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(54) Title: DEVICE AND METHOD FOR IDENTIFYING A FOREIGN MATERIAL

(57) Abstract: The disclosure relates to a device and a computer implemented method for identifying a contaminant in a printed circuit board (PCB) production line using an elemental analysis technique, preferably energy-dispersive X-ray spectroscopy (EDX) by comparing the elemental composition and carbon-oxygen ratio of the contaminant to the elemental composition and carbon-oxygen ratios of reference samples. In the comparison, the elemental composition is expressed as a first and a second value and the ratio of carbon-oxygen ratios as a third value. The method also comprises calculating a similarity score between the contaminant and each of the reference samples based on the first, second and third values. The aim is to trace the source of contamination in the production line and to take corrective action.



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DEVICE AND METHOD FOR IDENTIFYING A FOREIGN MATERIAL

BACKGROUND OF THE INVENTION

5 The present invention refers to identifying foreign material in a production line. In particular, the present invention refers to material identification in the printed-circuit board (PCB) and substrate industry.

10 In a production line, usually several steps are performed in a serial manner, where the objects that are to be produced or processed are transported between several processing stations. It can occur, that a station works improperly or that a transfer route is not optimal. In these or other cases, material from a tool, a casing, the transfer medium, or other sources that are not part of the objects, can be introduced onto the objects. Such material is considered to be foreign material, i.e., not part of the objects, and is deemed to be a contamination.

15 Often such contamination is only detected at the end of a production line, at a quality control point. Quality control points can also be between production line stations, but usually quality is not controlled after each station, due to the time and effort the quality control requires.

20 Production lines are ubiquitous and are for examples used in food creation and processing, bottling of liquids, creation of electronic parts, like printed circuit boards, assembly lines for cars and the like, and many other intended uses.

25 According to prior art, a sample of the foreign material is collected and examined, for example by Fourier-transform infrared spectroscopy (FTIR) and Energy-dispersive X-ray spectroscopy (EDX).

30 US 2018/150616 A1 describes a sample analysis system with a reference substance database including measurement results and component classification information of reference substances obtained by each analysis device on information of each reference substance, where in particular an EDX and FTIR database is described.

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US 2017/307551 A1 describes a sample-analyzing system used for identifying a target sample from its measurement data obtained using a plurality of analyzing devices including at least one device selected from a fluorescent X-ray analyzer, atomic absorption photometer and inductively coupled plasma emission analyzer as well as at least one device selected from an infrared spectrophotometer and Raman spectrophotometer.

US 10,126,250 B1 describes a foreign substance analysis system capable of accurately and easily analyzing a foreign substance contained in a sample. The foreign substance analysis system includes an infrared spectrum acquisition step of acquiring infrared spectrum information of a sample measured by an infrared spectrophotometer.

US 2017/067864 A1 describes a mass spectrometry method for performing a determination of an analyte compound contained in a sample, using a mass chromatogram acquired for one or a plurality of ions selected as a reference ion from the ions produced from the analyte compound.

US 2020/284719 A1 describes that spectra matching is widely used in various applications including the search for a spectrum of an unknown or subject material, chemical, or compound in an existing spectral database and quality control by means of comparing the spectra of products with standards. In particular, systems and methods are described for identifying an unknown compound by calculating the similarities of Fourier-transform infrared (FTIR) spectra of organic compounds.

Disadvantageous in the known methods is that previously the time to evaluate the cause for the contamination is rather long and can take several days. Consequently, the efficiency of a production line is significantly reduced if a containment occurs.

Furthermore, the known prior art methods usually require several measurements and/or analyses to define the unknown substance, and they consider a single substance only.

SUMMARY OF THE INVENTION

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The object of the present invention is thus to overcome the disadvantages of the prior art and to provide an improved method and system for identification of foreign material, or at least to provide an alternative to existing solutions.

- 5 The present invention solves this object by providing a method and system according to the independent claims. Further advantageous features are set out in the dependent claims.

According to an embodiment, a computer implemented method for identifying a foreign material in a production line from an existing set of material samples is provided. The chemical
10 analysis data for the material samples is known and stored in a memory, and the method comprises retrieving chemical analysis data of the foreign material. Then a first, a second, and a third value for each of the material samples in conjunction with the foreign material is calculated on the basis of the retrieved chemical analysis data of the foreign material and the stored
15 chemical analysis data of the material samples. Then a similarity score is calculated for each of the material samples based on the first, second and third value. Thereby the foreign material is identified by the material sample with the highest similarity score.

The presented method is advantageous, since less time is needed to evaluate the cause for the contamination in comparison to the prior art. Consequently, the efficiency of a production line
20 is improved. Further, the presented method only requires one measurement and/or analyses to define the unknown substance, and it can consider multiple material samples at once.

In another embodiment, the identified foreign material is compared with information stored in a database, wherein the information indicates parts of a production line and materials the parts
25 are composed of and/or that are used at the corresponding parts, thereby determining at which parts the foreign material was introduced.

This allows more efficient identification of the location of the contamination.

30 In another embodiment, the first, second and third value refer to a similarity in chemical composition, a mass difference, and a ratio of the carbon-oxygen-ratio. The order is interchangeable.

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These parameters have been found to be suited best for identifying the foreign material.

In another embodiment, the value indicating the ratio of the carbon-oxygen-ratio is evaluated to determine whether the foreign material consists of a mixture of different materials, or
5 whether the foreign material consists only of one material.

Thereby, even mixtures of different material can be identified.

In another embodiment, the retrieved chemical analysis data is compared to data from the
10 memory to obtain a quantitative statement, indicating the elemental composition of the material in wt%, mol% or vol%.

Thereby the method can advantageously indicate a quantitative statement.

15 In another embodiment, the foreign material is pre-screened by taking pre-screening measurement indicating the organic and inorganic content of the foreign material and whether the foreign material is mixture of different materials, or whether the foreign material consists only of one material.

20 It has been found to be useful to apply a pre-screen, preferably with a non-destructive measurement, in order to speed up the method, in case the pre-screen is already conclusive.

The retrieved chemical analysis data can represent measurement results of one or more of the following: an elemental analysis, preferably a spectroscopy, in particular preferably energy-dispersive X-ray spectroscopy, infrared spectroscopy, and/or magnetic resonance spectroscopy, preferably nuclear magnetic resonance spectroscopy. The same technologies can be
25 used for pre-screening.

For the calculations there are several calculation options:

30 The values can be calculated by functions from the following group: Jaccard coefficient, Manhattan distance, carbon-to-oxygen ratio, Pearson coefficient, Spearman's rank correlation coefficient, Kendall rank correlation coefficient, Dice's coefficient, Simpson coefficient. Euclidean distance, Chebyshev distance, Minkowski distance.

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The first value is preferably calculated by using one of a Simpson, Jaccard, and Dice coefficient.

- 5 The second value is preferably calculated by using one of a Manhattan, Euclidean, Chebyshev, Pearson, Spearman, Kendall, and Minkowski distance.

10 The similarity score can be calculated by using weighting of the first, second, and third values with a first, second, and third predetermined weight. Alternatively, these weights can be predetermined or determined during the method. The determination can be performed by machine-learning.

15 The above detailed calculation options have been found to be beneficial to the efficiency and accuracy of the method.

It has further been found to be beneficial that the first weight is between 0.15 to 0.45 (preferably at 0.3), that the second weight is between 0.45 to 0.75 (preferably at 0.6), and/or that the third weight is between 0 to 0.30 (preferably 0.10). It has further been found to be beneficial that the sum of the first, second, and third weight is 1.

20 In has been found to be especially beneficial, that the third weight is between 0 to 0.1 (preferably 0.05) if the foreign material consists of a mixture of different materials, and between 0.05 to 0.3 (preferably 0.1) otherwise.

25 In another embodiment, if one or more predetermined conditions are met, one or more actions can be triggered. These include notification by visual or audio signals, notifications on a screen, via an e-mail, push-notification to a mobile app, or text message to a mobile phone, signaling to a device or part of a production line to stop or shut-down, cleaning of chemical baths or conveyor belts, exchanging chemical baths, changing of filters, discarding of a production lot, observing a certain production lot, and/or starting a video recording device.

30 The notifications can comprise information on the detection of foreign material, a type or composition of the foreign material, a most probable location that was determined to be the

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source and/or that a signaling for stop, shut-down, cleaning, exchanging, changing, discarding, observing, or recording signaling was triggered.

In another embodiment, the determination whether one or more predetermined conditions are met can be performed by machine-learning.

Other embodiments include a device configured to carry out the presented methods and a computer program product.

BRIEF DESCRIPTION OF THE DRAWINGS

The preferred embodiments are illustrated in the drawings in which like reference numerals refer to like elements and in which:

- Fig. 1 shows a flowchart of the method according to the invention,
- Fig. 2 shows the surface of a workpiece,
- Fig. 3 shows a cross-section of the workpiece,
- Figs. 4 to 6 show magnified samples of the cross-section of the workpiece,
- Fig. 7 shows absorption curves for the samples of Figs. 4 to 6,
- Fig. 8 shows the absorption curve of the sample of Fig. 4 in comparison to reference samples,
- Fig. 9 shows energy curves of the sample of Fig. 5,
- Fig. 10 shows electron microscopy images of the sample of Fig. 5, and
- Figs. 11 to 16 show tables of values used in the method according to the invention.

It is noted that in the differently described embodiments, the same parts are provided with the same reference numbers or the same component designations, wherein the disclosure can be applied to the same or similar parts with the same or similar reference numbers or the same or similar component designations. The position designations in the description, such as top, bottom, side, etc., are related to the directly described and illustrated figure and these position designations can be transferred to other positions for other figures.

