITIONED IN THE LOCATION, AND
58
POSITIONING AN INFRARED CAMERA ALIGNED WITH THE LOCATION TO RECEIVE ELECTROMAGNETIC RADIATION FROM THE LAYER OF THE MATERIAL IN THE LOCATION WHICH HAS BEEN HEATED

FIG. 13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62
WITH A ROLLER APPARATUS ASSOCIATED WITH A BUILD TANK OF AN ADDITIVE PRINTER ASSEMBLY POSITIONED AT A FIRST ELEVATION RELATIVE TO A BOTTOM PORTION OF THE BUILD TANK, MOVING THE ROLLER APPARATUS TO A SECOND ELEVATION RELATIVE TO THE BOTTOM PORTION OF THE BUILD TANK, WHEREIN THE SECOND ELEVATION IS CLOSER TO THE BOTTOM PORTION OF THE BUILD TANK THAN THE FIRST ELEVATION; AND
64
MOVING THE ROLLER APPARATUS ACROSS THE BUILD TANK REMOVING THE LAYER OF MATERIAL FROM THE BUILD TANK

FIG. 14

ADDITIVE MANUFACTURING OPTICAL INSPECTION SYSTEM

PRIORITY

[0001] This application is a divisional of U.S. Ser. No. 17/501,078 filed on Oct. 14, 2021, which claims priority from U.S. Ser. No. 63/127,265 filed on Dec. 18, 2020. The entire contents of U.S. Ser. Nos. 17/501,078 and 63/127,265 are incorporated herein by reference.

FIELD

[0002] This disclosure relates to an inspection system and method for detecting contaminant in a material to determine whether the material is to be used for printing with an additive manufacturing assembly, and more particularly, a system and method to identify the presence of contaminant within a metal powder prior to commencing printing.

BACKGROUND

[0003] In additive manufacturing, with using an additive printer assembly, an intense laser beam is generally used to sinter metal powder for printing a part. The metal powder is either free from contaminant or if contaminant is present, the contaminant present needs to be at an acceptable level prior to allowing the metal powder to be used for printing the part. The presence of contaminant can compromise strength of the part being produced by the additive printing process. As a quality control measure, there is a need to identify and quantify the contaminant within the material, such as metal powder, to be sintered prior to deciding whether to permit the material to be sintered by the laser beam in the additive printing process.

[0004] Based on the particular part being fabricated by the additive printing process, the detection of contaminant within the material to be sintered provides the operator the opportunity to detect and quantify the contaminant. If there is an absence of contaminant in the material the operator of an additive printer assembly can proceed to use the material for printing. Should the operator detect and quantify contaminant contained within the material to be sintered, the operator can proceed with printing if the amount of contaminant present within the material to be sintered is acceptable to specifications for the part being manufactured. Should the amount of contaminant be unacceptable, the operator can choose to remove the contaminant from the material until the content is at an acceptable level or elect to remove the material containing the unacceptable content from the additive printing process.

[0005] In an example of additive printing, the material will contain metal powder and the contaminant, if present, will be a polymer fiber. Detection of contaminant, such as polymer fiber, is presently being carried out with the application of ultraviolet ("UV") electromagnetic radiation onto a layer of material on a building tank of an additive printer assembly prior to printing the layer of material. Should a polymer fiber be present and absorbs the UV electromagnetic radiation, the polymer fiber will in turn emit a visible light. This emitting of visible light is referred to as a fluorescent occurrence, which in this example is a weak electromagnetic radiation emission and is difficult to visually differentiate between the polymer fiber contaminant the metal powder, intended to be printed. In order to enhance the visual contrast between the polymer fiber contaminant and the metal powder intended to be printed, the operator has to increase the power of the UV electromagnetic radiation. Enhancing the power of the UV electromagnetic transmission to enhance a visual contrast between the polymer fiber contaminant and the metal powder is a safety issue with respect to exposure to humans of the enhanced UV electromagnetic transmission.

[0006] As a result, there is a need to provide a detection system and method for detecting contaminant within material intended to be additively printed, for example, such as detecting the presence of a contaminant of polymer fiber within a metal powder used in additive manufacturing, which provides a visually readably detectable electromagnetic emission contrast between the metal powder and the polymer fiber contaminant and yet not create a safety or health issue to the operator and the operator's personnel who work within proximity to the additive printing process.

SUMMARY

[0007] An example includes a system for detecting a contaminant, which includes a light source directed to heat a layer of a material positioned in the location. The system further includes an infrared camera positioned aligned with the location to receive electromagnetic thermal radiation energy from the layer of the material in the location.

[0008] An example includes a method for detecting a contaminant, which includes heating a layer of a material positioned in a location with a light source directed to the material positioned in the location. The method further includes receiving electromagnetic thermal radiation energy from the layer of the material with an infrared camera aligned with the location.

