MATC(MN)26

Measurement Note

Measurement Routines for Microstructural Analysis by Image Analysis

Digital image analysis routines have been developed for the measurement of size, shape and distribution of phases within materials as part of the microstructural characterisation of these materials. These materials included ceramics, hardmetals, and porous PM steels. This measurement note details the image analysis subroutines used and how they were applied to different types of microstructure.

Digital image analysis can easily and quickly provide a large amount of data, which cannot be readily obtained by other stereological techniques. However, the data obtained should not be taken at face value as the results obtained are influenced both by the size of the feature being measured, the imaging technique used to obtain the image, and how the software variables are set within the image analysis system that was used for this study.



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Measurement Routines for Microstructural Analysis by Image Analysis

1.0 Introduction

In project CPM54 a number of tasks involved the development of new automatic or semi-automatic image analysis routines for the measurement of phase homogeneity, porosity distribution and feature shape. In most digital image analysis system, the software to make such analyses is constructed from macros comprising a sequence of commands written within the particular package used. These commands may take different forms in different systems, but the principles of their functions are the same. In this document, the macros developed and applied within the project are described and documented (see Annex A) for the particular case of the KS400 analysis system and the command structure (see Annex B) that is employed.

2.0 Concepts of Digital Image Analysis

Image analysis can mean a plethora of different techniques depending on what is being measured. Measurement techniques involved can be a simple visual inspection such as the count of a particular feature in an image, or the number of sides of an object. More sophisticated techniques based on stereology require the systematic counting of image features intersecting a grid, line or curve placed over an image. For example, an image of a two-phase material is overlaid with a grid. By counting the number of intersections of the grid with one phase and knowing the total number of intersections of the grid on the image enables an estimate of the area fraction of that phase.

For the work and case studies involved in this project, digital image analysis was primarily used for microstructural characterisation. Digital images have a discrete number of picture elements unlike a photograph, which has far higher image resolution. Unlike stereological analysis, which uses only discrete points within an image, digital image analysis can use all points (pixels) within an image. Typical digital image resolutions used within the project are 1000 by 1000 pixels or 1000 by 774 pixels.

Image analysis technical terms have as yet not been standardised and are open to interpretation. For instance, when measuring a pore within a material, the pore is often referred to as a feature. In this report, individual pores; grains, carbides, or any other distinct phase will be referred to as a region. The measurements that can be made on such a region, such as size or perimeter, are referred to as a feature; i.e. features of a region.

Digital image analysis systems generally work in one of two modes. The first is the semi automatic mode where the image of the microstructure is displayed on a computer monitor. The operator marks off points or draws a line using a computer mouse and these points or lines are overlaid on the displayed image usually in colour. The image analysis system then computes the required value of the required feature.

For example, the outline of a region can be drawn around and the image analysis system will then calculate features of this region such as its area, or perimeter.

The second mode in which digital image analysis systems can work is in the automatic mode. This depends on the regions within the image having sufficient contrast from their surroundings and from each other to be clearly identifiable. For example, pores within a polished section of a steel sample will appear dark whilst the steel will appear bright. For a single-phase material, etching is usually employed such that the grain boundaries are dark and thus outlining and separating each grain. The pixels that make up such an image have a grey level associated with them; these are in the range 0 (black) to 256 (white) and the intermediate numbers represent a range of grey levels. Automatic image analysis works by selecting or discriminating the pixels within a grey level range of the image. For the sample that contains porosity, the grey levels for these regions may lie within the range, say, 0 to 10. By discrimination of the image on these ranges of grey levels a binary image is formed. In the binary image, the discriminated pixels of the selected grey levels are all turned to grey level 255 (white) and all other pixels are turned to grey level 0 (black). Thus the binary image consists of black and white pixels. Having obtained a binary image with distinct regions, the measurement of features of the regions is quickly computed by the image analysis system.

In practice, it is generally found that automatic image analysis cannot work on its own without some semi automatic image processing. Etching of samples may not always reveal all the grain boundaries with sufficient contrast for them to be discriminated automatically although they are obvious to the operator of the image analyser. In this case, they need to be drawn into the image manually at a different grey level. Images obtained from a scanning electron microscope may have electronic noise distributed throughout the images that overlaps the grey levels that need to be discriminated. To the eye, the regions within the image appear distinct. However, to the image analysis system, any small variation is obvious. This is due to the fact that the brain can only detect changes of grey level contrast of 5% or greater, thus, only 20 different grey levels can be seen within an image ranging from black to white. The brain has in effect integrated grey level variations over a small area and visualised a set grey level. The digital image analysis system on the other hand will "see" 256 grey levels and will try to discriminate on these levels.

It is worth noting that having obtained a binary image, stereological techniques can be applied to the image. For instance, a digital grid can be placed over the binary image and a count of intersections made automatically. The size of the grid can be adjusted accordingly. In the extreme, the size of the grid can be reduced to the pixel spacing, which corresponds to how the digital image analysis system works by measuring every point in the image.

3.0 Image Calibration

The calibration of the digital images is of paramount importance to ensure that the measurements made are traceable and reproducible. Calibration is carried out using a digital image of a calibrated and traceable stage graticule obtained under the same conditions as the digital images that are to be calibrated. For an optical microscope,

this would be for the same objective, step or intermediate zoom facility and illumination mode. For a scanning electron microscope, this would be for the same accelerating kV, working distance, spot size and image processing and acquisition variables. Figures 1 and 2 show typical images of calibration graticule for optical and scanning electron microscopes

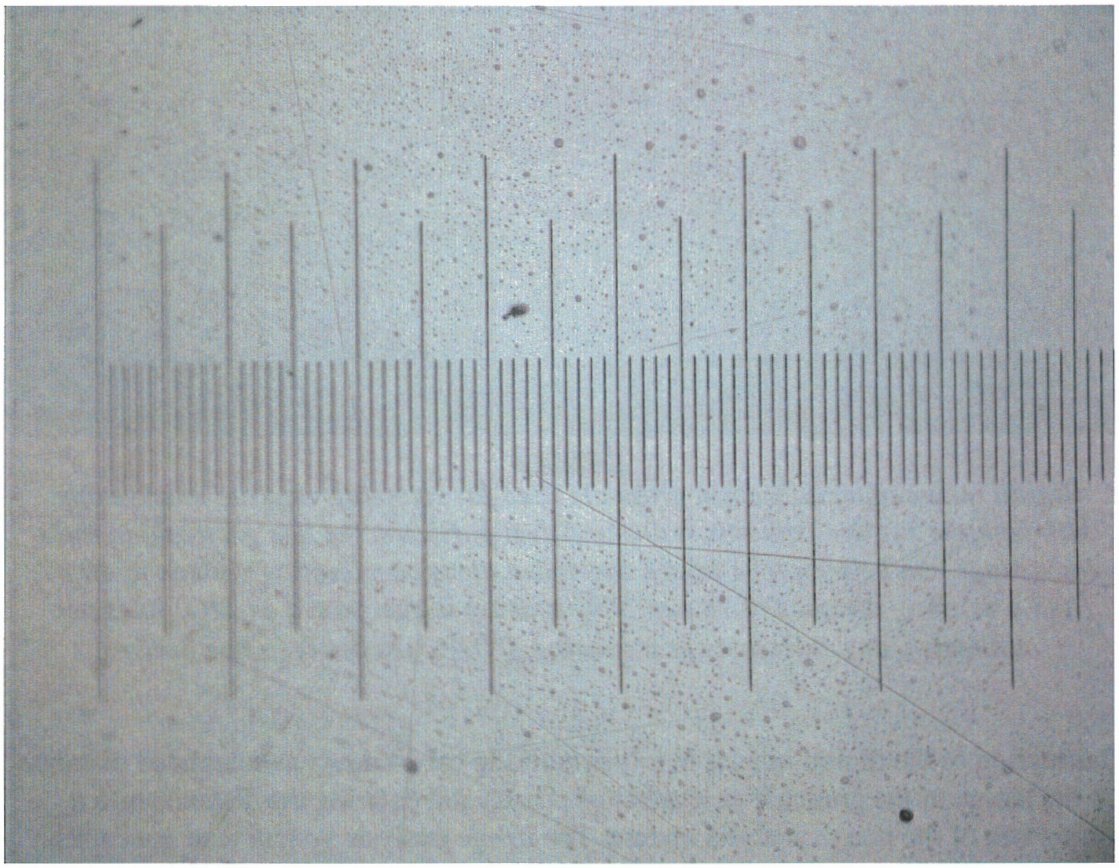


Figure 1

Digital image (00001435) of a calibration graticule used for optical microscopy. The spacing between the lines is 10μm.