DETAILED DESCRIPTION OF THE INVENTION

Infrared spectroscopy (IR) is based on the effect that most molecules absorb light in the infra-red region. The absorbed energy is further converted into a molecular vibration. Different functional groups and different chemical bonds show an individual vibration which can be detected with FTIR measurements. Thereby the absorption is measured as a function of the wavelength (raw signal). After Fourier transformation, a spectrum with a sort of “molecular fingerprint” can be obtained. Thus, the specific absorption allows for the characterization of the nature of each chemical bond and the functional groups present in a sample. FTIR measurements can be used to detect or identify organic molecules. FTIR measurements are often not suitable for the measurements of inorganic particles. It should be noted that instead of FTIR measurements NMR (nuclear magnetic resonance) measurements can also be used in the inventive methods, since both analyses are based on matching spectra. The obtained measurements can be used as a sort of pre-screening by spectra matching. This includes the search for a spectrum of an unknown material, chemical, or compound in an existing spectral database and a quality control by means of comparing the spectra of an unknown material with standards or references. The pre-screening allows already to identify the unknown organic material if the spectrum of the sample of the foreign material matches with a sample of the existing spectra database. Additionally, or as an alternative, to using FTIR measurements, EDX measurements can be performed.

For FTIR the samples can be solid or semi-fluid, powder (possibly compressed), semi-transparent or transparent film, or liquid. FTIR can be used to measure or detect organic substances and some inorganic substances, for example H_2O and CO_2 . Inorganic substances that can be measured with FTIR comprise in particular those that have an acid radical: SO_4^{2-} , H_2PO_4^- , NO_3^- , or similar. Symmetrical molecule structure (such as H_2 , O_2 , N_2 , $\text{Cl}_2, \dots$), metal and most inorganic substances cannot be tested with FTIR and are thus not recommended for FTIR analysis. An advantage of FTIR is that it is a non-destructive analysis method, that means that a sample used for FTIR can be used for further measurement(s), e.g., SEM EDX, afterwards.

Energy-dispersive X-ray spectroscopy (EDX) is another analytical method for the chemical characterization of materials. EDX systems are generally attached to an electron microscopy instrument such as transmission electron microscopy (TEM) or scanning electron microscopy

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(SEM). These are two different measurement methods and only the same apparatus is used to perform either SEM measurements or EDX measurements. For the present invention, only EDX measurements are used. Similar to FTIR measurements the characterization is based on the emission of energy (for FTIR the vibration-characteristic wavelength). For this measurement method X-rays are detected. X-rays occur when a beam of high energy hits a sample. Thereby an electron from an atom present in the sample is excited and leaves its original position. When an electron from a higher binding energy level falls into this very position an X-ray with characteristic energy is emitted. The emitted energy allows for the detection of the sample composition.

SEM-EDX measurements can also be used to quantitatively determine the elemental content, that is in percentage by mass or weight, i.e., mass% or wt%. These values can be obtained by integrating the spectra and normalizing the results. An exemplary measurement can be seen in Fig. 1. However, as it has been known in the prior art, the results are not reliable, as this method depends also on the measurement-position of the sample, e.g., where on the surface the composition is measured. An improvement of the prior art is suggested below. Therein it is comprised that the invention allows for the use of SEM-EDX data for predicting a chemical composition of a material based on a quantitative analysis. It is noted that SEM-EDX is basically not an elemental analysis. However, in terms of this invention, the results from an SEM-EDX are used in the same way as the results from an elemental analysis, since it is used as a qualitative method. Therefore, in terms of this text, elemental analysis is assumed to comprise SEM-EDX as an option to implement elemental analysis.

For EDX, samples can be solid, film, or powder, although powder is not recommended.

Samples cannot be liquid or semi-fluid, as they are placed on a sample holder, e.g., they need to stick on adhesive paper as an example. Samples can be put into a SEM vacuum chamber. Samples may have a size of a production panel format (e.g., 520mm * 520mm * 30mm), and preferably the sample size is smaller than 100mm * 100mm * 30 mm. Furthermore, the sample may be analyzed without further preparation. Alternatively, the sample may be prepared by for example embedding it into a polymer, e.g., for a cross section, and/or by coating the surface of the sample with electrically conductive material, e.g., gold for SEM measurements.

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With the inventive method, chemical analysis data of a foreign material that are collected by means of spectroscopy, as for example FTIR or EDX technique as described above, is used to calculate a similarity score which can be used to compare the foreign material against a database, that has stored other chemical analysis data of comparative materials, that are used in the production line. Thereby it is possible to identify the foreign material, and since it is known, where the comparative materials are used, the point of contamination can be identified or at least narrowed down.

Thus, the search for the tool or station not operating as expected can be shortened, and average productivity of the production line can be increased.

By identifying the foreign material, also the source of the foreign material can be identified or narrowed down. In particular with the foreign material being identified, a database query can be performed. The database can hold the materials that are used at the individual steps of the production line, and also the materials that the devices of the production line are made of. Thereby the potential insertion point of the foreign material can be identified or narrowed down. This is called tracing and refers to the identification of the source of the foreign material. This can be in particular useful, if a mixture of materials is identified, since the individual parts of the mixture can give additional constraints to the search of the source of the foreign material. It is also possible to employ machine-learning methods to assist with the tracing, whereby different information can be used to train a neural network to enable the identification and tracing of foreign material. Also, the route of contaminated production items can be followed to check for secondary contamination, i.e., whether the foreign material has been further transferred from the processed item to another device further down in the production line.

As the database also can include the locations where different materials are used, the probability for each part of the production line to be the origin of the foreign material can be calculated and/or determined.

An example for such a database information can be, that a photoresist is used for a lithography process at or in a certain machine, another element of the production line, or a certain production line altogether.

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A computer implemented method, e.g., machine-learning, can be used to trigger certain actions if certain conditions are met. Examples for such actions are notification by visual or audio signals, notifications on a screen, via an e-mail, push-notification to a mobile app, or text message to a mobile phone, wherein such notification can comprise any useful information. Such information can be that foreign material was detected, the type or composition of the foreign material, the most probable location that was determined to be the source, etc. A user can thereby be instructed to observe the location, a certain device or production line, etc.

The method can also issue a stop signal, thereby shutting down a production line, if necessary. This can be performed additionally to the notification or signaling, and the notification can contain the information that a shutdown was initiated.

Further potential actions to be triggered by the method could be: shut-down of individual machines and/or full production lines, cleaning of chemical baths or conveyor belts, fully exchanging chemical baths, changing of filters, discarding of a production lot, or observing a certain production lot, starting a video recording device, etc.

Such a machine-learning apparatus or neural network can remember and learn where a certain material was originally located and how and where it is passed onto the processed items. With the growing data that is available to the method, the results will also become better over time, and the prediction of the route and source of the contamination can be improved.

A further advantage of this invention is that basically only one EDX measurement and/or analysis is sufficient to describe the unknown substance. Instead of the EDX measurement/analysis other suitable methods can be used, e.g., FTIR. It has been found that very often the detected foreign material is not one pure material but rather an agglomerate of different materials. As an example, in the PCB (Printed Circuit Board) industry so-called prepreps are used, which comprise an epoxy-based resin and reinforcing agents, such as glass fibers.

Depending on the spot where the foreign material is measured, the elemental composition determined by any analysis can be either related to the epoxy-based resin or the glass-fibers. The glass fibers are based on Silicon dioxide, with a low carbon-oxygen content whereas the resin is based on a high carbon-oxygen content. When using a scanning electron microscopy with

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energy dispersive X-ray spectroscopy (SEM/EDX) on a certain position, the scanning result greatly depends on the composition of the foreign material in that position, such that either the carbon-oxygen content is high, which represents a bigger part of epoxy-based resin at that position, or the carbon-oxygen content is low, which represents a bigger part of silicon dioxide and thus glass-fibers at that position.

By using a method using a similarity value, the uncertainty of the carbon-oxygen ratio for instance will be compensated by a coefficient like the Jaccard coefficient and/or the Manhattan distance. Alternatives to these concrete values are indicated below. Additionally, referring to the carbon-oxygen result and the FTIR results only, the carbon-oxygen ratio also helps to identify whether the unknown material is composed of a single component or a mixture.

In more detail, the inventive procedures are described in the following. The method can identify a foreign material in a production line from an existing set of material samples, wherein chemical analysis data is known for the material samples and stored in a memory. The material samples are usually taken before, for example, when a new device, station or tool is installed, a corresponding sample is taken, analyzed, and added to the memory. The memory can be a database or other means of storing data.

In the figures and the corresponding text passages referring to the figures in the following, as an example, printed circuit boards (PCB) are shown. PCBs can exemplarily comprise organic polymers (reinforced with glass), glass or ceramic material as host material where copper traces and or active/passive components are embedded and/or surface mounted. The presented subject-matter can however be applied to any kind of workpiece and corresponding production line. A further example could be wafers, that are used in semiconductor industry. Wafers consist of highly pure (crystalline) silicon.

Another term used for PCBs is component carrier. Such component carriers can be laminated structures which comprise at least one electrically conductive layer, which can be structured, and at least one electrically insulating layer.

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Fig. 2 shows a workpiece, here a PCB is used as an example. The workpiece has several holes, and one hole, marked with an X, is contaminated. This can be residue from a previous processing step or some substance that has fallen onto the workpiece.

5 Fig. 3 shows some examples of such contamination in a cross-section. As can be seen in Fig. 3, there are several holes that have been drilled into the component carrier. The holes have been drilled mechanically, and are supposed to be open, i.e., unblocked, in order to receive component elements in a later process. However, as can be seen in the four depicted holes, foreign material is inside the drill hole and is therefore blocking the holes. It is noted that the
10 four holes are merely examples, which do not need to be arranged next to each other. The present subject-matter can be applied to each of the holes, and one hole being blocked by foreign material is sufficient.

Fig. 4 shows a magnified cross-section of a sample 1. This can for example represent a hole
15 that has not been completely manufactured, i.e., the bottom of the hole was not completely removed. It can be seen in Fig. 4 that the base material of the workpiece is connecting the left and the right side, and that after producing the hole some coating has been performed.