[0009] An example includes a method for removing a layer of material from a build tank of an additive printer assembly. With a roller apparatus associated with a build tank of the additive printer assembly positioned at a first elevation relative to a first bottom portion of the build tank, moving the roller apparatus to a second elevation relative to the first bottom portion of the build tank, wherein the second elevation is closer to the first bottom portion of the build tank than the first elevation. The method further includes moving the roller apparatus across the build tank removing the layer of material from the build tank.

[0010] The features, functions, and advantages that have been discussed can be achieved independently in various embodiments or may be combined in yet other embodiments further details of which can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a schematic view of an additive printer assembly, printing a part;

[0012] FIG. **2** is schematic view of the additive printer assembly of FIG. **1**, without a light source for printing and with a roller apparatus for moving material from a feed tank toward and onto a build tank for printing;

[0013] FIG. **3** is the schematic view of the additive printer assembly of FIG. **2** with the roller apparatus applying a layer of the material on the build tank from the feed tank for printing;

[0014] FIG. **4** is the schematic view of the additive printer assembly of FIG. **3** with a light source heating the layer of the material on the build tank intended to be printed and the material reflecting electromagnetic energy originating from the light source and emitting electromagnetic thermal energy toward the optical filter and the infrared camera;

[0015] FIG. **5** is the schematic view of the additive printer assembly of FIG. **4** with the roller apparatus removing the layer of the material from the build tank of FIG. **4** which has been determined to contain an unacceptable amount of contaminant prior to starting a printing process;

[0016] FIG. **6** includes two schematic views, the bottom schematic view is a top plan view of the layer of material on the build tank of FIG. **3**, which in this example includes a metal powder and a contaminant and the top schematic view is a cross section view of the layer of material along line **6-6** of the bottom schematic view, wherein the metal powder and the contaminant are at the same temperature;

[0017] FIG. **7** includes the two schematic views of FIG. **6**, wherein in the top schematic cross section view includes a light beam impacting the layer of the material on the build tank with the contaminant within the layer of material heating more quickly than the metal powder within the layer of material and emitting electromagnetic thermal radiation energy;

[0018] FIG. **8** includes the two schematic views of FIG. **7**, wherein more time has transpired with respect to the light beam impacting the layer of material of FIG. **7**, such that emission of electromagnetic thermal radiation energy by the metal powder reaches an equilibrium with the emission of electromagnetic thermal radiation energy of the contaminant;

[0019] FIG. **9** is a graph which represents an example of the intensity and spectrum of the electromagnetic thermal radiation energy emission from a metal powder and of a polymer fiber contaminant within the layer of material within FIG. **6** with both the metal powder and the polymer fiber contaminant at a same temperature;

[0020] FIG. **10** is a graph which represents an example of the intensity and spectrum of the electromagnetic thermal radiation energy being emitted from the metal powder and from the polymer fiber contaminant within the layer of material with the layer of material being initially exposed to a light beam for heating the layer of material as seen in FIGS. **4** and **7**;

[0021] FIG. **11** is a graph which represents the intensity and spectrum of the electromagnetic thermal radiation energy emission of the metal powder and the polymer fiber contaminant within the layer of material having reached thermal equilibrium, as seen in FIG. **8**, after time has transpired with subjecting the material within the layer of material to continued exposure to the light beam from the initial exposure to the light beam of FIG. **7**;

[0022] FIG. **12** represents a graph of heating of the polymer fiber contaminant and of the metal powder over time with being exposed to the light beam;

[0023] FIG. **13** is a method for detecting a contaminant, and

[0024] FIG. **14** is a method for removing a layer of material which includes a metal powder and a contaminant.

DETAILED DESCRIPTION

[0025] In fabricating parts by way of additive printing, quality control is important with respect to the material being used for the printing so as to provide sufficient strength for the finished part. An amount of contaminant allowed to be present within the material to be printed may vary based on the specifications for the part. In some instances the specifications may permit the presence of some contaminant and in other instances the specifications may not permit the presence of any contaminant. In an example, to be discussed herein, of printing a part, the material used for printing is a metal powder and an example of a contaminant, which is sought to be detected within the metal powder and which may or may not be present within the metal powder is a polymer fiber. The material for printing can vary as to composition and the contaminant intended to be detected can also vary as to composition.

