

## [54] ELECTRON BEAM SPECIMEN ANALYSIS

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### Related U.S. Application Data

[63] Continuation of Ser. No. 246,075, April 20, 1972, abandoned.

## [30] Foreign Application Priority Data

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[51] Int. Cl. .... G01n 23/04

[58] **Field of Search** ..... 250/306, 307, 309, 310,  
250/311, 397

[56] **References Cited**

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McClelland & Majer

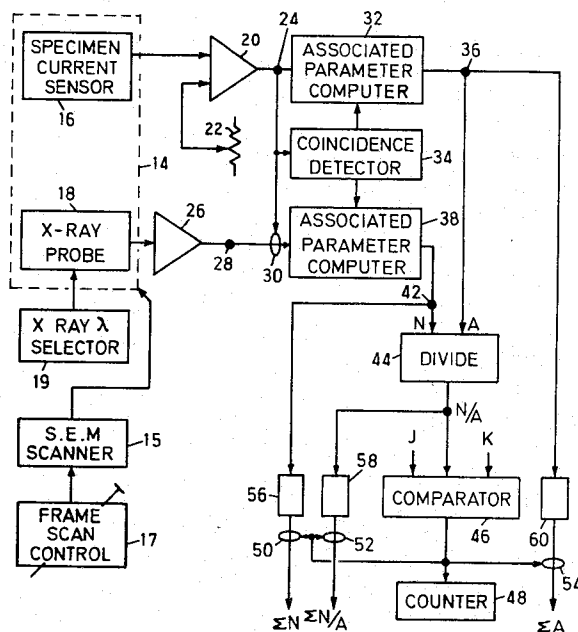
[57] **ABSTRACT**

Methods and apparatus are described for improving certain signals obtained by electron beam scanning of a specimen surface.

In the preferred embodiment pulses from an X-ray probe (responsive to X-rays emitted due to electron bombardment of the specimen surface) are gated by a signal derived from the specimen current of the electron beam scanning apparatus. The specimen current is converted to a voltage signal so that variations in current produce proportionate variations in amplitude of the voltage signal. The latter is compared with a reference voltage and amplitude excursions of the voltage signal which exceed the reference voltage are detected and for each such excursion a gating pulse is generated.

The X-ray pulses are inhibited by a gate which is opened only by a gating pulse. In this way X-ray pulses originating from only selected regions of the scanned surface are passed for analysis, selection being controlled by adjustment of the value of the reference voltage. Further discrimination is possible by tuning the X-ray probe.

## 2 Claims, 8 Drawing Figures



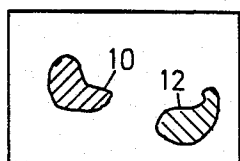


Fig.1

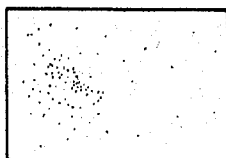


Fig. 2

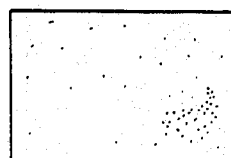


Fig. 3

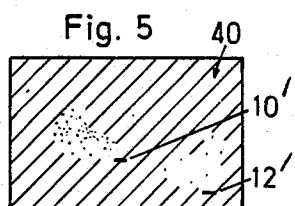
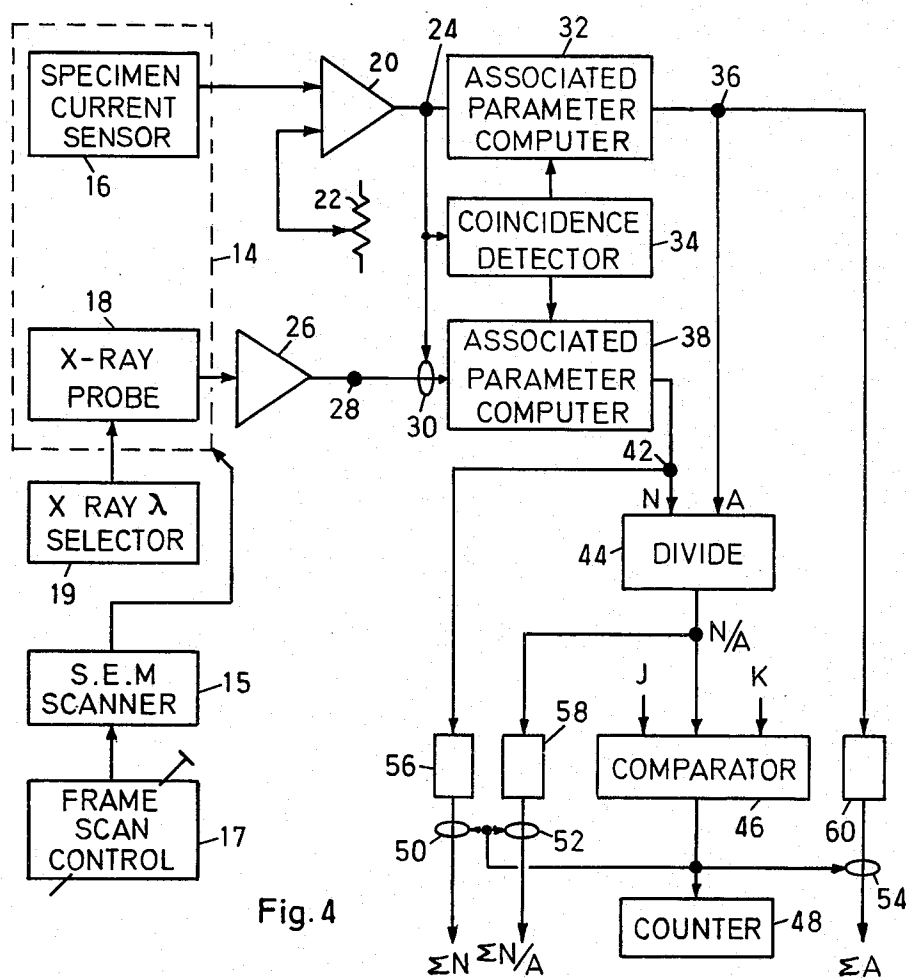