Fig. 5 shows a magnified cross-section of a sample 2. This can for example represent a hole
20 that has been completely manufactured, but before coating some object has entered the hole. It can be seen in Fig. 5 that the left coating and the right coating are connected by the coating of the object.

Fig. 6 shows a magnified cross-section of a sample 3. This can for example also represent a
25 hole that has been completely manufactured, but before coating some object has entered the hole. It can be seen in Fig. 6 that the left coating and the right coating are not connected by the coating of the object, but the object only touches the left side.

As known in the prior art, such foreign material can be isolated and retrieved from a work-
30 piece for examination.

The presented method refers to evaluating the results of this examination.

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Fig. 7 shows a spectrum comparison of the foreign material of Figs. 4 to 6. The dashed line refers to the residue of Fig. 4, the straight line to the residue of Fig. 5 and the mixed line to the residue of Fig. 6. As can be seen, the spectral graphs indicate that the residues of Figs. 4 and 5 are the same material, or at least very similar, while the characteristic peaks on the spectrum of the residue of Fig. 6 are too weak. This could be interpreted as the residue is too thin to be analyzed correctly. In order to achieve the best results, it is preferred that the residue has a residue size larger than 50 μm .

Additionally, and/or alternatively, an additional layer (e.g., metal coating) can be arranged between the residue and the measuring tool. Since the contact of said residue and said measurement tool is not a direct one, a decrease of the intensity of the measurement signal may occur, which can also lead to a weaker signal.

Fig. 8 shows a comparison of the characteristics of the foreign material with database information referring to sample materials. The dashed line refers a first sample material, Ref1, and the straight line to a second sample material, Ref2. The mixed line refers to the curve of the residue of Fig. 4 of Fig. 7. The lines are meant to correspond, even though the representation in the figures may differ.

As can be seen in Fig. 8, from 2750 - 3400 cm^{-1} there is a good alignment of the foreign material with the sample materials 1 and 2. From 500 - 1000 cm^{-1} there is a good alignment of the foreign material with sample material 2. Based on the alignment of Fig. 8 altogether, one possible interpretation might be, that the foreign material is a mixture of the first and the second sample material.

Fig. 9 shows the determination of elemental composition by an electronic microscope coupled with Energy-dispersive X-ray spectroscopy (EDX). In particular, the different curves refer to different measuring areas of a sample, here the sample of Fig. 6 is used. The different curves create the corresponding EDX spectra, which is shown in Fig. 9. By using the integral of the different peaks, and subsequent normalizing the results, the elemental content in wt% can be obtained. From the measurement in the figure, values like the following could be obtained: C 66 wt%, O 29 wt%, Ca 2 wt%, S 2 wt% and Si 1 wt%. These values are merely an example.

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Fig. 10 shows SEM-EDX images, where a coloration or a contrast change can be applied to indicate the presence of certain elements. The intensity of the color would then indicate the amount. In the greyscale depiction shown in Fig. 10 lighter areas indicate the corresponding element: top left carbon; top middle oxygen, top right silicon, bottom left sulfur, bottom middle calcium, and bottom right copper.

The method 100, as shown in Fig. 1, first retrieves in step 110 the chemical analysis data of the foreign material. The chemical analysis data can be obtained by any method capable of determining the elemental content of an unknown material, such as elemental analysis and spectroscopy, preferably energy-dispersive X-ray spectroscopy (EDX) and/or infrared spectroscopy (FTIR) or NMR (nuclear magnetic resonance) spectroscopy. Other chemical analysis techniques can also be used, in particular techniques that enable the generation of the element composition in wt%, mol% or vol%. However, any method capable of determining the elemental content of the unknown material would be a suitable basis for the present invention.

Optionally the retrieved chemical analysis data can be directly compared in step 160 with data from the memory, for example a database, to obtain a quantitative statement, which cannot be provided with the commonly known techniques. This step can basically be performed at any time after the chemical analysis data is retrieved in step 110. In Fig. 1 it is set after step 110, but it can also be after step 120, 130 or one of the optional steps detailed below.

Then in step 120, a first, a second, and a third value for each of the material samples in conjunction with the foreign material on the basis of the retrieved chemical analysis data of the foreign material and the stored chemical analysis data of the material samples is determined. The three values are in that sense three, preferably different, values that compare the foreign material with the existing material samples in the database.

The three values can have different means of comparing the chemical analysis data of the foreign material with the stored chemical analysis data of the material samples, that already exist in the memory.

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The first value can indicate a similarity of each of the material samples and the foreign material regarding their chemical composition. Examples for the first values are Simpson, Jaccard and Dice coefficient.

- 5 The coefficient is used in the first value to define, which elements are present in the unknown substance. The elements will be counted. Thus, the formula basically is used to determine whether a certain element is present or not, e.g., four out of five elements are present in the unknown substance and in the reference. Thus, the count number would be four.
- 10 The second value can indicate a difference in mass% or wt%, also referred to by mass difference in the following, between in the material sample and the foreign material. Examples for the second value are Manhattan, Euclidean, Chebyshev, Pearson, Spearman, Kendall, and Minkowski distance.
- 15 On the other hand, the second value uses absolute values. Thus, the wt% of the element will be subtracted from the element wt% of the reference. Analogously this applies for mass%, mol%, or vol%, which can be used alternatively. Consequently, the second value can determine how much of an element is present with respect to the reference sample. As an example, let's say the reference sample comprises 25wt% of silicon, whereas the unknown sample
- 20 comprises only 20wt% of silicon. A difference of 5wt% might indicate the presence of another material when compared with the reference sample.

The third value can indicate a ratio of the carbon-oxygen-ratios (C/O ratio or COR) of the material sample and the foreign material.

- 25 In other words, the C/O ratio is used to further reduce the uncertainty of the other two values to identify the unknown substance. If for instance the C/O ratio is close to or identical to the C/O ratio of an epoxy-based resin reference sample, it is clear, that the main composition is based on an epoxy-resin. If the C/O ratio deviates from the C/O ratio of the reference sample,
- 30 it is indicated that another substance might be present or that the unknown substance comprises more than one compound. Thus, in comparison with the first value, for example the Jaccard Coefficient, which determines the elements present in both, the reference sample and the unknown sample, i.e., foreign material sample, and the second value, for example the

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Manhattan Distance, which determines the amount of similar content in the reference sample and the unknown sample, i.e., foreign material sample, the unknown sample can be identified.

It should be noted that the order of the first, second, and third value can be exchanged. The chemical composition similarity can also be the second or third value, the mass difference can be indicated in the first or third value, and the carbon-oxygen-ratio can be indicated in the first or second value.

It is noted that value indicating the ratio of the carbon-oxygen-ratio can be evaluated in a step 150 to determine whether the foreign material consists of a mixture of different materials. This step can basically be performed at any time after the value indicating the ratio of the carbon-oxygen-ratio has been calculated in step 120. In Fig. 1 it is set after step 120, but it can also be after step 130 or one of the optional steps detailed below.

In step 130, the method then calculates a similarity score for each of the material samples based on the first, second and third score. In other words, the similarity score is based on the chemical composition, more precisely of the element composition in wt% and the C/O ratio of the unknown material. The foreign material can then be identified by the material sample with the highest similarity score. The simplest method to calculate the similarity score is to add up the first, second, and third value. They could also be multiplied, or other mathematical operation can be used.

In other words, considering the examples from above, it is known that the exact measurement position can influence the result of the materials composition. By combining the second value and the first value this uncertainty can be limited or minimized and the inventive method can be used to identify the unknown material.

The identified foreign material can be compared with a database in step 140, wherein the database stored information about the production line. This information can indicate which steps of the process or which machines or other elements use or are made of a certain substance, such that the point of introduction of the foreign material can be determined.

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When calculating the similarity score for each of the material samples, the first, second, and third values can be weighted with a corresponding first, second, and third predetermined weight. Thereby the overall efficiency of the similarity score can be further improved. By weighting the values, that is for example, the chemical composition, e.g., wt% of elements present, the mass difference and/or the carbon-oxygen-ratio, they can have a different impact on the similarity score. Thereby, if for example the mass difference value has a higher weight as the other two values, materials with a similar mass difference from the foreign material, will receive a higher overall similarity. The same can be stated for the other two values or course.

Alternatively, the first, second, and third weight are not predetermined, but are determined by the method itself in a step 180. This can be a part of the step of calculating the similarity score 130, as shown in Fig. 1, but this can also be an individual step before step 130. This can be achieved for example by using a rule-based system, an expert system, a machine learning system, or generally a neural network, or other decision systems.

Such a learning system could then adjust a weight as follows. The value of a weight could be increased the higher the corresponding value indicates a likeness of the foreign material and the samples, i.e., the more the first, second, and third values (which could represent, as an example, the Jaccard coefficient, the Manhattan distance, and the C/O ratio, respectively) indicate that the foreign material is similar to each sample is, the more the corresponding weight will be increased. For this, the learning system must also be able to interpret each of the three values individually. Value 1 of the unknown sample is compared with value 1 of each reference samples and then evaluated. Value 2 and 3 can be processed in an analogous manner. Threshold values can also be set, such that the range of a weight will not be increased or decreased beyond pre-set values.

The weights can constitute a percentage of contribution of the values to the similarity value. Therefore, the sum of all weights can amount to 1 or 100%.

Thus, the weighing of the values is depending on the elemental analysis of the unknown sample. The more similar the individual value of the foreign material is to the reference sample

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values, the more will the corresponding weighing be increased. Additionally, previous weightings can be taken into account as a starting point for each analysis.

It has been shown that good results with the described method can be achieved if the weight for the chemical composition similarity has a value between 0.15 and 0.45. In particular good results have been achieved with a weight of 0.3. That means, that the chemical composition similarity value accounts for 15% to 45%, preferably 30% of the similarity score.