[0026] Since the composition of the material to be printed is different than the contaminant, such as a metal powder for printing, and knows the composition of the contaminant needed to be detected and a polymer fiber as the contaminant, the operator will understand the absorptance to thermal inertia ratio for each of these compositions will likely be different. Absorptance, a, is defined as the "ratio of the absorbed radiant or luminous flux to the incident flux under specified conditions." Thermal inertia, I, is qualitatively defined as the "capacity of a material to store heat and to delay its transmission" and quantitatively defined as:

$$I=\sqrt{(kpc)}$$

[0027] k is thermal conductivity

[0028] p is density

[0029] c is specific heat capacity

[0030] In the example to be discussed herein, the absorptance to thermal inertia ratio for the metal powder, $(\alpha/I)_m$, will not be equal to the absorptance to thermal inertia ratio for the polymer fiber, $(\alpha/I)_p$, where the m and p subscripts stand for the metal powder and polymer fiber, respectively. This difference in absorptance to thermal inertia ratios for the different compositions can be expressed as:

$$(\alpha/I)_m \neq (\alpha/I)_p.$$

[0031] With one composition having a greater ratio than the other composition, the operator can apply a light beam to heat the material intended to be printed and the composition within the material with a greater absorptance to thermal inertia ratio will heat more quickly than another composition present within the material and will transmit electromagnetic thermal radiation energy with a greater intensity and spectrum than the other composition.

[0032] The transmission of greater intensity and spectrum from the composition in the material with the greater absorptance to thermal inertia ratio will provide a visible contrast with use of an infrared camera to another composition within the material with a lower absorptance to thermal inertia ratio. The visual contrast with use of an infrared camera provides the operator the ability to visually detect contaminant within the material. For example, should no visual contrast appear with the infrared camera, the material heated has the same composition, such as metal powder, and will be used for printing having no contaminant. However, if visual contrast(s) appears with the infrared camera, the contrast indicates the presence and location of a contaminant regardless of whether the metal powder or the contaminant has the greater absorptance to thermal inertia ratio. At that point, with the infrared camera providing the appearance of visual contrast image(s) the operator can locate and quantify a contaminant and determine whether or not to proceed to use the material for printing.

[0033] An amount of contaminant permitted to be within the material intended to be printed can vary from no contaminant is permissible to some percentage of presence of the contaminant is permissible for printing. As a result, it would be beneficial to have a system and method for detecting the presence of a contaminant within the material prior to printing such that an operator of the additive printer device can quantify the presence of contaminant and decide whether the material to be printed meets the specifications for the part to be printed. Based on a detection and determination of an amount of presence of a contaminant, the operator of the additive printing process can proceed with the printing the layer of the material for building the part, with removing the contaminant or with removing the layer of material which has an unacceptable content of contaminant in the layer. Should the layer of material be removed, a replacement layer of material can be provided and the operator can proceed with again using the system and method for detecting the presence of a contaminant prior to printing.

[0034] In referring to FIG. **1**, additive printer assembly **10** includes a light source **12**, which in this example includes laser light source, which generates light beam **14**, which in this example, includes a laser beam. Light beam or laser beam **14** is directed, in this example, to material **16** having an acceptable content as specified of contaminant in build tank **18**. In this example, material **16** is a metal powder which has an absence of or an acceptable amount of contaminant as specified for part **20** to be printed. Light beam or laser beam **14** is of sufficient energy so as to sinter material **16** to form part **20**.

[0035] Build tank **18** has first bottom portion **22**, which is movable so as to adjust a position of surface **24** of material **16** as needed in progressing through an additive printing of part **20**. Adjacent to build tank **18**, is feed tank **26**, which contains, in this example, material **16** which is fed into build tank **18** during the additive printing process. Feed tank **26** further includes second bottom portion **28**, which is also movable so as to adjust a position of surface **30** of material **16** as needed for facilitating feeding material **16** into build tank **18**, as will be discussed.

[0036] In referring to FIG. **2**, first bottom portion **22** of build tank **18** has been lowered, in contrast to FIG. **1**, after layer of part **20** has been printed. Lowering of first bottom portion **22** results in lowering surface **24** of material **16** or metal powder in build tank **18** with an acceptable content of contaminant, either none or an acceptable presence, for printing part **20**. Second bottom portion **28** of feed tank **26**, has been raised, relative to FIG. **1**, so as to position surface **30** of material **16** within feed tank **26** to a higher elevation such that roller apparatus **32**, which is moved across feed tank **26**, scrapes a portion of material **16** out of feed tank **26** forming new surface **30'** of material **16** within feed tank **26**, as seen in FIGS. **3** and **4**.

[0037] With first bottom portion **22**, which has been lowered, in FIG. **2**, thereby lowering surface **24** of material **16** within build tank **18**, roller apparatus **32** pushes material **16** from feed tank **26** into build tank **18** forming layer **34** of material **16** overlying surface **24** of material **16** in build tank **18** and forming a new surface **24'**, as seen in FIG. **3**. Layer **34** of material **16** overlies printed part **20** so as to provide additional material **16** to be sintered and added to part **20** with further application of light or laser source **12**. As seen in FIG. **3**, roller apparatus **32** completes spreading of material **16** across build tank **18** forming new surface **24'** of material **16** in preparation for sintering material **16** within layer **34** of material **16**, subject to an acceptable determination of contaminant within material **16** within layer **34**.