**Fig. 5**

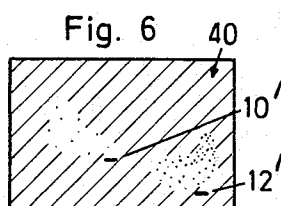


Fig. 6

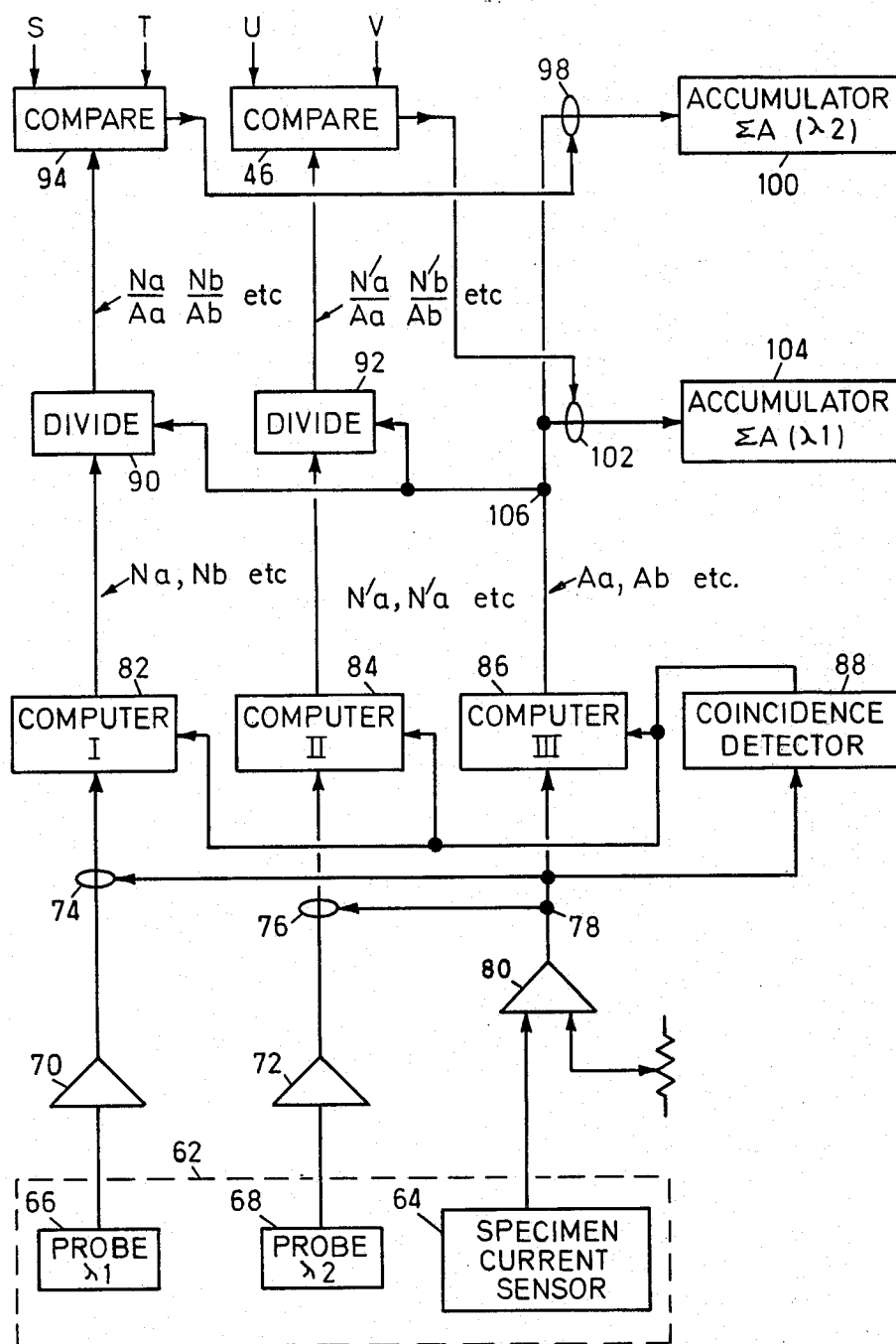


Fig. 7

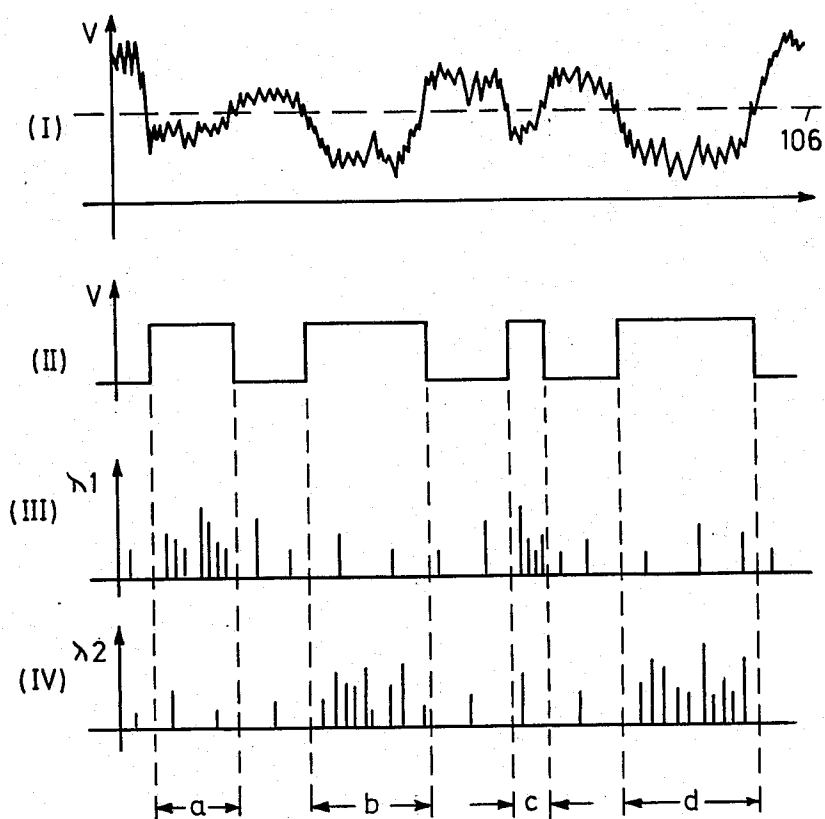


Fig.8

**ELECTRON BEAM SPECIMEN ANALYSIS**

This is a continuation of application Ser. No. 246,075, filed Apr. 20, 1972, now abandoned.

This invention concerns the analysis of specimens by electron beam scanning, in particular to analysis by a scanning electron microscope (SEM).

Various electrical signals can be derived during scanning of a specimen. Specimen current variations will provide a signal suitable for analysis but it is usually electrically noisy. Also, X-rays are emitted by many materials when bombarded by electrons, and the X-rays can be detected by an X-ray detector such as a spectrometer probe. Since different materials emit different wavelength X-rays a composition analysis is possible if the probe is tuned to different wavelengths and a graph of emission/wavelength plotted. Other signals are obtainable due to back scatter, cathode luminescence, secondary electron emission, specimen EMF and by direct transmission.

Most of these signals (hereinafter referred to as slow scan signals) require a very slow scan and/or integration over many fields before a usable signal level is obtained and those signals from which much useful information may be obtained seem to require the slowest scan rates and/or greatest number of fields. Such a slow scan signal is that obtained by determining the X-ray emission of selected  $\lambda$  due to electron bombardment of a specimen.

It is an object of the present invention to provide a method and apparatus whereby the advantages of specimen analysis using a slow scan signal can be performed at a much higher scan rate than has hitherto been possible.