It has also been shown that good results with the described method can be achieved if the weight for the mass difference has a value between 0.45 and 0.75. In particular good results have been achieved with a weight of 0.6. That means, that the mass difference value accounts for 45% to 75%, preferably 60% of the similarity score.

It is also noted that the mass difference generally can have a higher weight, since the mass difference is absolute compared to the chemical composition similarity and the C/O ratio.

It has also been shown that good results with the described method can be achieved if the weight for the carbon-to-oxygen ratio has a value between 0 and 0.30. In particular good results have been achieved with a weight of 0.1. That means, that the carbon-to-oxygen ratio value accounts for 0% to 30%, preferably 10% of the similarity score.

While it is possible that the weights are for example 0.2, 0.5 and 0.1, this is not indicative of percentages. Therefore, it is preferable, that the weights add up to the value 1, such that a value of 0.35 indicates that the corresponding value makes up 35% of the similarity score.

As an example, the memory, or database, could have stored the chemical analysis values of 7 material samples, shown in table 1 of Fig. 11.

Therein the common chemical symbols are used: C for Carbon, O for Oxygen, Si for Silicon, Al for Aluminum, P for Phosphorus, Cu for Copper, and Ni for Nickel.

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The values in the column detail the percentage of the components of the corresponding sample, in wt%, mol% or vol%. The last column is the total, which naturally should indicate 100 percent.

5 A detected foreign material could for example have the chemical analysis data shown in table 2 of Fig. 12.

From the chemical analysis data, now the first, second and third value can be calculated as detailed above. With the example data, the result of table 3, shown in Fig. 13 would be
10 achieved.

The values in table 3 indicate the similarity of different samples to the foreign material. Therefore, the first row contains the maximal similarity value, as the foreign material is 100% similar to itself. For the first value, this value is 1, for the second value this value is 0. The
15 third value, which is 2.40, is related to the C/O ratio indicates the integrated value of the carbon content divided by the integrated value of the oxygen content.

In table 3, value #1 is the first value, indicating the chemical composition similarity. Value #2 is the second value, indicating mass difference. Value #3 is the third value indicating the carbon-oxygen-ratio of the sample. As stated above, the values can be interchanged. It is noted,
20 that since sample #7 does not have any carbon or oxygen parts, the carbon-oxygen-ratio is also not defined, which is indicated by the value 0 in table 3. Further, for the foreign material the chemical composition similarity is 1, since it is 100% similar to itself, and the mass difference is zero. For the samples, the values are indicated with relation to the foreign material.

25 Due to the nature of the individual values, the value indicating the chemical composition could require normalization before it can be added to the other values. As an example, if the values are not already normalized the value could be normalized by multiplication with the value 100. Jaccard values are already normalized, so if Jaccard coefficient is used, there is no
30 need for normalization.

The value indicating the mass difference could also require normalization before it can be added with the other values. As an example, the normalization could be performed by (1-

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value/200). The value 200 constitutes the maximal distance for two materials, in that it is the sum of percentages of each material that cannot be found in the respective other material. As a simple example for this, a material 1 constituting of 30% Carbon and 70% Aluminum and a material 2 constituting of 40% Copper and 60% Nickel would have a distance of 200, since 100% of material 1 are not in material 2 and 100% of material 2 are not in material 1. The sum of 100% and 100% results in the distance 200.

Finally, the carbon-oxygen-ratio could be taken into account, by dividing the lower carbon-oxygen-ratio by the higher carbon-oxygen-ratio (always comparing each of the existing material samples with the foreign material).

After applying the Manhattan distance or other distance calculation, to the second value as indicated above, and after normalizing the third value, the resulting values of table 4, shown in Fig. 14, would be achieved.

In table 4, the values of the first column are taken from the table 3. The values of the second column can be calculated as

$$\text{Normalized Value \#2 (Sample)} = 1 - \text{Value \#2 (Sample)} / 200$$

Taking Sample #4 as an example: Normalized Value #2 = $1 - 73.8/200 = 0.631$, which means 63% similarity.

The third column is calculated, as stated above, by dividing the lower C/O ratio by the higher C/O ratio as

$$\text{Normalized Value \#3 (Sample)} = \frac{\text{MIN}(\text{Value \#3 (Sample)}, \text{Value \#3 (Foreign Material)})}{\text{MAX}(\text{Value \#3 (Sample)}, \text{Value \#3 (Foreign Material)})}$$

Taking Sample #4 as an example: Normalized Value #3 = $2.4 / 2.5 = 0.96$, which indicates a difference in the C/O ration of the sample and the foreign material. This difference can be used to reduce the uncertainty of the other two values to identify the unknown substance. If for instance the C/O ratio is close to or identical to the C/O ratio of an epoxy-based resin

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reference sample, it is clear, that the main composition is based on an epoxy-resin. If the C/O ratio deviates from the C/O ratio of the reference sample, it is known that another substance might be present or that the unknown substance comprises more than one compound.

5 In particular, the first value in tables 3 and 4 shows values from using the Jaccard coefficient, the second value from using the Manhattan distance. Other options, as detailed above are also possible.

For the Jaccard coefficient, the values are more detailed in table 5, shown in Fig. 15.

10

In table 5, the intersection count represents the number of identical elements present in the foreign material sample and the reference sample. The union count represents the total amount of existing elements present in the foreign material sample and the reference sample. As an example, the unknown sample comprises, C, O, Si and Al. The reference comprises C,
15 O and Si. Thus, the intersection count would be 3 and the union count would be 4.

With the first, second, and third values the similarity score can be calculated. As stated before, for example, by adding the values.

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$$\text{Similarity Score} = \text{Value1} + \text{Value2} + \text{Value3}$$

The values can optionally have weights, as laid out above:

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$$\text{Similarity Score} = \text{Weight1} * \text{Value1} + \text{Weight2} * \text{Value2} + \text{Weight3} * \text{Value3}$$

Or short: $\text{Score} = w_1 v_1 + w_2 v_2 + w_3 v_3$

With the above detailed normalizations, the formula would then be as follows:

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$$\text{Score} = w_1 v_1 * 100 + w_2 v_2 * 100 + w_3 * (\text{Lower COR/Higher COR} * 100)$$

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With the exemplary data discussed above, the samples would receive different scores when the weights are different. Exemplary results are given in table 6 of Fig. 16, wherein the scores are calculated with the following weights:

- 5 Score A: $w_1 = 0.3$; $w_2 = 0.6$; and $w_3 = 0.1$.
Score B: $w_1 = 0.45$; $w_2 = 0.45$; and $w_3 = 0.1$.
Score C: $w_1 = 0.6$; $w_2 = 0.3$; and $w_3 = 0.1$.

10 As can be seen, with the weights for Score A and B, Sample #1 is the most similar, while with the weights for Score C, Sample #3 is the most similar.

It has been shown that the weights as defined above for Score A or close to those are best suited.

15 It is noted that a foreign material can also be pre-screened in a step 170 by taking FTIR measurement, which are then used as a quick possibility to check the organic content of the foreign material, by comparing the taken spectra to identify the origin, e.g., whether the component is organic-based or inorganic-based or whether or not the unknown material is mixture of different materials. Further, regular EDX measurements can then be used to precisely identify the
20 material. As an alternative or in addition to the FTIR, other infrared measurements or resonance measurements, in particular NMR, can be used for pre-screening.

With the present invention, a sample of foreign material, that has been found to be a contamination in a production line, can be analyzed by FTIR spectroscopy. The obtained spectrum
25 will be compared with existing spectra from a database. If the obtained spectrum matches with or is close to an existing one, the foreign material can be identified. An allowed deviation to be considered a match can be for example a deviation of 5% or less. If not, the sample is further analyzed by EDX measurements. The data from the EDX measurement can further be used to obtain the Manhattan distance, the Jaccard coefficient and the carbon-oxygen-ratio.

30 The main advantage of this method is that it allows to compare the quantitative EDX data intuitively and quickly from the EDX analysis through the calculated total similarity score. Usually, EDX is referred to as a qualitative evaluation, not a quantitative one, which means that it

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can be learned which atoms are present in the sample but not how many atoms are present in the sample. This is achieved by integrating the EDX spectrum. The EDX device can be calibrated, for example, by using a reference material, where the chemical composition is known. After calibration, this method can be used for unknown materials. The final statement of the chemical composition of the unknown material can be done in combination with the similarity score. The calculated total score is further compared with the existing total scores from the database. The foreign material can be identified, if the total score of the sample matches, or is the closest to, a total score from the database. Again, an allowed deviation can be set, as laid out above. This means, that if the closest score deviates by a factor of more than 0.5, the material is for sure not the same.

In other words, usually in an EDX-Analysis, it can be learned which chemical element compositions are present in the sample and their mass/weight/atoms percentages. However, in the prior art, there is no suitable method to compare the similarity of different samples based on these quantitative EDX data or the element content of the samples. If the foreign material is inorganic or it is very small and it can only be analyzed with EDX, because FTIR can only measure organic materials and some special inorganic materials, it is very difficult to identify a foreign material sample even if a matching material sample is in the EDX database.

The total score shows the similarity of foreign material to different sample materials in the EDX database. The higher the score, the higher the similarity. Thus, the foreign material can be identified, if the matching sample has a relatively high total similarity score.

However, generally, the test procedures of FTIR and EDX are not interchangeable, unless there is a backup of the same sample, or the sample can be retained after removing the electrical conducting coating (usually an ultrathin gold/carbon layer) from the SEM sample preparation on the sample surface.

In order to remove this coating, sample surface will usually be grinded or polished with a grinding paper or a polishing cloth. If the sample size is very small and thin, like for example a tiny foreign material residue on the substrate surface, it can be easily removed after the grinding/polishing process and cannot be further analyzed by FTIR.

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Therefore, it is further advantageous to conduct a FTIR analysis before the EDX analysis.