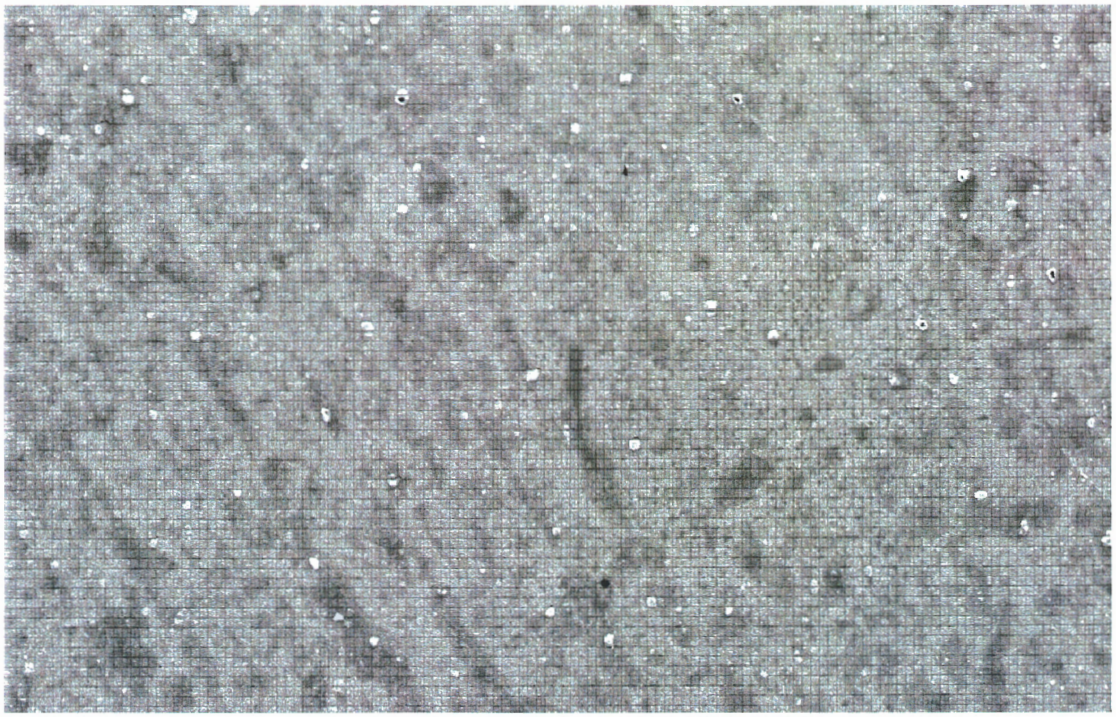


Figure 2

Digital image of a calibration graticule used for scanning electron microscopy. Although the surface contains stains and dust particles, the line graticule in the x and y stage can be seen .The image was taken at an accelerating voltage of 10 kV, and a working distance of 18 mm. The spacing is designated as 2160 lines per millimetre, this calculates as a spacing of 0.463µm between line centres.

Calibration of the digital images involves marking off a known or calculated distance on the image of the graticule (a number of pixels) and entering the distance into a dialog box of the image analysis system. The image analysis system then generates a calibration factor for the image, which is generally in µm per pixel. Calibration should take place in both the X and Y directions. This will allow for geometric distortion of a digital camera or for an image at an angle in a scanning electron microscope.

Having obtained a calibration factor for the image analysis system, it is good practice to check that the factor obtained is correct. This can be achieved by marking of known distances on the image of the graticule and checking that these are the expected values.

Calibration of the image analysis system is in general for distance only in the X and Y direction. However, the image analysis system is expected to measure region features such as area and perimeter that cannot easily be checked as to whether the correct value is being measured. Image analysis graticules with artefacts of traceable size do exist and can be used to check that measured features of a region are correct. Figure 3 shows part of a graticule for optical microscopy that contains artefacts of known size that can be used for checking the validity of measurements such as area that are subsequently made by image analysis.

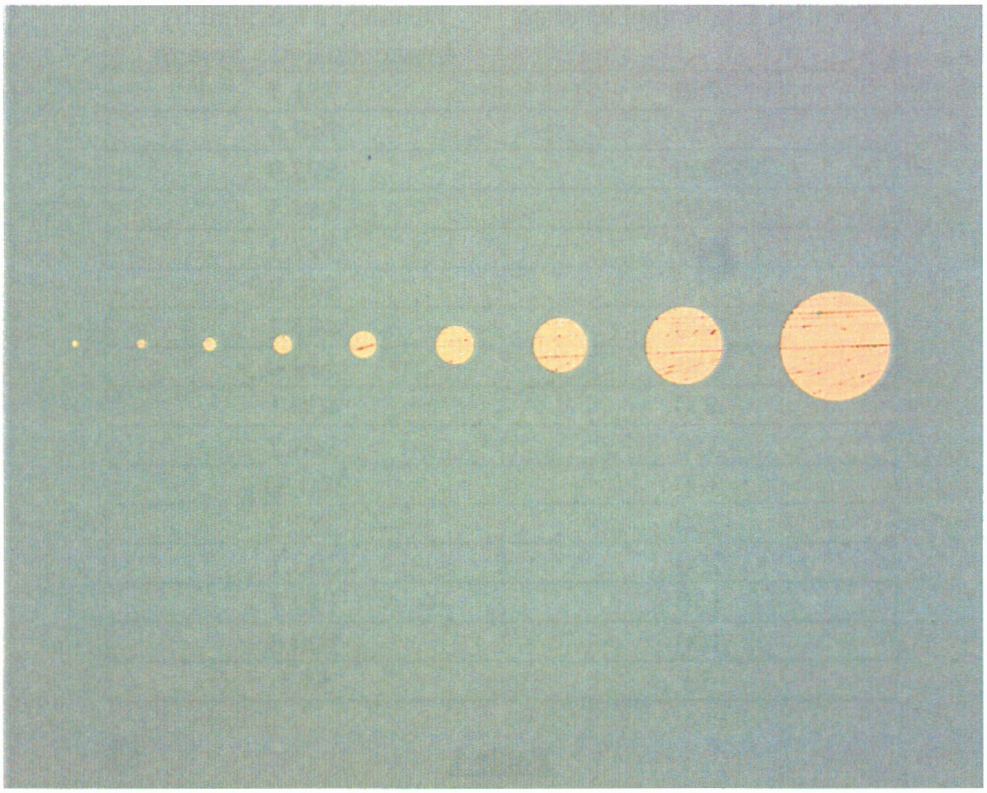


Figure 3

Digital image of an image analysis graticule used for optical microscopy. The calibration certificate describes this as a root – 2 array of nine spots from a nominal 3 μm to 48 μm diameter, (2.69 to 47.87 μm after calibration). The array is used for checking the calibration and resolution of the image analysis system.

Calibration data stored in a spreadsheet or database can be used to determine the mean magnification and standard deviation for a particular microscope operating condition. The data can then be used to determine the uncertainty of subsequent measurements.

The main steps for the calibration of an image are: -

- Obtain digital image of a traceable graticule.
- Save image for future reference or checks.
- Mark off the largest distance possible on the IA system of the markings of the digital image of the graticule.
- Enter the distance marked off in the previous step into the IA system.
- Note the value of the calibration returned by the IA system and enter into relevant spreadsheet or database.
- Check the image calibration by marking off different distances on the calibration image and checking that the IA system returns an expected value within the uncertainty of the system.

Nominal Graticule Distance	Distance Measured by Image Analysis System
750	751.7
750	748.4
700	698.9
650	648.5
600	597.2
550	548.2
500	497.2
450	448.6
400	400.1
350	348.2
300	300.51
250	252.3
200	200.1
150	150.7
100	100.6
50	51.1

Table 1

Results from calibration and subsequent checks of image analysis system using stage graticule as shown in figure 1.

Table 1 shows the data obtained from calibration of the image number 00001435 shown in figure 1. The image was obtained with a digital camera attached to an optical microscope with a x20 objective and 1.00 zoom. The maximum size of the calibration graticule obtained as a digital image was 750 µm wide and the IA system returned a value of 0.851305 µm per pixel. A check was then made with the same image over known nominal distances to ensure that the measured distance was within an acceptable range. The image is 1000 by 774 pixels, which represents a field of view of 851.3 µm by 658.9 µm, or 0.5609 mm^2.

Table 2 shows the results obtained over several calibrations obtained under the same microscope operating conditions and the uncertainty of measurements obtained.

Calibration ID*	Calibration Results, µm per pixel
40	0.857633
80	0.851305
84	0.854701
Mean	0.854546
Standard Deviation	0.003167

Table 2

** Calibration ID refers to a database, which stores details of calibration of all microscopes, used for obtaining digital images as part of the Materials Centre Microstructural Characterisation Facility. The history of calibration is used to determine the uncertainty of measurements.*

4.0 Image Analysis Macros

4.1 Reference Images

As part of the project, reference images of the materials were generated. The methods used to produce these images and the measurement parameters are discussed within this report. However, the measurement of these images and the results obtained are reported in a separate document.

Although monochrome digital images normally have grey levels 0 to 255, it is useful to change the range to 5 to 250. Thus, any manual image changes can be written into grey levels 0 or 255 and are easily identifiable.