[0038] Prior to sintering any portion of material **16** within layer **34** with laser source **12** so as to add another portion to part **20**, system **36**, as seen in FIG. **4** is employed for detecting absence of contaminant or presence of and location of contaminant, as seen in FIG. **6**, within layer **34** of material **16**. As mentioned earlier, an example of the material **16** to be sintered is a metal powder and an example of contaminant **40** which may or may not be present in material **16**, is a polymer fiber.

[0039] Should an undesired amount of contaminant be detected within material **16** within layer **34**, first bottom portion **22** of build tank **18** is raised, as seen in FIG. **5**, to adequately rise bottom **38** of material **16** of layer **34**, formerly designated surface **24** of FIG. **3**, such that roller apparatus **32** has access to bottom **38** of material **16** of layer **34**. With roller apparatus **32** having access to bottom **38**, roller apparatus **32** can be moved across build tank **18** and remove layer **34** of material **16** containing an unacceptable content of contaminant **40**, off of build tank **18**, as seen in FIG. **5**. With scraping off of layer **34**, material **16** within build tank **18** remains contaminant free or at least at a contaminant level that is an acceptable level for fabrication reuse.

[0040] In referring to FIG. **4**, system **36** for detecting contaminant within material **16** layer **34**, includes light source **42** or in this example, a laser source, positioned, such that light beam **44** or in this example, laser beam emitted from light source **42** is directed to location **46** to heat layer **34** of material **16** positioned in location **46**, which may or may not contain contaminant. System **36** further includes infrared camera **48** positioned aligned with location **46**. Without optical filter **50** being present in FIG. **4** and with material **16** being heated by light or laser beam **44**, material **16** emits electromagnetic thermal radiation energy **52** as a result of adsorptance to thermal inertia ratio of composition (s) within material **16**. With infrared camera **48** aligned with location **46**, infrared camera **48** receives electromagnetic thermal radiation energy from layer **34** of material **16** in location **46**. As a result, optical contrasts can possibly be seen with two different compositions being present within layer **34** by infrared camera **48**. With material **16** being all one composition, such as metal powder, the adsorptance to thermal inertia ratio of the single composition will transmit all the same or uniform electromagnetic thermal radiation energy to infrared camera **48** and infrared camera **48** will provide no visual contrast. With a single composition present in layer **34**, infrared camera **48** will show a single color with no visual contrast.

[0041] However, as seen in FIG. **6**, if there is presence of contaminant **40**, such as a polymer fiber, along with metal powder **41**, in layer **34** of material **16**, each composition of metal powder **41** and polymer fiber contaminant **40** within layer **34** will have different absorptance to thermal inertia ratios. In this example, when heating of material **16** with light source **42**, polymer fiber contaminant **40** will heat up more quickly than metal powder **41** within layer **34** of material **16** and will thereby commence transmitting electromagnetic thermal radiation energy earlier than metal powder **41** and providing a higher intensity at a common wavelength of the spectrum than that of metal powder **41**.

[0042] In this example, light source **42**, as seen in FIG. **4**, includes a laser source, such as for example a carbon dioxide laser source, such as for example, variable linewidth high-power "Transversely Excited Atmospheric" or TEA C02 laser source which emits a laser light beam **44**, as seen in FIG. **4**. In this example, laser source **12** as seen in FIG. **1**, for the sintering of material **16** in additive printer assembly **10**, is a relatively short-wave laser in contrast to light source **42** in system **36** which utilizes a relatively long-wave laser. For example, light beam or laser beam **44** of light source or laser source **42**, for system **36** for detecting contaminant, includes a wavelength within a wavelength range which includes a wavelength of four hundred nanometers (400 nm) up to and including a wavelength of one hundred micrometers (**100** urn).

[0043] As seen in FIG. **4**, system **36** will operate on layer **34** of material **16**, positioned on build tank **18** of additive printer assembly **10**. As mentioned earlier in the present example, layer **34** of material **16** will include metal powder **41** absent of contaminant or will include metal powder **41** which has contaminant **40** of polymer fiber within layer **34**, as seen in FIG. **6**.