In a further embodiment, the values can – at any stage of the process – be also displayed to an output device, like a monitor, display or screen, and an operating person could monitor the calculations. The operating person could also modify the values as needed, for example with an input device like a keyboard or other controlling elements, thereby overruling the provided data if needed.

After a foreign material has been identified an action can be triggered in step 191. Such an action could be the cleaning of a conveyor band for instance. The obtained results can also lead to new standard procedures: If the same foreign material (e.g., a photoresist) is detected on panels always after a certain time period (e.g., every week) then the action might be to implement a mandatory cleaning step latest every week. The main advantage is that by identifying the foreign material also its origin can be traced. If the foreign material is a photoresist, the processing step, in which the contamination occurs, is known and this further allows for process optimizations.

The triggering 191 can depend on determining 190 whether certain conditions are met.

Aforementioned actions can also be triggered by a machine-learning system. If the system is trained with the corresponding information, comprising also for example where which materials are used in the process of the production, the result of the analysis could be assigned to an origin, as laid out above. As an example, in the process of electroplating remains of a solder resist. By tracking the part number in correlation with the data where solder resist is used, the origin of the foreign material can be determined.

Thereby the route of the contamination can be followed, the origin of the contamination and the position of the detection of the contamination.

It is noted that in terms of the presented embodiments, a machine-learning device or system performs one or a combination of several learning methods, such as Decision Tree Learning, k-Nearest Neighbor, Linear Regression, Logistic Regression, Winnow, LASSO, Ridge Regression, ARIMA, Perceptron, Artificial Neural Networks, Deep Learning, Naive Bayes,

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Bayesian Network, Support Vector Machine, Boosting, Reinforcement Learning, Markov Chain or Hidden Markov Model.

Another embodiment according to the invention is a device for identifying a foreign material in a production line from an existing set of material samples, preferably a computer, which is configured to carry out the method of described above.

In particular, the device can comprise a memory wherein chemical analysis data is stored for the material samples, a transmitter for receiving chemical analysis data of the foreign material, and a processing unit. The processing unit is configured to calculate a first, a second, and a third value for each of the material samples in conjunction with the foreign material on the basis of the retrieved chemical analysis data of the foreign material and the stored chemical analysis data of the material samples, and a similarity score for each of the material samples based on the first, second and third values. Thereby the foreign material is identified by the material sample with the highest similarity score.

A further embodiment is a computer program product with a program for a data processing device, comprising software code sections for executing the steps of the method described above when the program is executed on the data processing device.

This computer program product can comprise a computer-readable medium on which the software code sections are stored, wherein the program can be loaded directly into an internal memory of the data processing device.

The exemplary embodiments show possible implementation variants, whereby it should be noted at this point that the invention is not limited to the specifically described design variants, but rather various combinations of the individual features with one another are possible. In particular, the features described in context of the method can also be included into the device.

The scope of protection is determined by the claims. However, the description and the drawings are to be used to interpret the claims.

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Individual features or combinations of features from the different exemplary embodiments shown and described can represent independent inventive solutions. The object on which the independent inventive solutions are based can be found in the description.

- 5 All information on value ranges in the present description are to be understood in such a way that they include any and all sub-ranges thereof, e.g. the information 1 to 10 is to be understood in such a way that all sub-ranges, starting from the lower limit 1 and the upper limit 10, are also included, i.e. all sub-ranges begin with a lower limit of 1 or greater and end at an upper limit of 10 or less, for example 1 to 1.7, or 3.2 to 8.1, or 5.5 to 10.

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C l a i m s

1. Computer implemented method (100) for identifying a foreign material in a production line from an existing set of material samples, wherein chemical analysis data is known for the material samples and stored in a memory, the method comprising:
 - retrieving (110) a chemical analysis data of the foreign material;
 - calculating (120) a first, a second, and a third value for each of the material samples in conjunction with the foreign material on the basis of the retrieved chemical analysis data of the foreign material and the stored chemical analysis data of the material samples;
 - calculating (130) a similarity score for each of the material samples based on the first, second and third value; whereby the foreign material is identified by the material sample with the highest similarity score.
2. Method (100) according to any one of the previous claims, further comprising comparing (140) the identified foreign material with information stored in a database, wherein the information indicates parts of a production line and materials the parts are composed of and/or that are used at the corresponding parts, thereby determining at which parts the foreign material was introduced.
3. Method (100) according to any one of the previous claims, wherein
 - the first value indicates a similarity of the material samples and the foreign material regarding their chemical composition;
 - the second value indicates a mass difference between in the material samples and the foreign material; and/or
 - the third value indicates a ratio of the carbon-oxygen-ratio of the material samples and the foreign material.
4. Method (100) according to claim 3, further comprising evaluating (150) the value indicating the ratio of the carbon-oxygen-ratio to determine whether the foreign material consists of a mixture of different materials.

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5. Method (100) according to any one of the previous claims, wherein the method further comprises:

comparing (160) the retrieved chemical analysis data to data from the memory to obtain a quantitative statement, indicating the elemental composition of the material in wt%,
5 mol% or vol%.

6. Method (100) according to any one of the previous claims, wherein the method further comprises pre-screening (170) the foreign material by taking pre-screening measurement indicating the organic and inorganic content of the foreign material and whether the for-
10 eign material is mixture of different materials.

7. Method (100) according to any one of the previous claims, wherein the chemical analysis data of the material samples and the foreign material represent data of one or more of the following and/or wherein pre-screening (170) is performed through one or more of the fol-
15 lowing:

an elemental analysis, preferably a spectroscopy, in particular preferably energy-disper-
sive X-ray spectroscopy,
infrared spectroscopy, and/or
magnetic resonance spectroscopy, preferably nuclear magnetic resonance spectroscopy.

8. Method (100) according to any one of the previous claims, wherein calculating (120) the first, second and third values is performed by functions from the following group: Jaccard coefficient, Manhattan distance, carbon-to-oxygen ratio, Pearson coefficient, Spearman's rank correlation coefficient, Kendall rank correlation coefficient, Dice's coefficient, Simp-
25 son coefficient. Euclidean distance, Chebyshev distance, Minkowski distance.

9. Method (100) according to any one of the previous claims, wherein calculating (120) the first value uses one of a Simpson, Jaccard, and Dice coefficient.

10. Method (100) according to any one of the previous claims, wherein calculating (120) the second value uses one of a Manhattan, Euclidean, Chebyshev, Pearson, Spearman, Ken-
30 dall, and Minkowski distance.

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11. Method (100) according to any one of the previous claims, wherein calculating (130) the similarity score for each of the material samples comprises weighting the first, second, and third values with a first, second, and third predetermined weight.
- 5 12. Method (100) according to any one of claims 1 to 10, wherein calculating (130) the similarity score for each of the material samples comprises determining (180) a first, second, and third weight, and weighting the first, second, and third values with the determined first, second, and third weights.
- 10 13. Method (100) according to claim 12, wherein determining (180) the first, second, and third weights is performed by machine-learning.
14. Method (100) according to any one of the previous claims,
wherein the first weight is determined or predetermined between of 0.15 to 0.45, preferably at 0.3;
15 wherein the second weight is determined or predetermined between 0.45 to 0.75, preferably at 0.6; and/or
wherein the third weight is determined or predetermined between 0 to 0.30, preferably 0.10;
20 and/or the sum of the first, second, and third weight is 1.
15. Method (100) according to any one of the claims 4 to 14, wherein
if it is determined that the foreign material consists of a mixture of different materials
the third weight is determined or predetermined between 0 to 0.1, preferably 0.05,
25 and
if it is determined that the foreign material does not consist of a mixture of different materials the third weight is determined or predetermined between 0.05 to 0.3, preferably 0.1.
- 30 16. Method (100) according to any one of the previous claims, further comprising determining (190) whether one or more predetermined conditions are met, and if yes, triggering (191) one or more actions,

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wherein the actions are one or more of notification by visual or audio signals, notifications on a screen, via an e-mail, push-notification to a mobile app, or text message to a mobile phone, signaling to a device or part of a production line to stop or shut-down, cleaning of chemical baths or conveyor belts, exchanging chemical baths, changing of filters, discarding of a production lot, observing a certain production lot, and/or starting a video recording device,

wherein such notifications can comprise information on the detection of foreign material, a type or composition of the foreign material, a most probable location that was determined to be the source and/or that a signaling for stop, shut-down, cleaning, exchanging, changing, discarding, observing, or recording signaling was triggered.

17. Method (100) according to claim 16, wherein the step of determining (190) whether one or more predetermined conditions are met is performed by machine-learning.

18. Device for identifying a foreign material in a production line from an existing set of material samples, preferably a computer, configured to carry out the method (100) of any of the previous claims, the device comprising:

a memory wherein chemical analysis data is stored for the material samples;

a transmitter for retrieving chemical analysis data of the foreign material;

a processing unit, configured to calculate:

a first, a second, and a third value for each of the material samples in conjunction with the foreign material on the basis of the retrieved chemical analysis data of the foreign material and the stored chemical analysis data of the material samples; and

a similarity score for each of the material samples based on the first, second and third value; whereby the foreign material is identified by the material sample with the highest similarity score.

19. A computer program product including a program for a processing device, comprising software code portions for performing the steps of any one of claims 1 to 17 when the program is run on the processing device.

20. A computer program product according to claim 19, wherein the computer program product comprises a computer-readable medium on which the software code portions are

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stored, wherein the program is directly loadable into an internal memory of the processing device.