The example illustrated here is that of an Alumina Zirconia ceramic with porosity present. Figure 4 shows a typical microstructure of the ceramic obtained using a Field Emission Scanning Electron Microscope fitted with a digital image acquisition system. As can be seen, the grain boundaries are not a single grey level and the edges of the pores fluoresce and appear at the same grey level as the Zirconia grains. Also, electronic noise in the image causes an overlap of grey levels and the image is therefore not suitable for grey level discrimination.

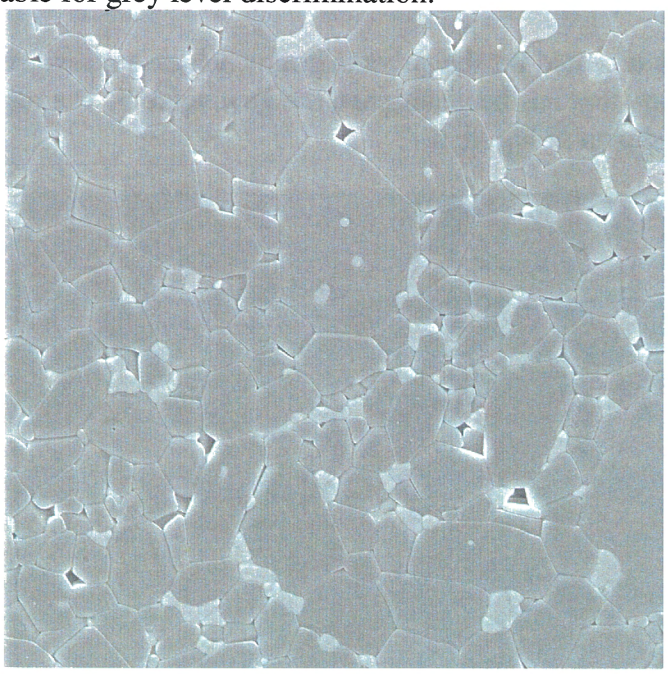


Figure 4

Alumina zirconia ceramic, thermally etched at 1500° C for 15 minutes. Sputter coated with Gold Palladium alloy to produce conductive surface. Field emission scanning electron microscope conditions, 10 kV, beam current 9μA, working distance 16 mm. Digital images obtained using a Kontron SEMIP unit, 1024 by 1024 pixels.

The grain boundaries are discriminated by manual processing; these are drawn into the original image and merged at a single grey level, value 0 for this example. In some cases, many of the grain boundaries may be discriminated by grey level discrimination and manual image processing is only required to fill in missing grain boundaries or to remove erroneous boundaries, e.g. polishing scratches. When the grain boundaries have been assigned a single grey level (0 for this example), they can easily be extracted to a binary image by grey level discrimination as shown in figure 5. The process of grey level discrimination assigns a grey value of 255 to all the selected pixels and a value of 0 to all other pixels thus producing a binary image. For a single-phase material, the binary image obtained is suitable for a reference image whereby the grain boundaries have been assigned the grey value 255 and the grains the value 0. However, for a multi phase material, each of the phases present must be assigned a unique grey level, the value of which is chosen by the operator.

For a multi phase material, having obtained a binary image of the boundaries (value 255) and the grains (value 0), a region growing subroutine was used to assign the regions to a grey level representative of the phase. With reference to figure 4 and figure 5, a region of alumina is selected using the "region grow" function of the image analysis system. By selecting the relevant parameters (see "reggrow" function in Appendix B), the whole of the region is discriminated and written into the graphics plane of the IA system. Each region corresponding to the alumina phase is selected in turn until all the regions have been selected. The contents of the image plane are then merged into a single grey level within the original image (value 100 in the example).

The process is then repeated for the zirconia grains, which are assigned the grey value 200, and the porosity that has been assigned the grey value 5. The resulting reference image obtained is shown in Figure 6.

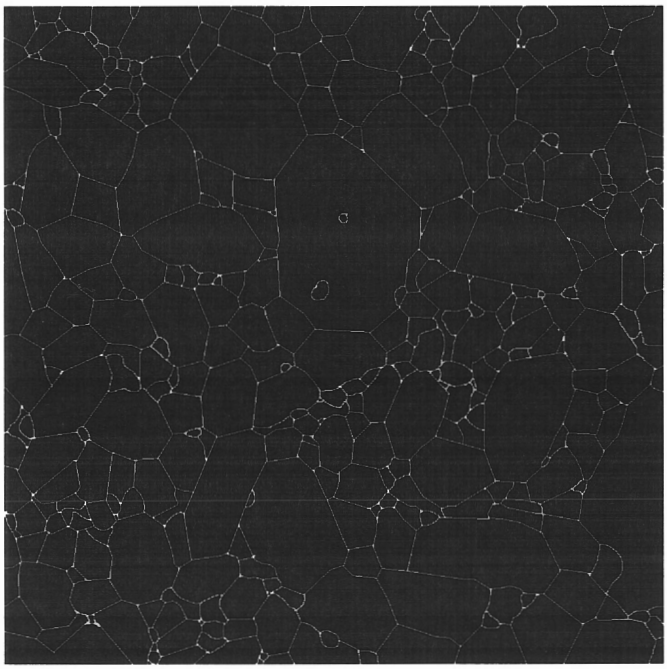


Figure 5
Grain boundaries extracted from figure 4 by manual processing.

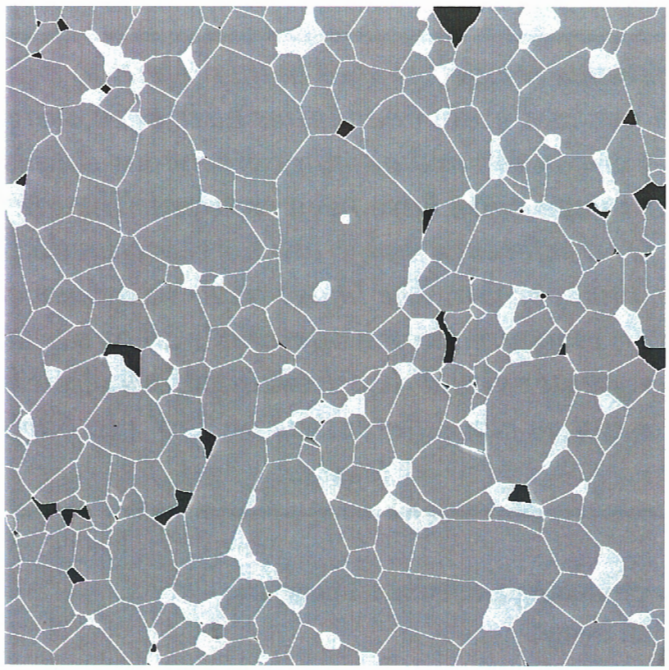


Figure 6

Typical reference image obtained after detecting grain boundaries and use region grow function to assign different grey levels to the alumina (100), zirconia(200), porosity(5) and grain boundaries (200).

In some cases, extra clarity for the operator can be achieved by coding the grey levels obtained into a RGB (red, green blue) image as shown in figure 7.

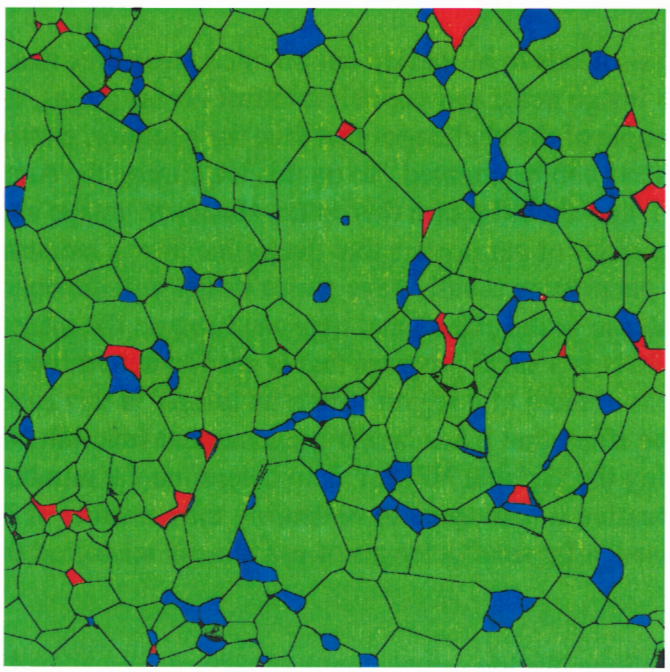


Figure 7

Colour image obtained by copying the grey levels of figure 6 into the RGB image memories, green for alumina, blue for zirconia, red for porosity and the grain boundaries are at grey level 0 in each of the colour images.

The term "Reference Image" is used in this report to define images in which the phases and grain boundaries have been assigned unique grey levels or colours and all other erroneous details such as scratches or image noise have been removed. The grey levels or colours used for a reference image are for reproduction or aesthetic appeal only to the operator. The image analysis system can detect all 256 grey levels compared to the operator's 20 or so. Although the operator has greater visual discrimination for colour images, the image analysis system can differentiate on 256^3 (16.6 million) colour levels.