[0044] In the present example, system **36** for detecting contaminant **40** further includes optical filter **50**, as seen in FIG. **4**. Optical filter **50** is positioned aligned with infrared camera **48** and positioned between infrared camera **48** and material **16** of layer **34** in location **46**. Optical filter **50** in this example includes a band pass interference filter which allows a designated portion or band width of the spectrum to pass through the filter and rejects or blocks all other wavelengths. Optical filter **50**, can be employed, in one example, to block reflecting electromagnetic energy that originates from light source **42**, which in this example is a laser source which emits a light beam **44** or laser light beam onto material **16** of layer **34** and which reflects (not shown) toward optical filter **50**. Removal of reflecting electromagnetic energy originating from light source **42** enhances visual resolution of electromagnetic thermal radiation energy **52**, as seen in FIG. **7**, received by infrared camera **48** from the heated composition, in layer **34**, having a greater absorptance to thermal inertia ratio. In this example, polymer fiber contaminant **40** has a greater absorptance to thermal inertia ratio than that of metal powder **41** and heats up more quickly than metal powder **41**. In an initial time period in which these compositions are exposed to laser or light beam **44** and the composition with a greater absorptance to thermal inertia ratio emits electromagnetic thermal radiation energy **52** in a greater intensity and spectrum than that of metal powder **41**, providing a visual contrast with infrared camera **48** to that of metal powder **41** within layer **34**.

[0045] Optical filter **50** can further be used to more selectively block electromagnetic energy spectrum from reaching infrared camera **48** so as to further enhance visual contrast of electromagnetic thermal radiation energy of the composition(s) being heated in material **16** in layer **34**. In referring to FIGS. **9**-**11**, various intensities and spectrums of electromagnetic thermal radiation energy is emitted from different compositions that can be present in material **16** of layer **34**. As mentioned earlier, should material **16** not contain any contaminant **40**, there is no visual contrast created and infrared camera **48** does not present any visual contrasts. However, in the present example, with a presence of polymer fiber contaminant **40**, as seen in FIG. **6**, present in layer **34** with metal powder **41**, there would be presence of materials with different compositions having different absorptance to thermal inertia ratios.

[0046] Material **16**, as seen in FIG. **6**, has the presence of two compositions, metal powder **41** and polymer fiber contaminant **40**, and both compositions are at the same temperature, which in this example would be room temperature. At the same temperature, both compositions are emitting a black body thermal radiation which are very similar in radiation intensity and in wavelength spectrum ("A."), as seen in FIG. **9**. Under these circumstances, the electromagnetic thermal radiation energy from both compositions which reaches infrared camera **48** are very similar in spectrum and intensity. This similarity in spectrum and radiation intensity will not provide a sufficient readable visual contrast between metal powder **41** and the polymer fiber contaminant **40** by infrared camera **48**. In this graphical representation, metal powder **41** composition is represented by the solid line in the graph and polymer fiber contaminant **40** composition is represented by the dashed line in the graph. Thus, at the same temperature condition each composition has a radiation intensity and spectrum ("A.") of emission of thermal electromagnetic radiation energy that is substantially in equilibrium with each other and as mentioned earlier does not provide sufficient visual contrast with infrared camera **48**.

[0047] In FIG. **10**, light source **42** is turned on and light beam **44**, in this example a laser beam, begins to heat up material **16** in layer **34**, as seen in FIG. **7**. In this example, material **16** includes metal powder **41** and polymer fiber contaminant **40**. Polymer fiber contaminant **40**, in this example, such that as represented in FIG. **12** polymer fiber contaminant **40** with a greater absorptance to thermal inertia ratio than that of metal powder **41**, heats up quicker than metal powder **41**. The absorptance to thermal inertia ratio for polymer fiber contaminant **40** is 0.75/601~0.001 for example for polymethylacrylate composition, and is much greater than the absorptance to thermal inertia ratio for metal powder **41** is 0.59/7,017~0.0001, for example for titanium powder. The properties of these compositions were obtained, for example, from Tolochko, Nokolay K., et al., "Absorptance of powder materials suitable for laser sintering" of Rapid Prototyping Journal (2000).

[0048] As a result, in an initial period of time of exposing material **16** to heating by light or laser beam **44** polymer fiber contaminant **40** climbs in temperature more quickly than metal powder **41** of material **16** in layer **34**, as seen in FIG. **12** and emits electromagnetic thermal radiation energy with greater intensity at a similar spectrum as seen in FIG. **10**, and with an expanded shifted spectrum and with a greater intensity than that of metal powder **41** in the same initial period of time of being exposed to light or laser beam **44**. Based on the material composition of polymer fiber contaminant **40** and the known light source **42** energy imparted onto layer **34** of material **16**, the operator will be able to determine a peak thermal wavelength or lambda maximum ("A. max"), as seen in FIG. **10**, which is a wavelength of maximum intensity for this polymer fiber contaminant **40**. Calculation for peak thermal wavelength, in this example for polymer fiber contaminant **40** is derived using Wein's displacement Law: "A. max=b/T" wherein b is Wien's displacement constant and Tis an absolute temperature of a black body. The operator will then have optical filter **50** block out all wavelengths of electromagnetic thermal radiation energy coming from material **16** of layer **34**