Although the invention will be described specifically as applied to analysis of an X-ray emission signal from an SEM, it is to be understood that it may be applied to any of the slow scan signals obtained from scanning a specimen by an electron beam, whether an SEM is used or not and in most cases it is envisaged that a significant increase in the speed of analysis will be obtained.

According to the present invention a method of analysing a specimen comprises the steps of scanning the specimen by an electron beam to produce a first electrical signal of the slow-scan type for analysis, circuit means for detecting a current or voltage variation produced as the electron beam scans across regions in the specimen which have differing electrical properties to produce a second electrical signal the amplitude of which varies as different regions of the specimen are scanned, comparing the amplitude excursions of the second signal with a reference signal and detecting any which exceed the reference signal, generating from the detected excursions detected signal pulses and gating the first signal by the detected signal pulses or pulses derived therefrom thereby to inhibit the passing of the first signal for analysis except when the amplitude of the second signal is sufficient to exceed the reference signal.

Typically the first signal comprises that due to X-ray emission due to electron bombardment of the specimen and will comprise a series of electrical pulses, while the second signal is derived from the variation of specimen current during scanning.

Conveniently the specimen current variations are converted into a varying amplitude video-type signal voltage and the detection is achieved by comparing the

instantaneous signal amplitude with a reference voltage and generating an electrical pulse each time the amplitude exceeds the reference voltage, the duration of each pulse being equal to the duration of the amplitude excess over the reference voltage. A more complicated detection criterion may be employed when it is necessary to obtain a greater degree of discrimination between video signal amplitudes. Thus for example a second reference voltage may be employed and a detected signal pulse generated only for amplitude excursions of the second signal which exceed the first reference voltage and are less than the second reference voltage. In any event the detected pulses are usually of constant height and the signal can be thought of as a binary type of signal.

If the first signal is also in the form of or converted to a binary type signal (e.g. comprises voltage pulses corresponding to discrete bursts of X-radiation) it may be gated by the detected signal pulses in a simple logic AND - function circuit.

Alternatively any convenient form of gating circuit may be employed by which the first signal is inhibited between the detected signal pulses.

Where the first signal is that due to X-ray emission, the X-ray probe is preferably tunable thereby to select X-radiation of a given wavelength.

Alternatively, two or more X-ray probes may be employed each tuned to a different wavelength, the outputs from the probes forming two separate "first signals" which may be gated by the one gating signal to produce simultaneously X-ray emission signals relating to different wavelengths.

If the analysis circuit is a pulse counter, the total count at the end of a field scan will indicate the total X-ray emission of that wavelength from those regions of the specimen which produce a sufficient change in the specimen current and the resulting video signal amplitude as to satisfy the detection criterion applied to the second signal. Where for example the specimen contains metallic regions separated by non-metallic regions, the specimen current variations as between metallic and non-metallic regions can readily be detected by appropriate selection of the reference voltage value and the total X-ray count will therefore apply to the selected regions (i.e., metallic or non-metallic) only.

The detected signal pulses may be summed in known manner to produce a total signal at the end of a field scan equivalent to the total area of the "selected" region(s) in the specimen. An average X-ray emission factor for the selected region(s) may thus be obtained by dividing the total X-ray emission signal for the field by the area signal.

Where there is only one region to be "selected" in a specimen, the results obtained during a complete field scan will only relate to that one region. Where however there are two or more regions which will be selected by the one value of the reference voltage, a so-called coincidence detector and associated parameter computer may be employed, of the type described in British Patent Specification Nos. 1,264,804 and 1,264,805. This apparatus generates a unique signal (referred to as an anti-coincidence signal) at the completion, in the field scan, of scanning each of the separate selected regions (often referred to as "features" since they can be distinguished in some way from their surroundings or background), which can be used to control a gate and release one or more signals computed from the electri-

cal signals derived during the scanning of the particular region. In this application the computer is adapted to accumulate all the "first" signal which originates during the scanning of a "selected" region in a memory in a manner which causes the first signal pulses from each separate selected region to be associated separately (as described in the aforementioned British Patent Specification No. 1,264,805) and the accumulated "first" signal for each region is released by (or by a signal derived from) the anti-coincidence signal for that region. Thus the total X-ray count for each selected region may be obtained separately.

As described in our co-pending British Patent Application No. 53403/69, two or more associated parameter computers may be operated simultaneously to derive two or more different parameters from the field and in this manner a signal relating to some parameter such as area, size, shape etc. of the region(s) may simultaneously be obtained.