The main steps for producing a reference image are: -

- Obtain digital image
- Obtain calibration image
- Detect grain boundaries by grey level discrimination
- Manually fill in grain boundaries or delete erroneous grain boundaries
- Assign the regions of each phase to a single grey level in either a monochrome or colour (RGB) image.
- Save reference image.
- Measure regions of each phase.

4.2 Region

Often, image analysis needs to be carried out on microstructures that pose real problems owing to image noise and variable contrast across grains, especially in SEM images. As an example of the challenges that face the operator, consider how the number of grain facets can be counted. To do this we choose the measurement subroutine NPOLY that should return this value. However, image analysis systems are dependent on a series of parameters that determine how a measurement process is carried out. These parameters usually have preset values and the operator may not be aware of their existence or the effects that they can have on the measurement process. The program REGION is a small program that is used to determine the effect of an IA variable on the measurement of a region within an image. In this case, the variable is POLYDIST and the effect that it has on the measurement function NPOLY. The reason for measuring the variable NPOLY is to determine the number of sides that a region has. The situation is analogous to measuring the coastline of Britain. If a rule of 1 kilometre is used, a far smaller length of coastline is measured than if a rule of 1 metre is used.

Figure 8 shows a Silicon Nitride sample that has been plasma etched. To the eye, the regions of Silicon Nitride are quite apparent. However, the image is full of electronic noise and so could not be easily discriminated by grey levels alone. Also there was a gradual change of grey levels across the grain interfaces. Thus, the region "growing" subroutine was used to identify these regions to produce the binary image shown in

Figure 9. Subsequent measurement of these regions by automatic image analysis produced some spurious results for the value of the variable NPOLY. Thus the program Region was used. The program assumes that a binary or reference image of the feature of interest exists. The region feature chosen is NPOLY. The measurement property that is varied is POLYDIST. This is analogous to the size of a ruler being used to measure the distance around an object. For a digital image, the smallest size that the ruler can be is 1 pixel in length. The discrimination stage is required if a reference image instead of a binary image is used. The feature of interest is then measured. Within Figure 9, a region of discriminated Silicon Nitride was chosen to be measured as indicated. When the measurement function "Msmeasmask" is executed, the region of interest is selected by the cursor and a note made of the measured parameter NPOLY. This has to be done manually since a lot of data is automatically generated from each region and this is the only way of being certain that the measurement comes from the desired region.

Figure 9 shows a region from a binary image that was used to determine the effect of POLYDIST on NPOLY, the results are shown in figure10.

According to the KS400 image analysis software, NPOLY returns the number of ordinates of polygon approximation. For a square, it was assumed that it would return the value of four. Instead the value of 5 was returned. In all cases for simple geometric shapes, it always returned the value equal to the number of sides plus one. Evidently, the additional ordinate is the same as the first and is required for drawing the shape since it must return to the origin. The accuracy of NPOLY is set by the value of the variable POLYDIST.

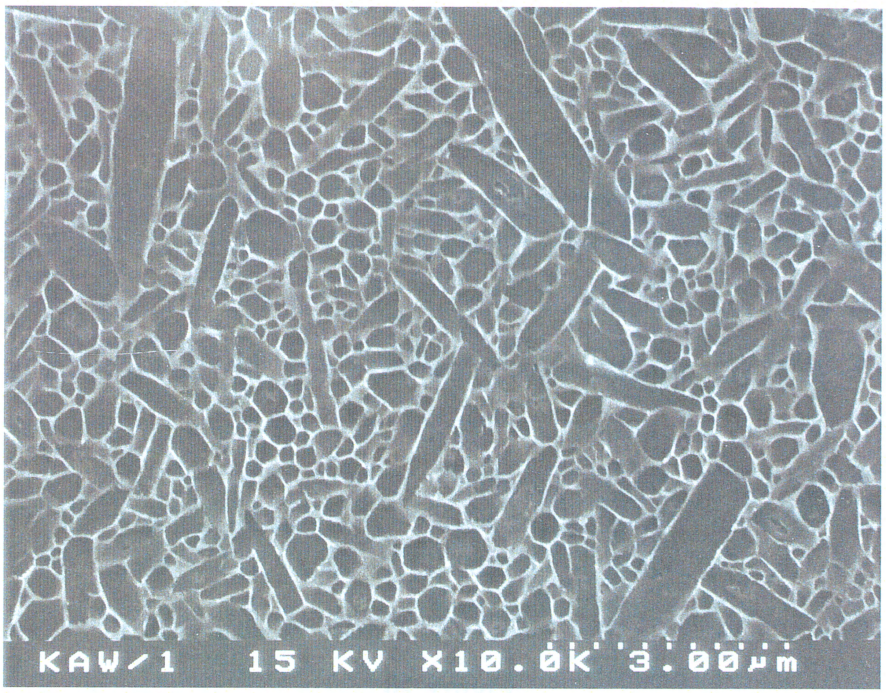


Figure 8

Plasma etched surface of silicon nitride sample. The image was originally obtained as a photomicrograph from a scanning electron microscope. The image was then digitised by a scanner at a resolution of 300 dots per inch (DPI).

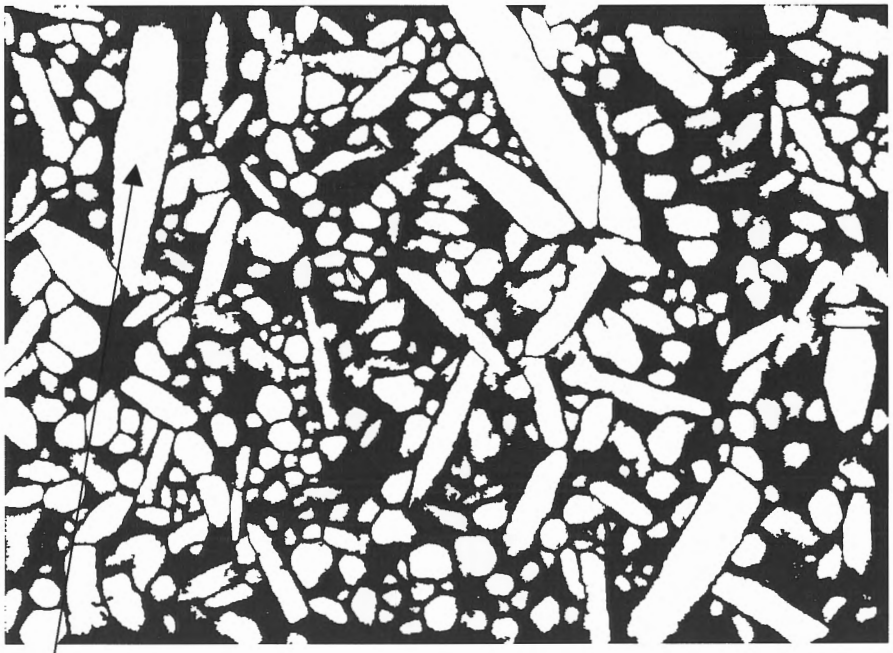


Figure 9

Area of interest used to assess the effect of image analyser variable POLYDIST. An approximation by eye would expect the value of NPOLY to return a value of 8 for a 7-sided region.

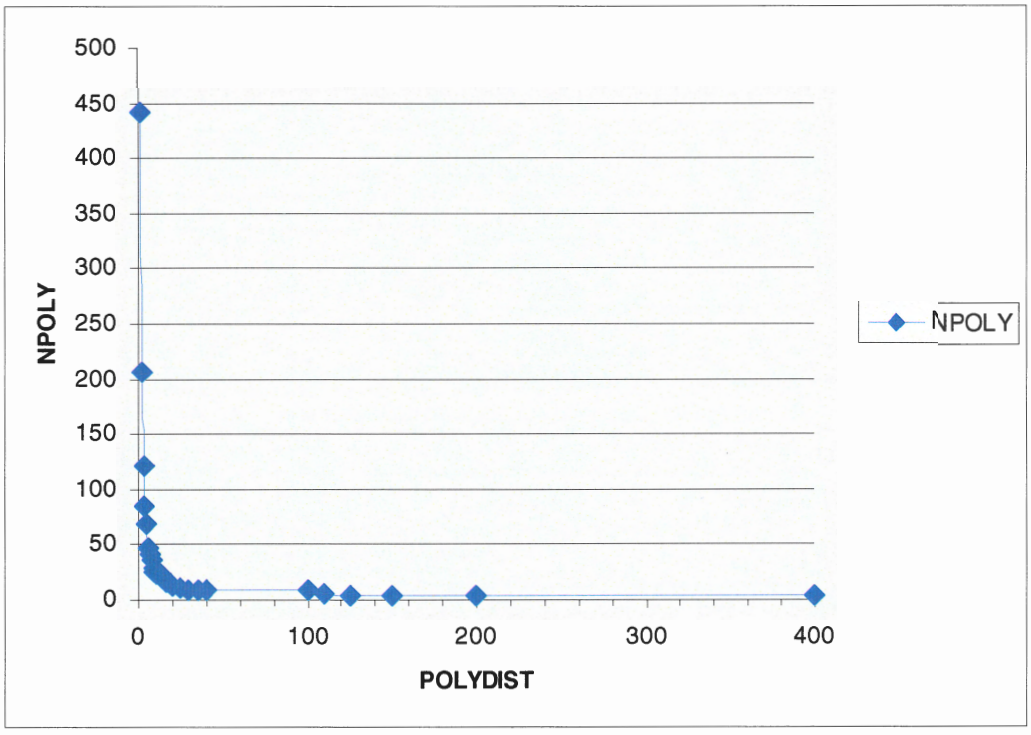


Figure 10

The effect of varying the value of POLYDIST on the measured variable NPOLY for the region identified in figure 9. The default value of POLYDIST was set at 4, which gave a value of NPOLY of 85. Other regions within Figure 9 gave even larger values.