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Fig.1

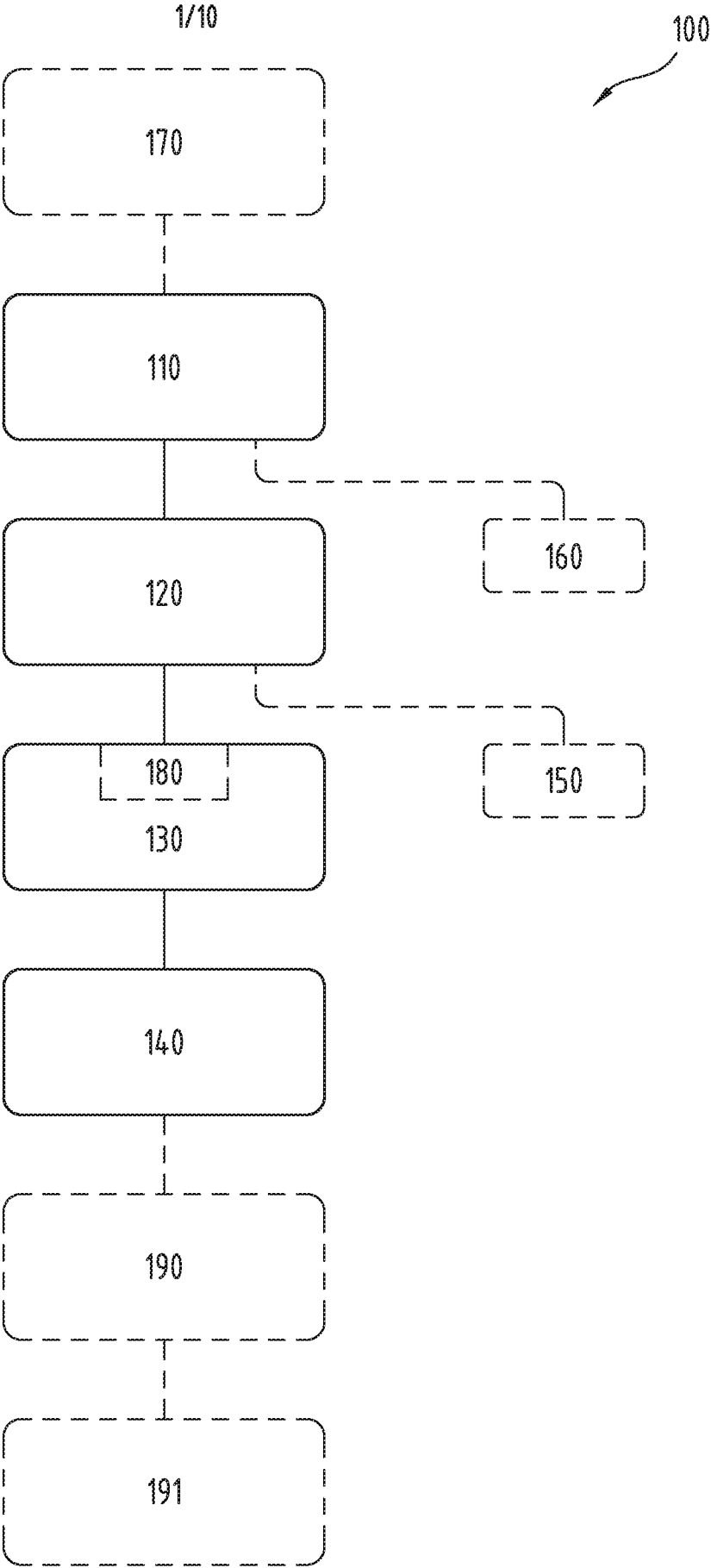


Fig.2

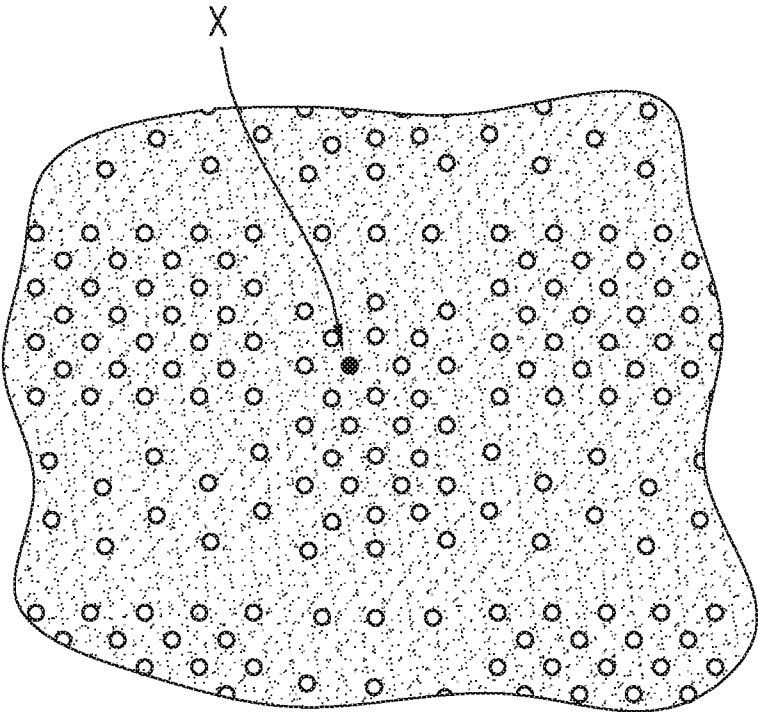


Fig.3

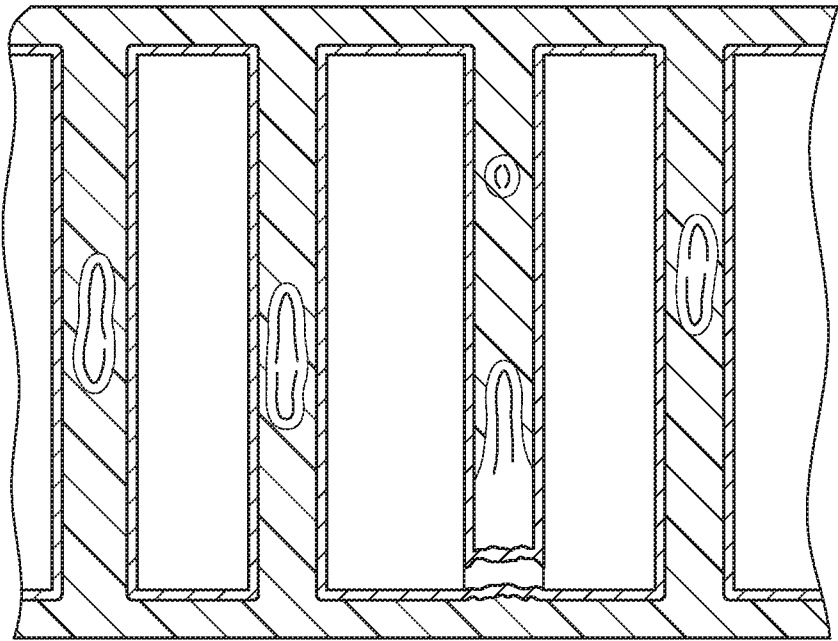
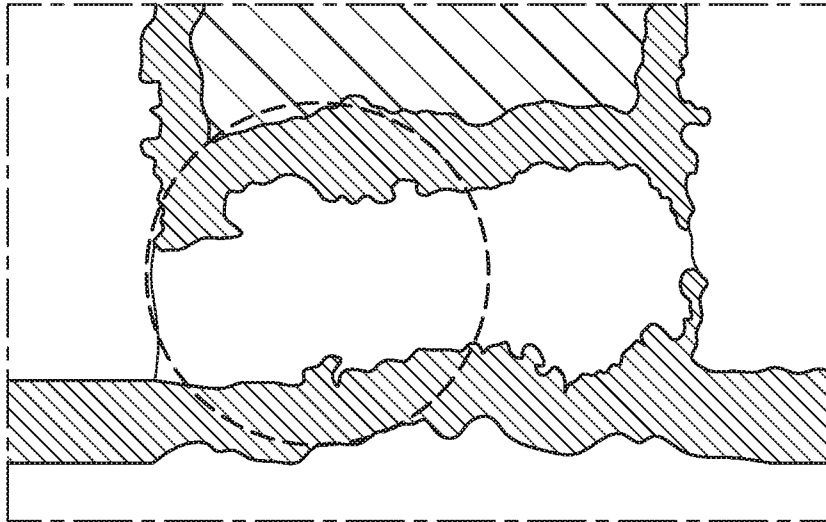
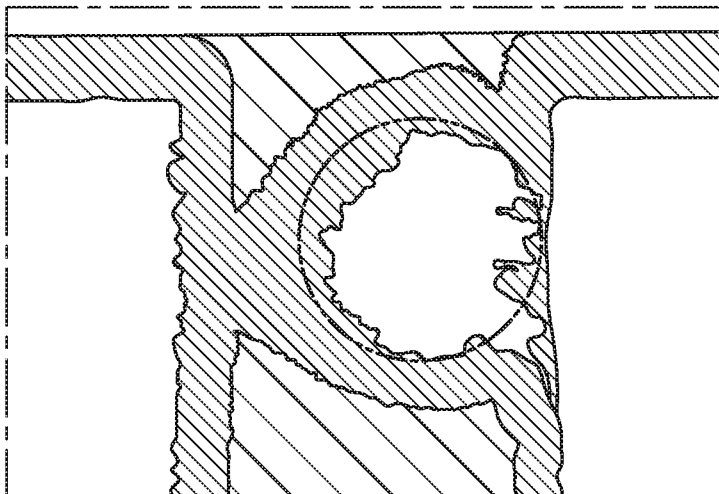