Secondary associated parameters may also be derived from two or more of the parameter signals previously described. Thus for example an X-ray emission factor may be obtained for each detected region by dividing the total X-ray count  $N$  from each region by its area signal  $A$ . Also the value of the emission factor for any region may be employed to determine whether a count pulse shall be released for the region (i.e., to indicate a region predominately radiating X-rays of a given  $\lambda$ ) or whether area or X-ray count information from the region shall be passed to an accumulator.

The invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 illustrates a monitor display of the specimen current signal after detection from an SEM scanning a non-metallic specimen having two differing metallic regions,

FIG. 2 illustrates a monitor display of the X-ray emission signal pulses from an X-ray probe tuned to the  $\lambda$  of the X-rays emitted from one of the metals,

FIG. 3 illustrates a monitor display of the X-ray emission signal pulses with the probe tuned to the  $\lambda$  of the X-rays from the other metal,

FIG. 4 is a block circuit diagram of a specimen analysis system employing an SEM and embodying the present invention,

FIGS. 5 and 6 are similar to FIGS. 2 and 3 respectively, and illustrate the monitor display of the X-ray signal after gating by the detected specimen current signal as provided by the present invention,

FIG. 7 is a block circuit diagram of a specimen analysis system employing an SEM with two differently tuned X-ray probes,

FIG. 8(i) is a graph of a voltage derived from the specimen current during a line scan intersecting four metallic regions  $a$ ,  $b$ ,  $c$  and  $d$ ,

FIG. 8(ii) is a graph of the binary type signal obtained by threshold detection of the voltage signal of FIG. 8(i),

FIG. 8(iii) illustrates the electrical signal output from the probe tuned to the  $\lambda$  of the X-radiation emitted by regions  $a$  and  $c$ , and

FIG. 8(iv) that of the probe tuned to the  $\lambda$  of the X-radiation emitted by regions  $b$  and  $d$ .

In FIG. 1 the two shaded areas 10, 12 represent two differing metallic regions in a non-metallic specimen (not shown). The display is obtained by detecting the

amplitude excursions of a video signal obtained from the specimen current variations of an SEM set to scan the specimen and applying the binary type detected signal pulses to control the display on a television type monitor which is scanned in synchronism with the SEM scan.

The SEM is shown diagrammatically at 14 in FIG. 4. Only the two relevant sections thereof, namely the specimen current sensor 16 and X-ray probe 18, are itemised. The specimen current signal is applied to a comparator 20 for comparison with a reference voltage from e.g. a potentiometer 22. The binary-type detected signal pulses at junction 24 serve as the display control voltage referred to above.

The output from the X-ray probe will comprise electrical pulses corresponding to the quanta of X-radiation emitted during scanning of the specimen. These pulses are amplified by amplifier 26 and the output at junction 28 constitutes a so-called slow-scan-signal, (see earlier definition) which may be employed for analysis. If used to control the brightness of the television type monitor described above, the display will appear as shown in FIG. 2 or FIG. 3 depending on whether the probe is tuned to the  $\lambda$  of the radiation from metal 10 or 12.

The  $\lambda$  of the radiation emitted by any material is characteristic of the material. However, due to random scatter, etc., the particular  $\lambda$  radiation may appear at other points in the field. In the known methods of analysis the whole field must therefore be scanned very slowly to increase the information content relating to the regions of selected material.

In accordance with the invention, the system of FIG. 4 includes a gate 30 for inhibiting the X-ray signal from 28 except when coincident with a detected signal pulse from the comparator 20 or a pulse derived from one of the detected signal pulses such as by shrinking or stretching or combining the individual signal pulses from the comparator 20.

It is possible in theory to discriminate between specimen current-video signal amplitude variations due to metal 10 and metal 12, thereby producing detected signal pulses at junction 24 corresponding to one or the other metal. Gating the X-ray signal with the probe tuned to the  $\lambda$  of metal 10 will then ensure that only the X-ray signal pulses due to metal 10 are passed during each frame scan. Likewise for metal 12. To this end, a wavelength selector 19 is shown.

However, in practice it is difficult and time consuming to effect the accurate setting of the reference voltage required to discriminate between two metals. Furthermore, differing metal phases will often produce similar amplitude changes in the specimen current video signal, and in these circumstances this method is not even possible.

Since the voltage derived from the specimen current is a video signal it may be employed to control the beam current in the cathode ray tube of a television monitor (not shown) whose scanning is controlled in synchronism with that of the SEM, and the detected signal pulses may be displayed simultaneously, superimposed, to facilitate the correct setting of the reference voltage as described in British Patent Specification No. 1,127,742. However it is found that due to slow scanning speeds of an SEM, a long time will elapse between an adjustment of the reference voltage and the appearance on the monitor screen of the corresponding change in the display of the detected signal pulses.