As can be seen from the plot in figure 10, quite a large value of POLYDIST was required before the value returned by the variable NPOLY approached the approximate number of sides that the operator would find acceptable. The problem is caused by two factors. The first is that there is a lot of electronic noise in the image. The second is that the image was obtained from a scan of a photograph. The scanner operates at a far higher resolution and thus produces interpolated pixels. As a result far more pixels are used to describe the image that in turn increases the number of pixels on the perimeter of the object which is the same effect as decreasing the ruler size.

Scanned images of photomicrographs should be avoided as the subsequent pixelation is at a higher resolution than the imaging device and will add additional interpolated pixels to the image. This results in an increase in the coding (number of pixels required to define the regions) of the image and subsequently results in higher perimeter and number of side measurements.

The main steps for determining the effect of an IA variable are:-

- Obtain binary or reference image of regions
- Set up measurement parameters, NPOLY for this example
- Set value of IA variable, POLYDIST in this example
- Measure the region feature, NPOLY in this example
- Repeat previous two steps for different values of IA variable
- Plot the results

4.3 Ultimate Dilation

The ultimate dilation program is used for determining the space occupied by regions of a phase such as porosity or carbide precipitates. The regions are discriminated by grey levels into a binary image. The ultimate dilation increases the sizes of these regions until they occupy all adjacent areas, but they do not overlap. The sizes of these dilated regions are then measured as the area over which each region has influence. This is sometimes referred to as the zone of influence.

Figure 11 shows carbide precipitates within the microstructure of a tool steel. The ultimate dilation program is used to determine if each carbide region has an equal zone of influence by dilating the regions that have been discriminated in a binary image, shown in Figure 12, until they almost touch. The ultimate dilation image is shown in Figure 13a.

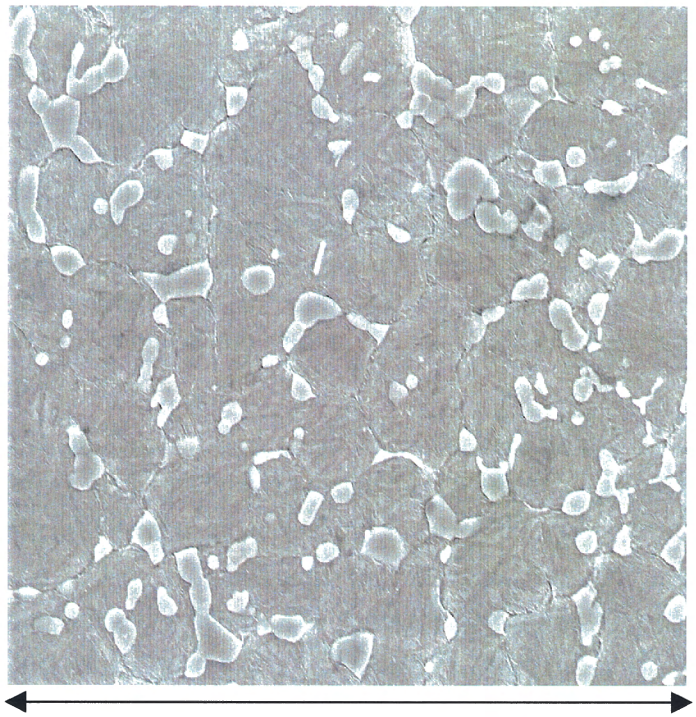


Figure 11

Microstructure containing regions of carbide precipitates whose zone of influence is to be measured.

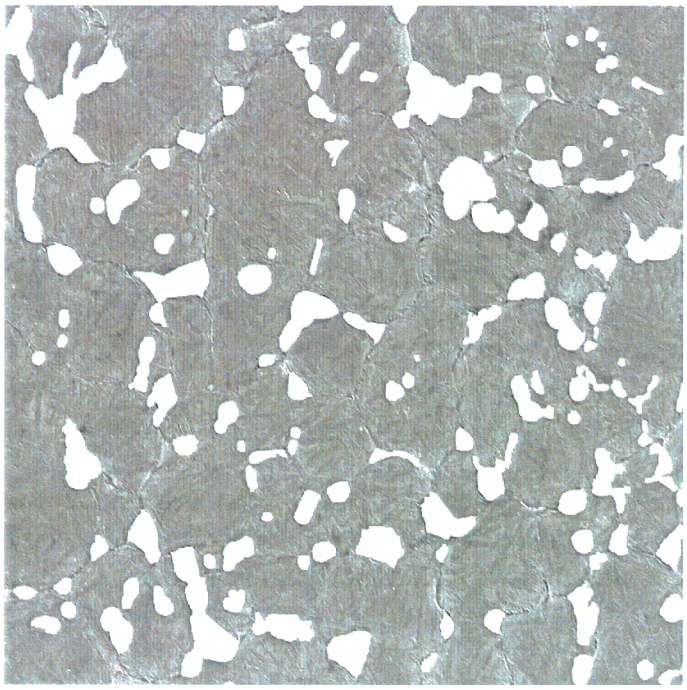
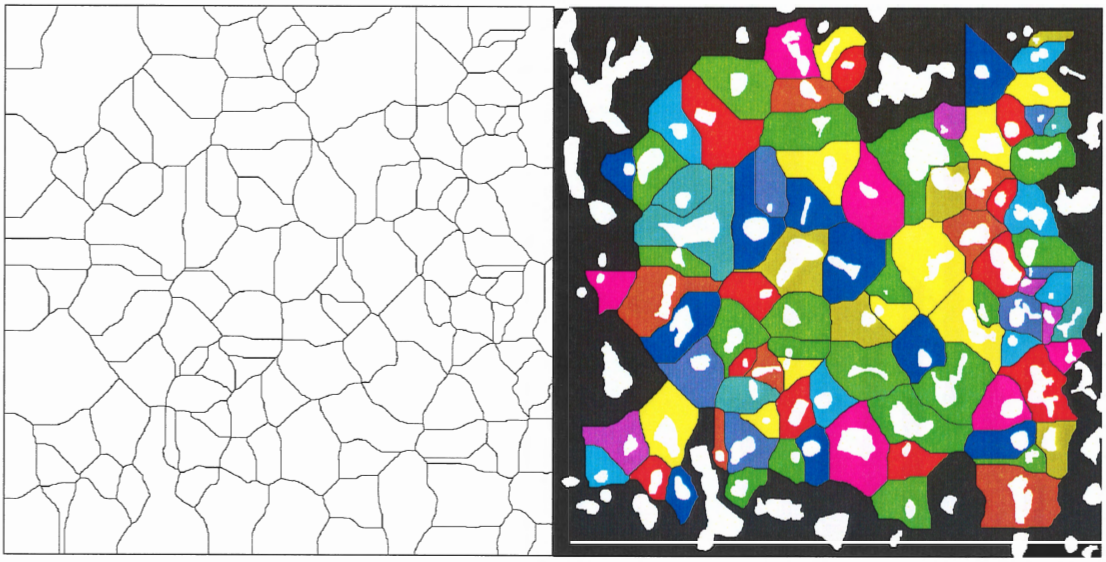


Figure 12

The regions of carbide precipitates in Figure 11 have been identified by grey level discrimination and are shown over the original image for comparison. Small regions that may be carbides or electronic noise have been selectively scrapped; these are regions that comprise of less than 20 pixels.



a) **b)**

Figure 13

a) Carbide regions ultimately dilated to show zones of influence. b) Composite image showing original regions of carbide and, colour coded regions of the zones of influence that have been obtained from the measurement mask. The use of the "frame" prevents regions that overlap the edge of the image from being measured.

As can be seen in Figure 13a, many of the dilated regions extend to the border of the image. For measurement purpose, regions that overlap the edge of the image are not measured for two main reasons. Primarily, they extend beyond the image frame so there is no information as to their full size. Secondly, regions that lie outside of the image are not dilated and so do not encroach into the measuring frame and act as a barrier. The measuring frame must be smaller than the image size by at least 4 pixels in both the X and Y directions and positioned such that there is a region of at least one pixel wide outside of the frame. For a region not to be measured, it must overlap the frame by at least one pixel. The effect of imposing a measuring frame is shown in figure 13b. This shows a composite image of the original detected carbides and their resulting zones of influence. The regions of carbide or their zones of influence that overlap the frame are not measured and are not shown in the coloured measurement mask.