Fig.4

Sample 1

**Fig.5**

Sample 2

**Fig.6**

Sample 3

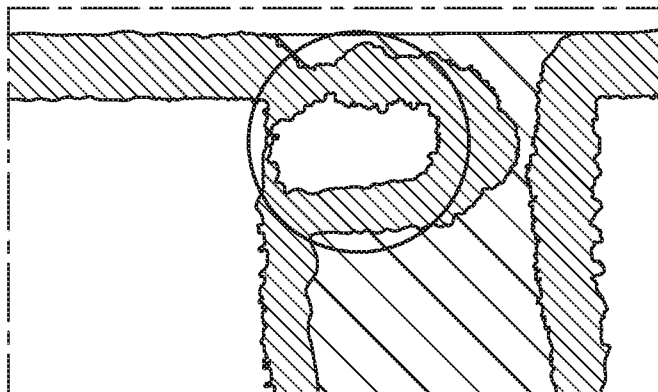


Fig.7

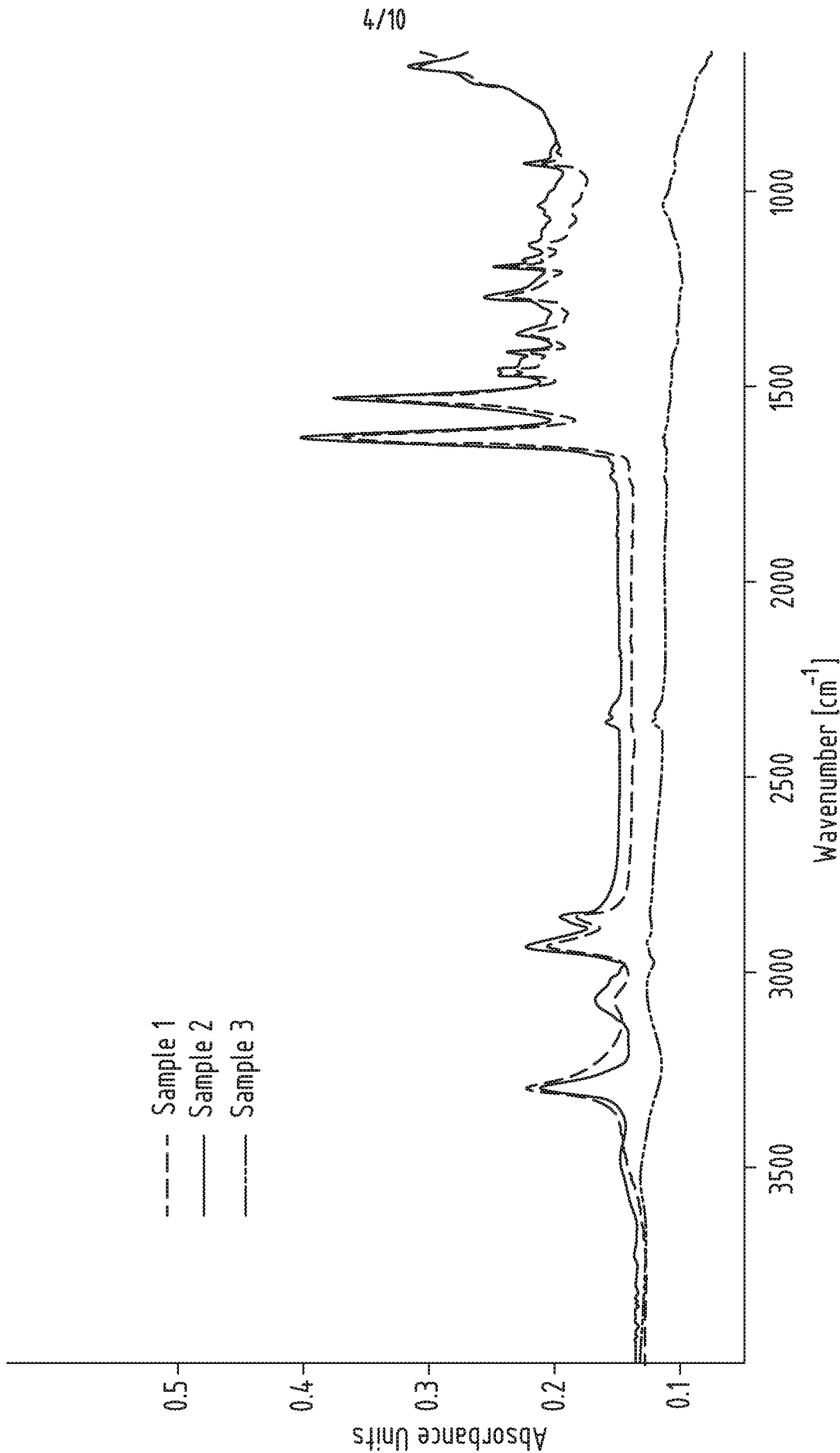


Fig. 8

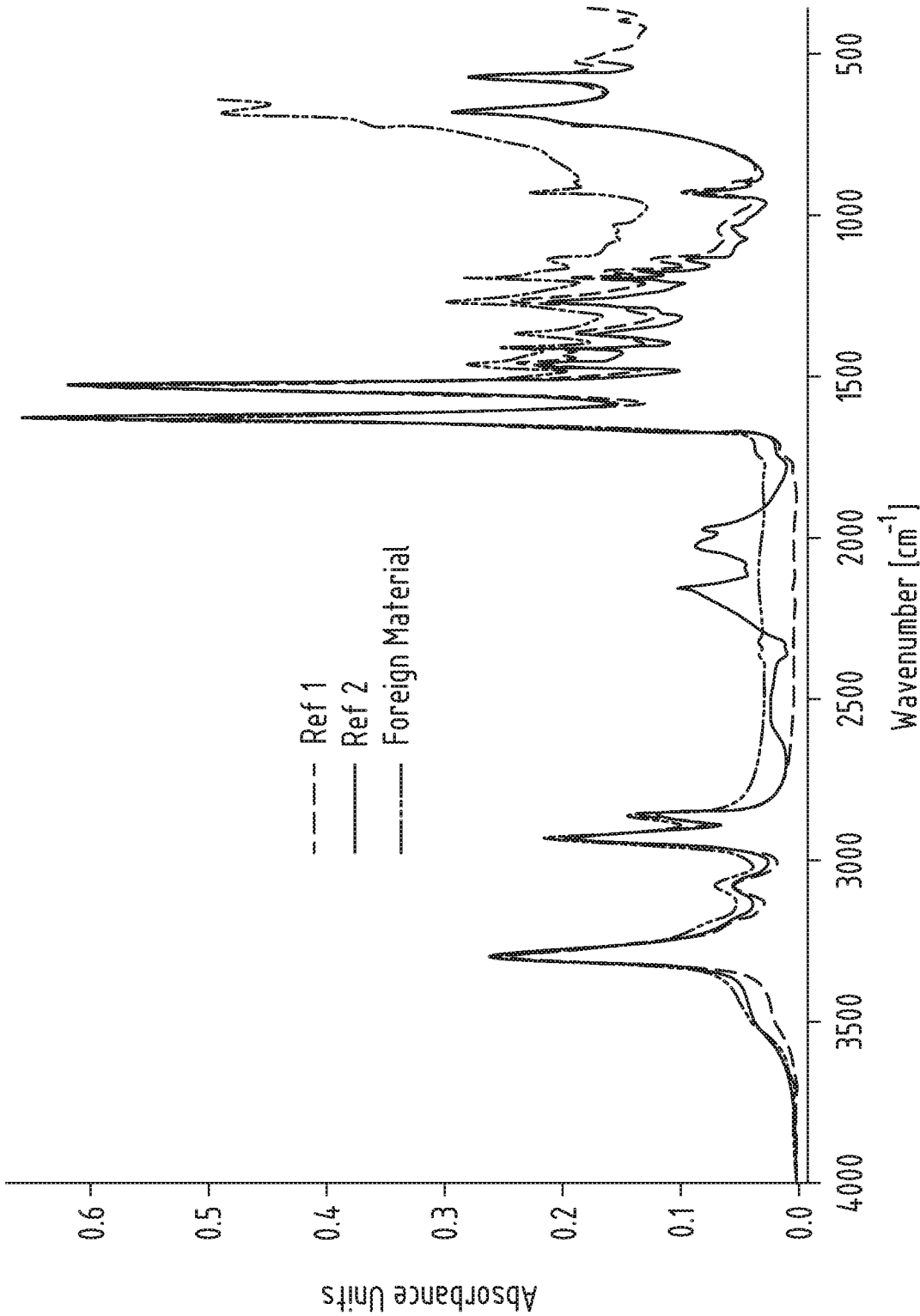
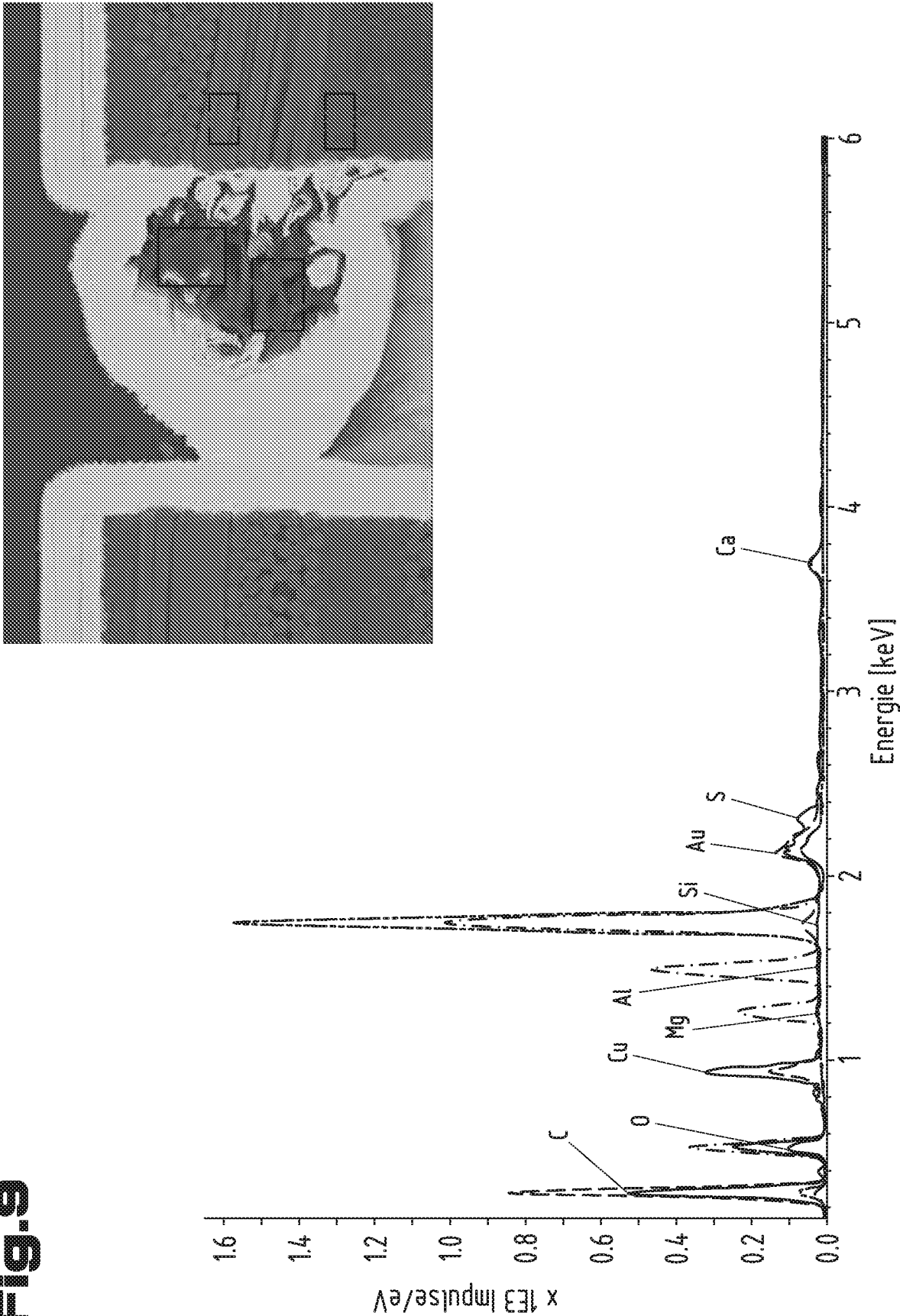