To help overcome this deficiency the number of scan lines employed in the SEM raster may be reduced when any adjustment is to be made to the reference voltage setting of the comparator 20. Typically the number of lines is reduced to 5-10% of the usual number making up the raster. The frame scan period is likewise reduced so that the effect of a threshold adjustment will be seen after a lapse of 5-10% of the time previously required. To this end the SEM scanner 15 may be controlled from a control unit 17, by which the frame scan rate may be adjusted.

In fact the analysis circuits to be described do not require an accurate setting of the reference voltage, and it is simply necessary to set the reference voltage just above the limit set by noise, so that both amplitude excursions from both metallic regions 10 and 12 are "detected."

The detected signal at 24 is supplied to an associated parameter computer 32 adapted to operate so as to generate a signal for each detected region whose magnitude is equivalent to its area. It is controlled by a coincidence detector 34 and the two units 32, 34 operate in the manner described in British Patent Specifications Nos. 1,264,804 and 1,264,805. At the anti-coincidence point for each detected region the area signal for the region is made available at junction 36 and this signal is denoted by A.

A second associated parameter computer 38, also controlled by coincidence detector 34, is supplied with the X-ray signal pulses via the gate 30 which is opened while each of the metal regions is scanned. The resulting X-ray signal pulses, if displayed on a monitor screen, would appear as shown in FIG. 5 when the probe is tuned to  $\lambda_1$  (metal 10) and in FIG. 6 when tuned to  $\lambda_2$  (metal 12). The shaded area 40 in FIGS. 5 and 6 indicates the time gate 30 is closed. The anti-coincidence point for each of the regions is also shown identified by 10' and 12' respectively.

The computer 38 is set to count the X-ray pulses applied to it and by the control of the coincidence detector 34, the pulses arising from the two detected regions 10, 12 are counted separately. A total count for each region is available at the anti-coincidence point for the region and this total is made available at junction 42 as an output N, simultaneously as the area output A is made available from computer 32.

Since the X-radiation of  $\lambda_1$  will predominantly come from metal region 10, the value of N for region 10 (whose area is say A1) will be high (say N1) while that for region 12 (whose area is say A2) will be very low (say N2). Conversely  $N1 \ll N2$  when the probe is tuned to  $\lambda_2$ . The two regions can thus be distinguished by dividing the value of N for the region by its area. For  $\lambda_1$ , this quotient will be high for region 10 and low for region 12 and vice versa for  $\lambda_2$ .

To this end a divide circuit 44 is provided and the output of (N/A) is compared in a comparator 46 with upper and lower limits J and K respectively. J and K may be pre-set. If the quotient lies within the range of J K, the comparator produces an output signal. This can be counted in a counter 48 and the total at the end of a field scan will correspond to the number of regions in the field whose (N/A) at that  $\lambda$ , satisfied the condition  $J < (N/A) < K$ .

The output from comparator 46 is also employed to open a gate 50 which will release the total X-ray pulse count for the region if the latter has an appropriate

(N/A). The total for all such regions in a field (i.e., for any  $\lambda$ ) may be obtained by accumulating the individual totals released by gate 50 during a field scan.

Likewise the (N/A) value for each region which satisfies the J - K limits may be released by a second gate 52 and the total (N/A) for the field (for the given  $\lambda$ ) accumulated.

Likewise the total area of all regions having appropriate (N/A) values may be computed from the area information released by a further gate 54.

Delays 56, 58, 60 are provided in the signal paths to gates 50, 52, 54 respectively to compensate for any delay in the comparator stage 46.

Whilst the arrangement of FIG. 4 will provide all the information necessary to plot a distribution of e.g.  $\lambda$  against area, which by correlation using a look-up table of  $\lambda$  against material, will enable a composition analysis to be made, the results obtainable during any one field relate only to X-rays of one wavelength. When a larger number of fields must be scanned per specimen in order to provide a given degree of accuracy, and when it is only necessary to know the areas of inclusions of two different materials for each specimen, the arrangement of FIG. 7 may be adopted.

In FIG. 7 an SEM 62 includes a specimen current sensor 64 and two X-ray probes, one 66 tuned to  $\lambda_1$  and the other 68 tuned to  $\lambda_2$ . The X-ray signal outputs from the probes 66, 68 are amplified by amplifiers 70, 72 respectively and the outputs thereof are gated by gates 74, 76 respectively.

These gates are controlled by the detected signal pulses at junction 78 obtained by comparing the voltage signal derived from the specimen current signal with a reference voltage in a comparator 80. The reference voltage is adjustable and although not shown, provision may be made to reduce the number of lines per frame scan of SEM 64 to facilitate adjustment, as before described.