Image analysis systems can generate a lot of data very quickly and verifying that the data even makes sense can be time consuming. The use of the measurement mask to show which regions have been measured can be quickly verified visually and adds confidence to the measurements.

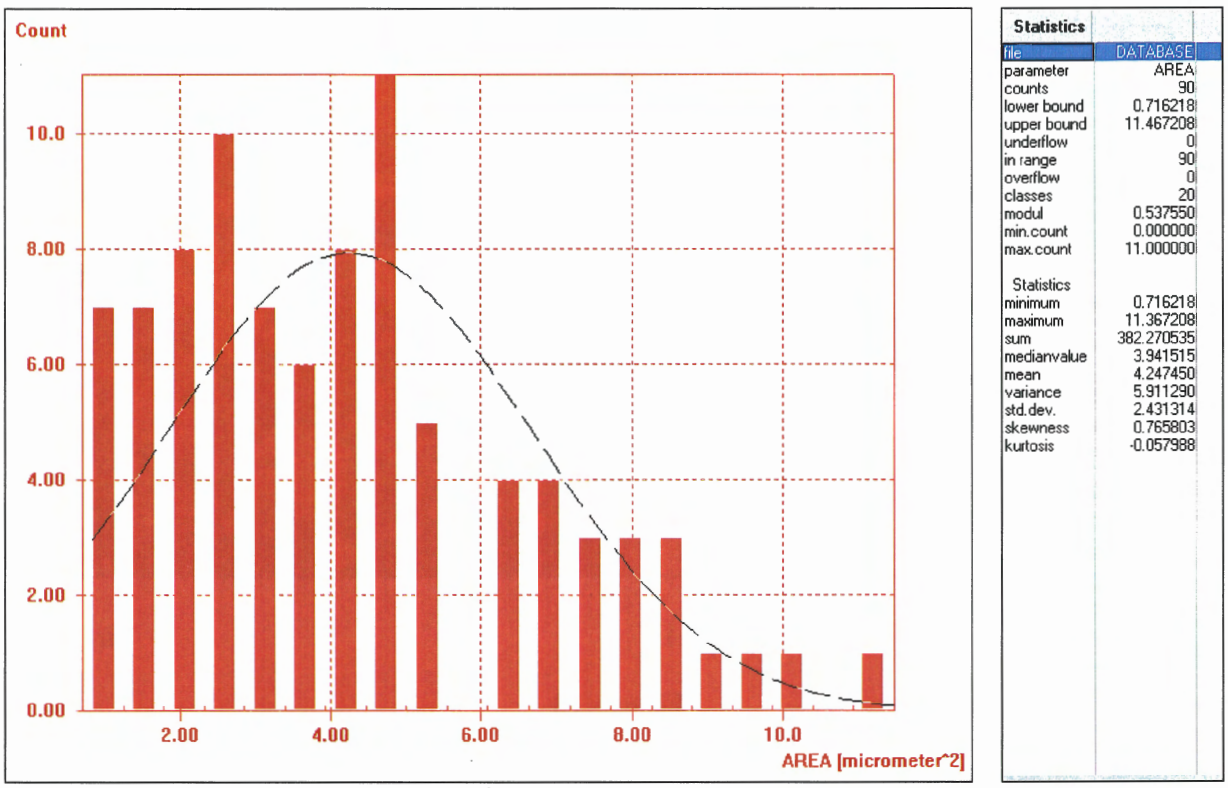


Figure 14

Results of the measurement of the areas of the zones of influence shown in figure 13a.

The main steps for determining the zones of influence are:-

- Obtain binary or reference image of regions
- Calibrate the image
- Scrap small regions that may be an effect of noise in the system, or below the resolution of the imaging device
- Set a measuring frame so that regions that touch or overlap the edge of the image are not measured
- Measure the areas of the zones of influence
- Plot the results as a distribution of areas

The results for the measured areas of the zones of influence after the ultimate dilation process are shown in the histogram in Figure 14. As can be seen from these results, there is quite a small distribution of areas, the majority of which lie between 2 and 8μm. However, the results give no indication as to whether the carbides are clustered and this is discussed in Section 4.5, Spatial Distribution of Regions by Dilation.

It should be noted that the ultimate dilation program is designed for use with materials that contain secondary phases such as carbides or porosity. It has no

practicality on single-phase materials since the regions that would be dilated are the grains of the material.

4.4 Porosity Distribution.

The porosity distribution program was developed and used for the measurement of pore size and size distribution within 6 porous samples. A total of 30 images were measured for each material and a separate database was set up for each of the images as well as an additional database that was used to produce running averages for each measurement parameter as well as a total set of measurements. The details of the measurements are contained in a separate document for the measurement of porosity distribution.

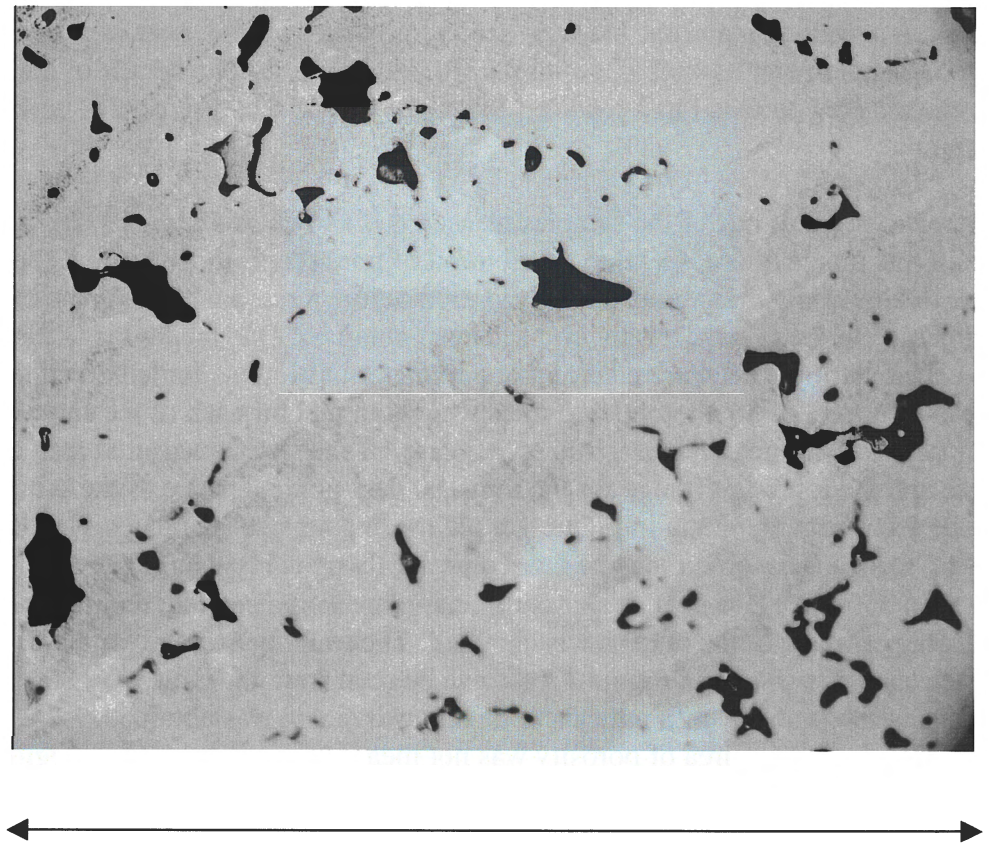
A photomicrograph of one of the samples measured is shown in Figure 15. As can be seen from this image, there is a wide distribution of pore shape and size. The question arises as to how many measurements are required before a reasonable estimate of the desired parameter (size, aspect ratio etc) has been obtained. One method is to plot the running average of the measurement of that parameter until it has settled down to a mean value. A total of 30 photomicrographs were obtained for each of the samples by random sampling of the polished surfaces. Figure 16 shows the measured area of pore size and the running average for the first 100 data points for one of the samples. As can be seen from the graph in Figure 16, the mean pore size is apparently still increasing in size. This effect may be caused primarily by the few large pores of size greater than 350 μm^2. However, it shows that more measurements are required before a reasonable estimate of the pore size is obtained. The running average for all 30 images measured is shown in Figure 17. As can be seen from the data, over 800 measurements were made until a mean value that was stable was obtained. Additionally, the largest area of porosity was not measured until over 2,500 regions of porosity had been measured. The statistics for the full set of data results are shown in Figure 18.

When measuring the porosity in the sample, it was assumed that the material was homogeneous and images were obtained at random from the surface of a polished specimen. However, for inhomogeneous samples, images are generally taken from a profile across the specimen. The specimen is sectioned or sufficient material is removed from the surface by grinding such that the surface effects will then appear only at the edges of the polished specimen.

The main steps of the process are: -

- Obtain and store images of microstructure
- Calibrate image analysis system
- Set up databases for each image and also one for running total
- Set up measurement parameters such as area or perimeter
- Set up measurement conditions such as minimum area and measurement frame

- Load image for measurement and perform shading correction or other image enhancing operation as required
- Produce binary image of regions of porosity by grey level discrimination
- Measure regions of porosity, data entered into individual database for each image and into the running average database
- Repeat process for each image
- Copy data to spreadsheet



272 μm

Figure 15

Porosity in sample LDA1, image number 0000063, calibration image number 00000660. As can be seen from the image, there is a wide distribution of both pore size and shape.