Fig. 9



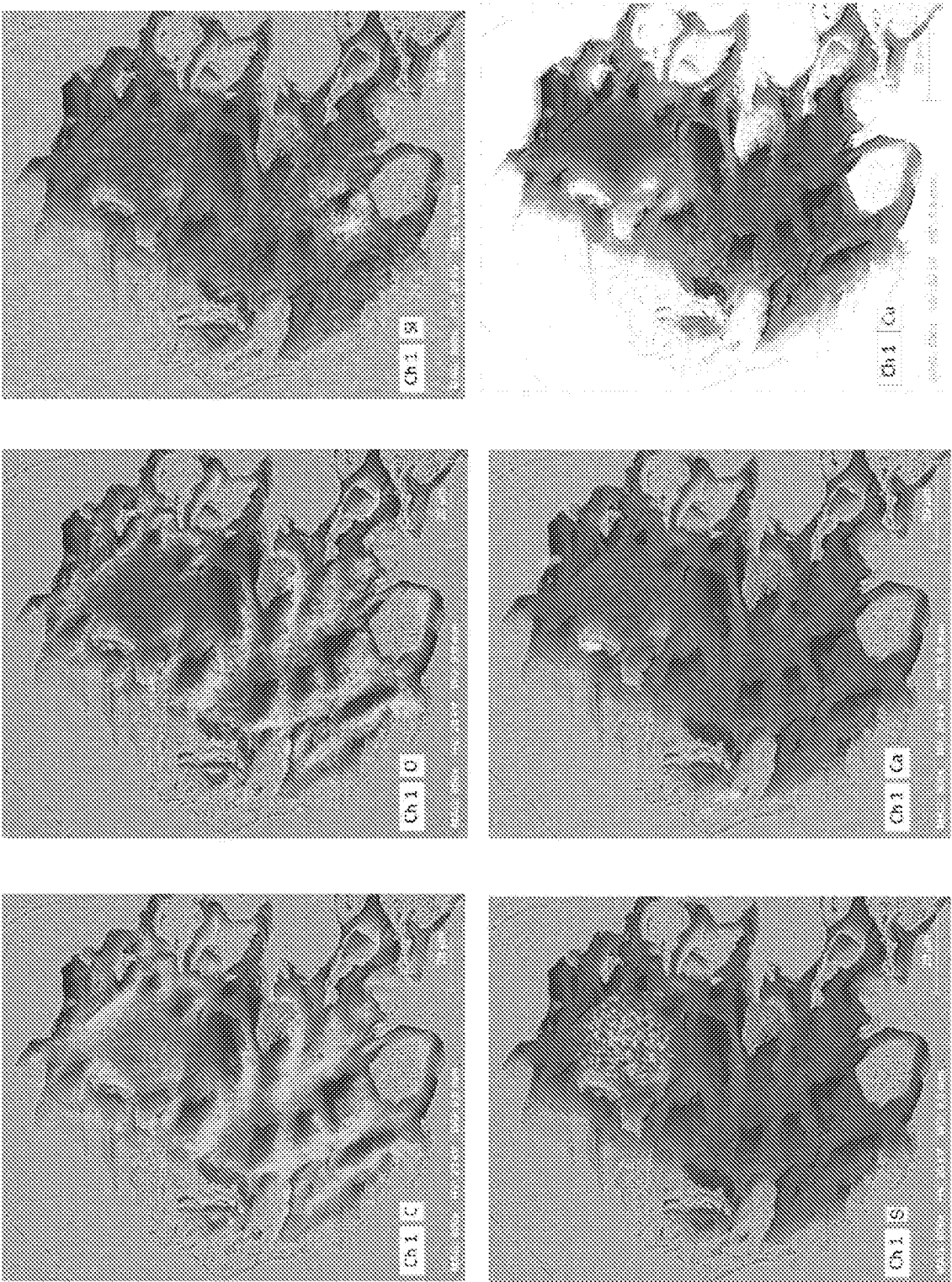


Fig.10

Fig.11

Sample	C	O	Si	Al	P	Cu	Ni	Total
Sample #1	58	24	13.1	3	1.4	0.5		100
Sample #2	64	26			10			100
Sample #3	41	13	41	5				100
Sample #4	35	14	14	0.5	0.4	31	5.1	100
Sample #5	28	41	14	0.5	0.4	11	5.1	100
Sample #6	1.9	4.3			8.8	5	80	100
Sample #7					5	85	10	100

Table 1

Fig.12

Sample	C	O	Si	Al	P	Cu	Ni	Total
Foreign Material	60	25	14.9	0.1				100

Table 2

Fig.13

Sample	Value #1	Value #2	Value #3
Foreign Material	1.00	0.00	2.40
Sample #1	0.67	9.60	2.42
Sample #2	0.40	30.00	2.46
Sample #3	1.00	62.00	3.15
Sample #4	0.57	73.80	2.50
Sample #5	0.57	65.80	0.68
Sample #6	0.29	187.60	0.44
Sample #7	0.00	200.00	0

Table 3

Fig.14

Sample	Value #1	Value #2	Value #3
Foreign Material	1.00	1.00	1.00
Sample #1	0.67	0.952	0.99
Sample #2	0.40	0.85	0.98
Sample #3	1.00	0.69	0.76
Sample #4	0.57	0.631	0.96
Sample #5	0.57	0.671	0.28
Sample #6	0.29	0.062	0.18
Sample #7	0.00	0.00	0

Table 4

Fig.15

Sample	Intersection count	Union count	Jaccard
Foreign Material	/	/	/
Sample #1	4	6	0.67
Sample #2	2	5	0.40
Sample #3	4	4	1.00
Sample #4	4	7	0.57
Sample #5	4	7	0.57
Sample #6	2	7	0.29
Sample #7	0	7	0.00

Table 5

Fig.16

Sample	Score A	Score B	Score C
Foreign Material	/	/	/
Sample #1	87	83	79
Sample #2	73	66	59
Sample #3	79	84	88
Sample #4	65	64	63
Sample #5	60	59	57
Sample #6	14	18	21
Sample #7	0	0	0

Table 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/AT2023/060196

A. CLASSIFICATION OF SUBJECT MATTER INV. G16C20/20 ADD.		
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) G16C		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 10 539 520 B2 (SHIMADZU CORP [JP])	1-20
	21 January 2020 (2020-01-21)	
	cited in the application	
Y	column 1, line 1 - column 2, line 62	2
	column 6, line 52 - column 9, line 48;	
	figures 3-7	

	-/--	
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document 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
27 September 2023		10/10/2023
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Nurmi, Jussi

INTERNATIONAL SEARCH REPORT

International application No

PCT/AT2023/060196

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	HINDELANG FLORINE ET AL: "Forensic investigation in the pharmaceutical industry: Identification procedure of visible particles in (drug) solutions and different containers by combining vibrational and X-ray spectroscopic techniques", JOURNAL OF PHARMACEUTICAL AND BIOMEDICAL ANALYSIS, vol. 148, 20 October 2017 (2017-10-20), pages 334-349, XP085252177, ISSN: 0731-7085, DOI: 10.1016/J.JPBA.2017.10.015 pages 342-348 -----	2
A	Anonymous: "EDX of Contamination on PCB", , 1 January 2019 (2019-01-01), XP093086468, Retrieved from the Internet: URL:https://www.eag.com/wp-content/uploads/2019/07/M-038019-EDX-of-contamination-on-PCB_w.pdf [retrieved on 2023-09-27] the whole document -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/AT2023/060196

Patent document cited in search report	Publication date	Patent family member(s)	Publication date	
US 10539520	B2	21-01-2020	CN 107367621 A	21-11-2017
			CN 110244069 A	17-09-2019
			EP 3236245 A1	25-10-2017
			JP 6638537 B2	29-01-2020
			JP 2017194360 A	26-10-2017
			US 2017307551 A1	26-10-2017