except a band width which contains the peak thermal wavelength or A. max for, in this example, polymer fiber contaminant **40**, which has the greater absorptance to thermal inertia ratio to that of metal powder **41**. Bandwidth **39** permitted to pass through optical filter **50** is a bandwidth of approximately 200 nano meters (nm) in this example including wavelength 8.3 micrometers (μm) to and including wavelength 8.5 micrometers (μm) which includes the peak thermal wavelength or A. max of 8.4 micrometers (μmm) for polymer fiber contaminant **40**, in this example, polymethylacrylate. Metal powder **41** or titanium powder in this example has a radiation intensity **43**, as seen in FIG. **10**, as represented by the shaded portion within bandwidth **39** positioned below the solid line in graph representing metal powder **41** and contaminant or polymer fiber **40** of polymethylacrylate in this example has a greater radiation intensity **45** as represented by the shaded portion within bandwidth **39** positioned below the dashed line in the graph representing polymer fiber contaminant **40**. The greater intensity of radiation intensity of polymer fiber or contaminant **40** to that of radiation intensity of titanium powder or metal powder **41** provides a visual contrast for infrared camera **48** thereby providing visual detection by the operator of contaminant or polymer fiber **40** in material **16** of layer **34**, in this example.

[0049] The filtering by optical filter **50** blocks electromagnetic thermal radiation energy exclusive of a bandwidth, as mentioned above, of electromagnetic thermal radiation energy spectrum transmitted to and otherwise reaches infrared camera **48** from the composition which contains the peak thermal wavelength or A max for that composition and which has a greater absorptance to thermal inertia ratio.

[0050] The filtered electromagnetic thermal radiation energy permitted through optical filter **50** to infrared camera **48**, which includes for example bandwidth **39** and peak thermal wavelength A max provides a higher visual contrast to, in this example, radiation intensity of the electromagnetic thermal energy emitted by metal powder **41** in the same spectrum. The differential in radiation intensity as discussed above for radiation intensity **45** to that of radiation intensity **43** provides the visual contrast image with infrared camera **48** providing detection and location of the polymer fiber contaminant **40**, in this example, with a higher contrast with respect to the electromagnetic thermal radiation energy of metal powder **41**. The operator with looking at infrared camera **48** is able to visually detect and identify the location of polymer fiber contaminant **40** within layer **34** of material **16** which also includes metal powder **41** by way of differential in radiation intensity.

[0051] It should be understood with respect to the absorptance to thermal inertia ratio of a particular composition, the composition with a higher ratio could be the composition used in constructing the part, metal powder, for example, rather than that of in this example polymer fiber contaminant **40**. In that case, the visual imaging will be that of the composition of the higher absorptance to thermal inertia ratio visually showing in the infrared camera **48** the presence and location of the material used for example in the additive building of the part such as the metal powder. Thus, gaps in the visual image from the infrared camera **48** will be that of contaminant **40**. The positive visual imaging in the infrared camera **48** is dependent on the composition of material to be detected having a greater absorptance to thermal inertia ratio than another composition within material **16** in layer **34**. The operation of system **36**, in this example, operates positively imaging the composition within material **16** of layer **34** having a greater absorptance to thermal inertia ratio. The composition which has a greater absorptance to thermal inertia ratio emits electromagnetic thermal radiant energy which has a band width of such electromagnetic thermal radiant energy which includes the composition's peak thermal wavelength or A max pass through optical filter **50** to infrared camera **48** imaging that composition within layer **34** of the material.

[0052] In referring to FIGS. **8** and **11**, more time has transpired with respect to exposing material **16** to heating with light source **42**. As reflected in the graph of FIG. **12**, as time progresses with material **16** being exposed to heating with light source **42**, the temperature of metal powder **41**, for example, and polymer fiber contaminant **40**, for example, reach an equilibrium. As a result, as seen in FIGS. **8** and **11**, both metal powder **41** and polymer fiber contaminant **40** reach an equilibrium state of emitting a similar spectrum and intensity of electromagnetic thermal radiation energy as seen in FIG. **11** and emit a similar spectrum and intensity of electromagnetic thermal radiation energy **53**, as seen in FIG. **8**.

[0053] In the present example, with metal powder **41** and polymer fiber contaminant **40** reaching an equilibrium state of temperature an insufficient difference in intensity of a given wavelength in the spectrum between metal powder **41** and polymer fiber contaminant **40** does not provide a sufficient difference in intensity so as to provide visual contrast in infrared camera **48**. As a result, the visual contrast imaging for system **36** is time dependent on the compositions being exposed to light source **42** to be heated.