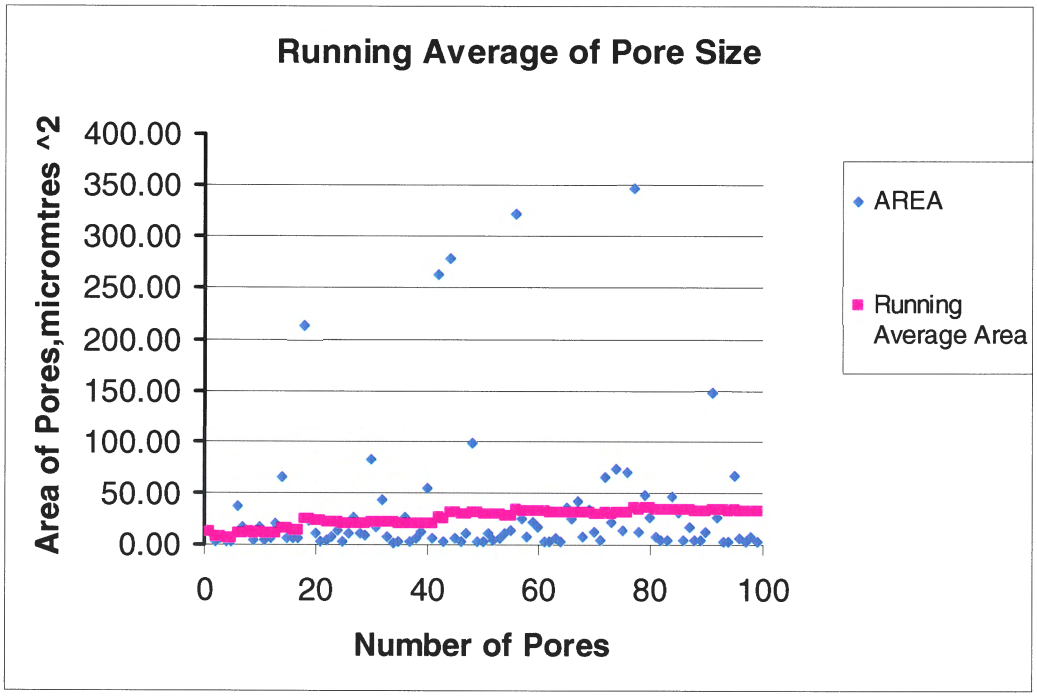


Figure 16

Running average for pore area from the first 100 measurements. As can be seen from the graph the mean value appears to be increasing.

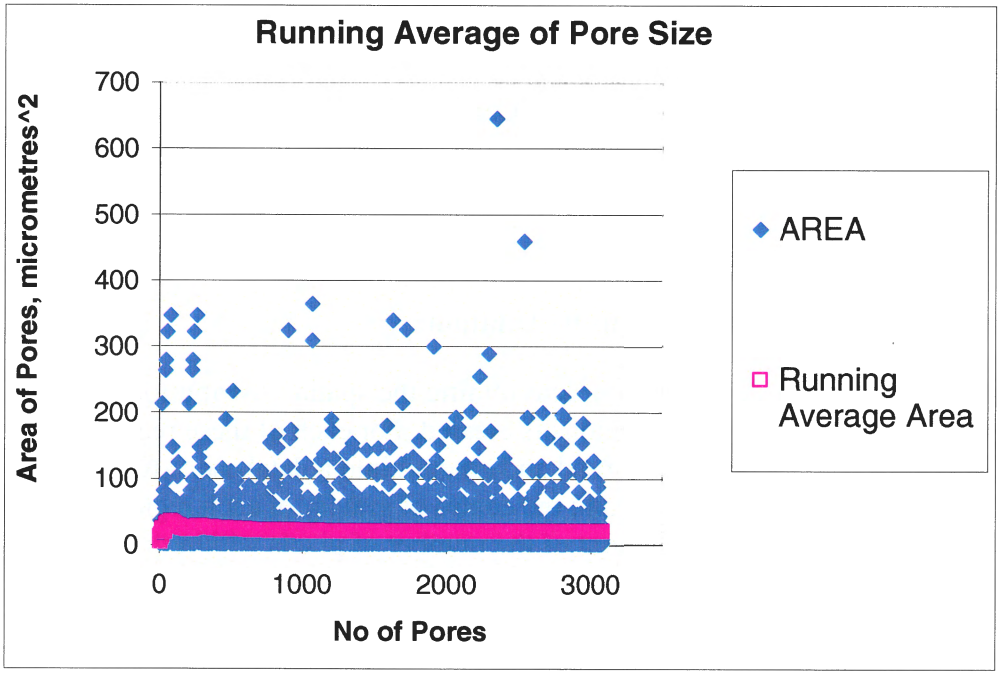


Figure 17

Results from measurement of 30 images of sample LDA1 measured in random order. As can be seen from the graph, the running average has settled down to a mean value after 800 measurements and the subsequent occurrence of large areas of porosity have little effect on the mean value.

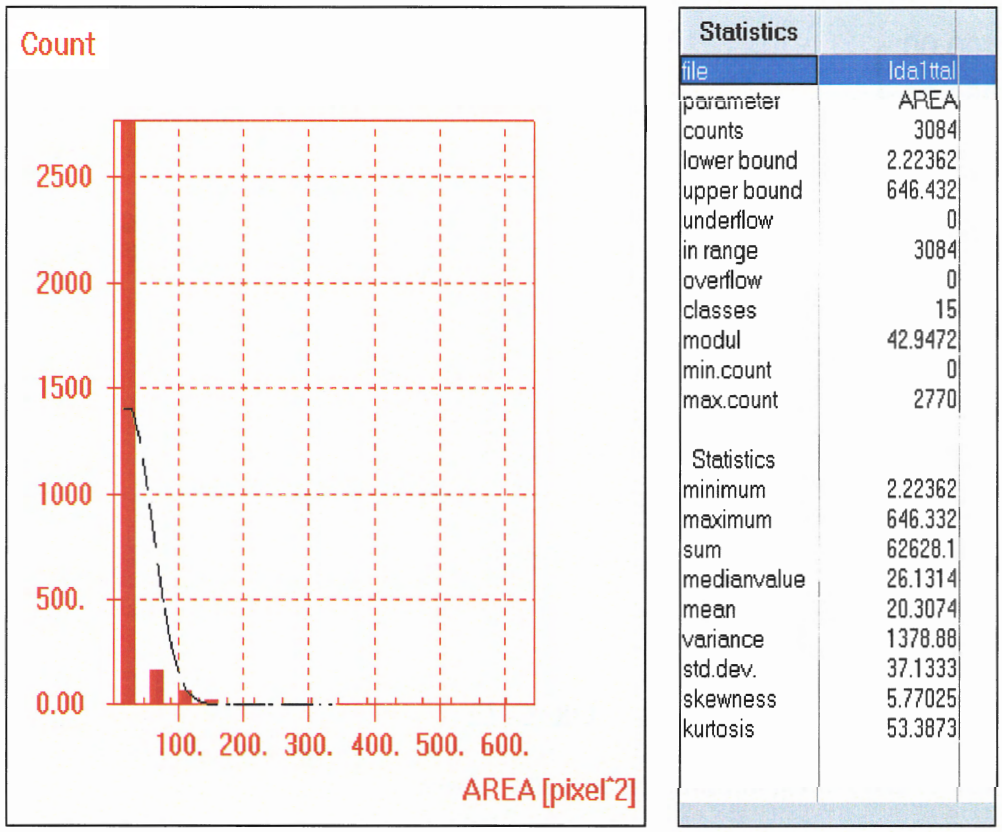


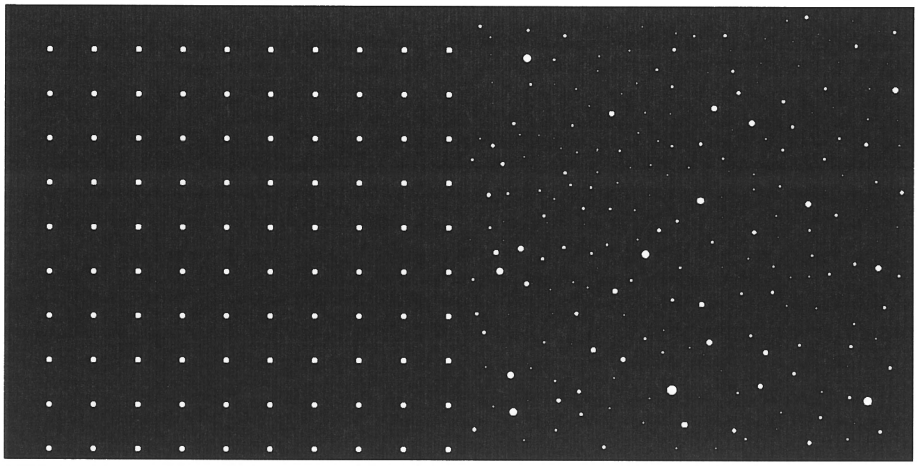
Figure 18

Statistical results from the measurement of porosity of 30 images of sample LDA1. The mean size of regions of porosity is 20.31 μm^2. However, the largest region of porosity was 646.3 μm^2.