The gated X-ray signals and the comparator output are applied to three separate associated parameter computers 82, 84, 86 respectively which are controlled by a single coincidence detector 88. The computers 82-86 and detector 88 are of the type described in British Patent Specification Nos. 1,264,804 and 1,264,805.

The action of computers 82 and 84 is to add the X-ray pulses from 66 and 68 and store the values so obtained in a memory in positions related to the positions in the scan at which the pulses originate. Each pulse therefore updates the value for its associated region in the field. If there are four separate detected regions in the field, there will be four separate values computed during each field scan. The total value for each region is delivered as an output signal at the anti-coincidence point for the region determined by detector 88. At these four separate points in each field scan, the value of X-ray count for the region will be released. These are denoted as Na, Nb etc. for computer 82 (and correspond to the X-ray count for X-rays of  $\lambda_1$  from the four regions) and Na', Nb', etc. for computer 84 (corresponding to the  $\lambda_2$  counts).

In a similar manner the associated parameter computer 86 generates an area signal for each region from the detector output and this signal is also released at the anti-coincidence point for each region. This will be independent of wavelength etc. and a single value As, Ab etc. will be available for each region.

The (N/A) value for each detected region is obtained as previously described in relation to FIG. 4 and to this end divider networks 90, 92 are provided to provide the (N/A) value for the two wavelengths  $\lambda_1$  and  $\lambda_2$  for each region.

The (N/A) value is compared in a comparator 94 or 96, depending on the wavelength, and different limits S, T and U, V may be applied to the two comparators.

If the output from divide network 90 is between limits S and T, a signal is generated to open a gate 98 and allow the area signal for that region into an accumulator 100. Likewise, a satisfactory output from 92 will cause gate 102 to be opened to allow the area signal for the corresponding region into a second accumulator 104.

A delay (not shown) may be incorporated between junction 106 and the gates 98, 102 to compensate for any delay in the divide and comparison stages.

At the end of a field the signal stored in accumulator 100 will be the total area of all detected regions emitting  $\lambda_1$  X-rays and that in accumulator 104, the total area of all detected regions emitting  $\lambda_2$  X-rays.

It will be appreciated that more than two X-ray probes may be employed each tuned to a different wavelength. The only requirement is a separate amplifier, associated parameter computer, divided network and comparator for each additional probe.

FIGS. 8(i) to 8(iv) illustrate the typical signal/waveform obtainable during a single line scan intersecting four metal regions *a*, *b*, *c* and *d* (not shown) of which *a* and *c*, and *b* and *d* respectively are of similar material, thereby producing similar amplitude excursions of the specimen current signal 8(i). Due to the typical noise component on the latter, it is difficult to set the comparator reference voltage 106 with sufficient accuracy to distinguish between the regions of differing material. However when the detected signal 8(ii) is combined with the outputs from the two probes 8(iii) and 8(iv) it will be seen that the different regions can be readily classified according to their X-ray count for each wavelength.

It will be appreciated that if regions *a*, *b*, *c* and *d* all produced the same size amplitude excursions in the specimen current signal — the invention would represent the only method of identifying the separate areas.

The important advantage which arises from employing the present invention can be seen from a consideration of the known method of analysis with that proposed by the invention when the field includes a lead region and a solder region (solder being e.g. 50% lead and 50% tin). With the probe tuned to the  $\lambda$  of the X-rays emitted by lead, the X-ray emission density of the lead area will be approximately twice that for the solder area.

Where the areas are to be determined from the X-ray signals and for example each area can be considered to be made up of a large number of incremental areas (picture points) which are scanned in turn and only one photon is emitted every 10th picture point at a particular scanned rate N, then the scanning rate will have to be reduced to one-tenth N in order to ensure that at least one photon is received for each picture point. The lead area can then be distinguished from the solder area by appropriate adjustment of a reference voltage with which signals derived from the total photon emission are compared.

By employing the invention it is only necessary to obtain a total of 10 photons from the entire area of lead to enable the correct analysis to be performed since if 10 are received from the lead area approximately five will be received from a similar area of solder. Where the areas differ the emission densities may be compared. If in the examples given above the lead area is equivalent to 1,000 picture points and a scanning rate (previously mentioned) of N picture points per unit time gives on average one photon per 10 picture points then a scanning rate of one-tenth N (as described above) is required in the known methods but a scanning rate of  $(10 \times N)$  may be employed if the present invention is utilised.

The present invention will thus allow analysis to be carried out in one one-hundredth of the time previously required. For a bigger feature an even greater saving in time will be obtained.