[0054] In referring to FIG. **12** the difference in the rate of heating of the compositions results in the differing in emitting of electromagnetic thermal radiation energy for each composition of metal powder **41** and the polymer fiber contaminant **40** used in this example. The quicker the composition heats up the quicker that composition emits electromagnetic thermal radiation energy **52** which, as described above provides a differential in intensity of the electromagnetic thermal radiation energy being emitted by the particular composition in contrast to the other composition present in layer **34**. Thus, polymer fiber contaminant **40** provides the emission of electromagnetic thermal radiation energy creating a differential in intensity of the electromagnetic thermal radiation energy of that of metal powder **41** as described above that results in providing an image in infrared camera **48** of that composition. Metal powder **41** and polymer fiber contaminant **40** start out within layer **34** at a common or room temperature, as mentioned earlier, with respect to FIGS. **6**, **9** and **12**. With heating these compositions within layer **34**, the differential of absorptance to thermal inertia ratios in the compositions results in the greater ratio value composition providing an image in infrared camera **48** as described above providing a visual image contrast between the compositions which provides the operator a visual image which detects the presence and location of polymer fiber contaminant **40** in layer **34**. As time progresses with respect to the application of light or laser beam **44** to layer **34**, temperatures of the compositions, metal powder **41** and polymer fiber contaminant **40**, reach equilibrium temperature as seen in FIG. **12**. As a result, the spectrum and intensity of their electromagnetic thermal radiation energy emission also reach equilibrium as seen in

FIGS. **8** and **11** resulting in the diminishing of visual contrast provided by infrared camera **48**.

[0055] System **36** further includes roller apparatus **32** associated with build tank **18** of additive printer assembly **10** as seen in FIGS. **2**, **3** and **5**. Roller apparatus **32**, as earlier discussed, moves material **16** from feed tank **26** to build tank **18**. In addition, roller apparatus **32** is used to remove layer **34** from build tank **18** when system **36** detects an unacceptable presence of polymer fiber contaminant **40**, in the present example, within for example, metal powder **41** of material **16**.

[0056] Roller apparatus **32** is positioned at first elevation D**1** relative to first bottom portion **22** of build tank **18**, as seen in FIG. **3**, and moved across build tank **18**, resulting in layer **34** of material **16** being added on build tank **18** with material **16** from feed tank **26** as seen in FIG. **2**. Alternatively, roller apparatus **32** positioned in second elevation D**2**, as seen in FIG. **5**, relative to the first bottom portion **22** of build tank **18** and moved across build tank **18** layer **34** of material **16** is removed from build tank **18**, which occurs with system **36** detecting in this example polymer fiber contaminant **40** content within metal powder **41** within layer **34** of material **16** which is unacceptable.

[0057] In referring to FIG. **13**, method **54** for detecting contaminant **40** includes heating **56** layer **34** of material **16** positioned in location **46** with light source **42** directed to layer **34** of material **16** positioned in location **46** such that light beam **44** from light source **42** reaches layer **34** of material **16** in location **46**. Method **54** further includes receiving **58** electromagnetic thermal radiation energy from layer **34** of material **16** positioned in location **46** with infrared camera **48** aligned with location **46**. Method **54** further includes positioning layer **34** of material **16** on build tank **18** of additive printer assembly **10**, wherein layer **34** of material **16** includes one of metal powder or the metal powder and polymer fiber, which is contaminant **40**. Light source **42** includes a laser light source wherein light beam **44** emitted from the laser light source includes a laser light beam in this example.

[0058] Method **54** further includes positioning optical filter **50** aligned with infrared camera **48** and positioned between infrared camera **48** and material **16** of layer **34**. Method **54** further includes filtering, with optical filter **50**, electromagnetic radiation of light beam **44** from light source **42** which is reflected by material **16** of layer **34**. As discussed earlier, method **54** further includes filtering, with optical filter **50**, electromagnetic thermal radiation energy emitted from material **16** of layer **34**, wherein material **16** includes a metal powder and a contaminant **40** polymer fiber, exclusive of a peak wavelength or A max from one of the metal powder or the polymer fiber, which ever has a greater absorptance to thermal inertia ratio allowing the peak wavelength or A max to be transmitted from material **16** to infrared camera **48**.

[0059] In referring to FIG. **14**, method **60** for removing layer **34** of material **16** including metal powder and contaminant **40**, such as seen in FIG. **6** includes with roller apparatus **32** associated with build tank **18** of additive printer assembly **10** positioned at a first elevation D**1**, as seen in FIG. **3**, relative to first bottom portion **22** of build tank **18**, moving **62** roller apparatus **32** to second elevation D**2** relative to first bottom portion **22** of build tank **18**, wherein second elevation D**2** is closer to first bottom portion **22** of build tank **18** than first elevation D**1** of FIG. **3** and moving **64** roller apparatus **32** across build tank **18**, as seen in FIG. **5**, removing layer **34** of material **16** from build tank **18**. In this example, layer **34** of material **16** removed from build tank **18** includes metal powder and an unacceptable content within material **16** of layer **34** of contaminant **40**, which in this example includes a polymer fiber. Once layer **34** is removed roller apparatus **32** can be used to add another layer **34** on build tank **18** wherein in this example, system **36** is employed for detecting presence of contaminant **40** within material **16** prior to determining whether to proceed with printing with additive printer assembly **10**.

[0060] While various embodiments have been described above, this disclosure is not intended to be limited thereto. Variations can be made to the disclosed embodiments that are still within the scope of the appended claims.

What is claimed is:

1. A method for detecting a contaminant, comprising:

heating a layer of a material positioned in a location with a light source directed to the layer of material positioned in the location, and

receiving electromagnetic thermal radiation energy from the layer of the material positioned in the location with an infrared camera aligned with the location.

2. The method of claim **1**, further comprising:

positioning the layer of the material on a build tank of an additive printer assembly, wherein the layer of the material comprises one of a metal powder or the metal powder and a polymer fiber; and

the light source comprising a laser light source, wherein a light beam emitted from the laser light source comprises a laser light beam.

3. The method of claim **1**, further including positioning an optical filter aligned with the infrared camera and positioned between the infrared camera and the material.

4. The method of claim **3**, further including filtering, with the optical filter, electromagnetic radiation energy of a light beam from the light source which is reflected by the material.

5. The method of claim **3**, further including filtering, with the optical filter, electromagnetic thermal radiation energy from the material, comprising a metal powder and a polymer fiber, exclusive of a peak wavelength from the metal powder or the polymer fiber.

6. The method of claim **5**, wherein the peak wavelength is transmitted from one of the metal powder or the polymer fiber which has a greater absorptance to thermal inertia ratio.

7. A method for removing a layer of material from a build tank of an additive printer assembly, comprising:

with a roller apparatus associated with the build tank of the additive printer assembly positioned at a first elevation relative to a first bottom portion of the build tank, moving the roller apparatus to a second elevation relative to the first bottom portion of the build tank, wherein the second elevation is closer to the first bottom portion of the build tank than the first elevation; and

moving the roller apparatus across the build tank removing the layer of material from the build tank.

8. The method of claim **7**, wherein the layer of material removed from the build tank includes a metal powder and a contaminant comprising a polymer fiber.

9. A method for manufacturing a part using an additive printer assembly, the method comprising:

positioning a layer of material in a build tank of the additive printer assembly;

directing a light beam from a light source onto the layer of material to heat the layer of material;

receiving electromagnetic thermal radiation energy emitted from the layer of material with an infrared camera; and

determining, based on the received electromagnetic thermal radiation energy, whether the layer of material includes a contaminant prior to building the part.

10. The method of claim **9**, wherein the light source comprises a laser light source configured to emit a laser light beam having a first wavelength.

11. The method of claim **9**, wherein the infrared camera is aligned with the layer of material to detect variations in electromagnetic thermal radiation energy indicative of one or more contaminants.

12. The method of claim **9**, further comprising positioning an optical filter between the infrared camera and the layer of material, wherein the optical filter is configured to block electromagnetic radiation at a wavelength of the light beam.

13. The method of claim **12**, wherein the optical filter comprises a bandpass filter configured to transmit a bandwidth including a peak thermal wavelength corresponding to a known contaminant.

14. The method of claim **9**, wherein determining whether the layer of material includes a contaminant comprises identifying a visual contrast in thermal emission intensity between two materials having different absorptance-to-thermal-inertia ratios.

15. The method of claim **9**, wherein the material comprises a metal powder and the contaminant comprises a polymer fiber.

16. The method of claim **9**, further comprising removing the layer of material from the build tank if the contaminant is determined to exceed a predefined threshold.

17. The method of claim **16**, wherein removing the layer of material from the build tank comprises using a roller apparatus to remove the layer from the build tank.

18. The method of claim **9**, further comprising removing the contaminant from the layer of material prior to proceeding with building the part.

19. The method of claim **9**, further comprising proceeding with sintering the layer of material in the build tank if the contaminant is determined to be within an acceptable range.

20. The method of claim **9**, wherein determining whether the layer includes a contaminant comprises quantifying the contaminant based on intensity differentials in thermal emission captured by the infrared camera.

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