I claim:

1. A method of analysing a specimen comprising the steps of:

scanning the specimen by an electron beam to produce a first electrical signal of the type normally requiring integration over many fields before reliable information is obtained for analysis,

detecting specimen current or voltage variations produced as the electron beam scans across regions in the specimen which have differing electrical properties,

converting detected specimen current or voltage variations into a second electrical signal the amplitude of which varies as different regions of said specimen are scanned, and which represents regions of said specimen having differing electrical properties;

comparing the amplitude excursions of the second signal with a reference signal and detecting any amplitude excursions which exceed the reference signal,

generating signal pulses from the detected excursions, said signal pulses representing borders of said regions of said specimen having differing electrical properties;

gating said first signal by said signal pulses or pulses derived therefrom inhibit the passing of said first signal for analysis except when the amplitude of said second signal is sufficient to exceed said reference signal, so that said first signal is gated for analysis only in regions of said specimen having said differing electrical properties, whereby the need for integrating said first signal over many fields is eliminated;

wherein the first signal is obtained from an X-ray detector probe set to detect any X-ray emission from the specimen due to electron bombardment thereof and said second signal is derived from the variation of the specimen current during scanning, comparing the instantaneous amplitude of the second signal with a reference voltage,

generating a signal pulse each time the amplitude exceeds the reference voltage,

comparing the instantaneous amplitude of the second signal with a second reference voltage,

inhibiting the generation of a signal pulse if the amplitude exceeds said second reference voltage, tuning the X-ray probe to preferentially select X-ray radiation of a given wavelength,

counting the pulses from the X-ray probe,  
producing an electrical signal equivalent to the total  
number of pulses,  
accumulating the signal pulses,

deriving from the total accumulated signal a measure 5  
of the total area of the region or regions of the  
specimen which produce amplitude excursions of  
the specimen current signal which exceed the ref-  
erence voltage; and  
dividing the X-ray pulse count signal by the area sig- 10  
nal.

2. A method of analysing a specimen comprising the  
steps of:

scanning the specimen by an electron beam to pro-  
duce a first electrical signal of the type normally 15  
requiring integration over many fields before reli-  
able information is obtained for analysis,  
detecting specimen current or voltage variations pro-  
duced as the electron beam scans across regions in  
the specimen which have differing electrical prop- 20  
erties,

converting detected specimen current or voltage var-  
iations into a second electrical signal the amplitude  
of which varies as different regions of said speci- 25  
men are scanned, and which represents regions of  
said specimen having differing electrical prop-  
erties;

comparing the amplitude excursions of the second  
signal with a reference signal and detecting any am- 30  
plitude excursions which exceed the reference sig-  
nal,

generating signal pulses from the detected excur-  
sions, said signal pulses representing borders of  
said regions of said specimen having differing elec- 35  
trical properties;

gating said first signal by said signal pulses or pulses  
derived therefrom to thereby inhibit the passing of  
said first signal for analysis except when the ampli-  
tude of said second signal is sufficient to exceed  
said reference signal, so that said first signal is 40

gated for analysis only in regions of said specimen  
having said differing electrical properties, whereby  
the need for integrating said first signal over many  
fields is eliminated;

wherein the first signal is obtained from an X-ray de-  
tector probe set to detect any X-ray emission from  
the specimen due to electron bombardment  
thereof and said second signal is derived from the  
variation of the specimen current during scanning,  
comparing the instantaneous amplitude of the second  
signal with a reference voltage,  
generating a signal pulse each time the amplitude ex-  
ceeds the reference voltage,

comparing the instantaneous amplitude of the second  
signal with a second reference voltage,  
inhibiting the generation of a signal pulse if the am-  
plitude exceeds said second reference voltage,  
tuning the X-ray probe to preferentially select X-ray  
radiation of a given wavelength,

counting the pulses from the X-ray probe,  
producing an electrical signal equivalent to the total  
number of pulses,

accumulating the signal pulses,  
deriving from the total accumulated signal a measure  
of the total area of the region or regions of the  
specimen which produce amplitude excursions of  
the specimen current signal which exceed the ref-  
erence voltage,

wherein the signal pulses arising from scanning each  
distinct region of a specimen surface are accumu-  
lated separately and a separate area signal is gener-  
ated for each region, the pulses from the X-ray  
probe are likewise accumulated separately for each  
distinct region of the specimen surface, as deter-  
mined by the separate area signals, and a separate  
X-ray pulse count is generated for each distinct  
area, and wherein the area signal and X-ray pulse  
count signal for each region are released simulta-  
neously and the latter is divided by the area signal.

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