4.5 Spatial Distribution of Regions by Dilation

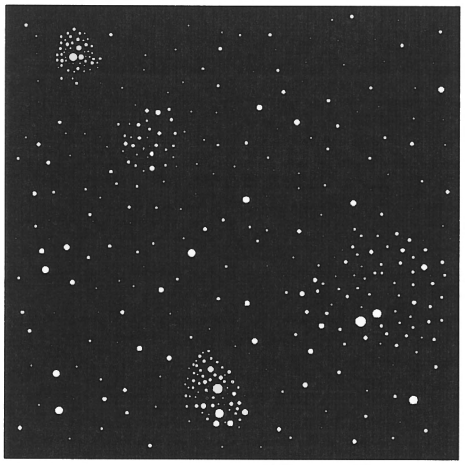
The Dilation program was developed for determining the spatial distribution of regions. First a binary image of the regions is created. For each of these regions, the centre of gravity is automatically measured and entered into a database. An unscaled image of the same size is then created and the centre of gravity of each region is copied into this image as a pixel. A count of the number of pixels within the image is then made. The pixels representing the regions are then dilated by adding a shell of pixels. A count is then made of the number of regions. The dilation process is repeated and a new count is made. As this process continues, the regions grow together and the count decreases. Eventually, all the regions join together and the count is just one. By plotting the number of regions against the number of dilation stages, a plot can be made which represents the spatial distribution of the regions.

A full description of the program is contained in the IAG summary note, which covers CPM milestones 5.4/ T2/ M10 and 5.4/ T2/ M20.



a) Image CPMTST

b) Image CPM1



c) Image CPM2

Figure 19

Idealise binary images of microstructural spatial distributions. a) A structured array of equally sized regions, b) An unstructured array of different sized regions, and c) A semi structured array of different sized regions. The clustering of the regions at certain positions in the image suggests both short-range structure as well as a long range structure or texture.

Figure 19 shows three idealised binary image structures of spatial distribution of regions. For the regions in Figure 19a, as they are dilated, they grow equally until just a single dilation step is required until the merge into a single region. This is shown plotted in Figure 20.

For the images in 19b and 19c, as the regions are dilated, they grow together at different rates. For example, the clustered regions in 19c will merge after just a few dilation steps causing a sudden decrease in the number of regions present. In contrast, the regions in 19b will gradually merge causing a slow but continuous drop in the number of regions present. A comparison of the dilation plot for all three hypothetical cases is shown in Figure 21.

To convert the dilation steps to distance, the calibration factor for the image in micrometres per pixel must be known. At each dilation step, the boundaries of

regions move towards each other in steps of two pixels. Thus, each dilation represents a distance of twice the calibration factor.

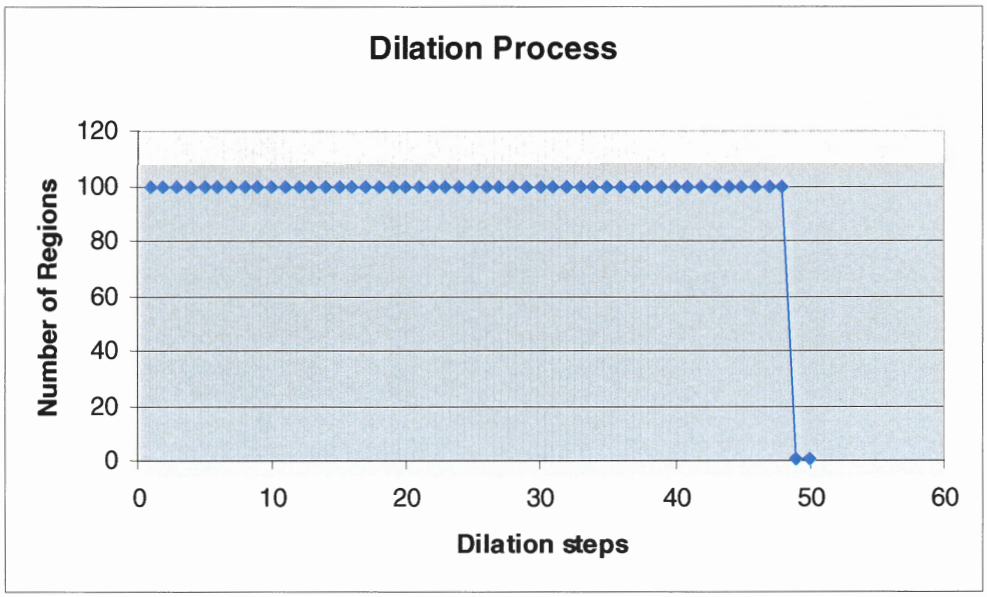


Figure 20

Plot of dilation steps against number of regions, image CPMTST.

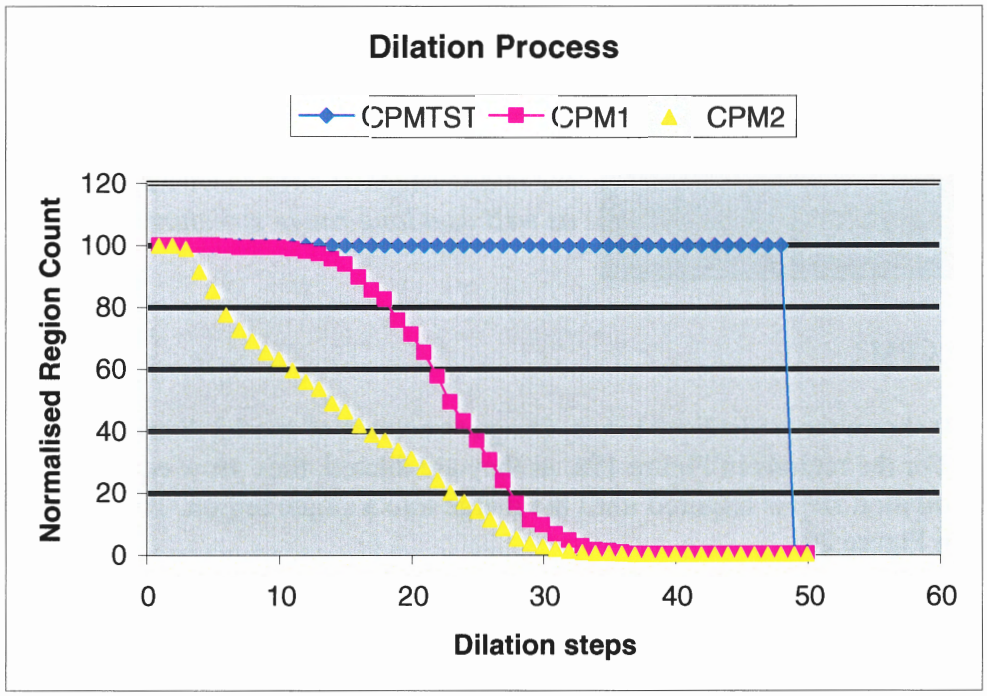


Figure 21

As can be seen from the dilation plot, the differences in the types of structure are quite clear. The regular structure of image CPMTST requires a maximum number of steps before convergence of the regions. In comparison, the random structure of image CPM1 slowly converges. The structure of image CPM2 shows an initial convergence of the clusters and another convergence as the long range structure or texture converges

The main steps of the process are:-

- Obtain and store images of microstructure
- Calibrate image analysis system
- Obtain binary images of regions by digital image processing
- Set up measurement parameters for centre of gravity of regions
- Obtain co-ordinates of centre of gravity of regions and write to database
- Make a new blank image of equal size
- Obtain each data point from database and write a single pixel at the co-ordinates of the centre of gravity of the original regions.
- Set up field measurement parameter for count of regions in image.
- Count regions in image and dilate by 1 pixel
- Repeat previous step until number of regions has decreased to a single region
- Copy data to spreadsheet
- Repeat process for other images as required.
- Plot dilation data.

4.6 Nearest Neighbour

The "nearest neighbour" macro has been developed for determining the nearest neighbour distance between regions. The position of the centre of gravity of each region is determined and written into a database called "temp". An iterative process is then carried out on each of the regions on the database to determine which other region is nearest to it. The distance between the two regions is then calculated and written into the database "NEAREST". A listing and histogram of the nearest neighbour distances is then calculated.

The main steps of the program are:-

- Obtain and store image of microstructure
- Calibrate image analysis system
- Obtain binary images of regions by digital image processing
- Set up measurement parameters for centre of gravity of regions
- Obtain co-ordinates of centre of gravity of regions and write to database
- Calculate minimum distance between regions, i.e. nearest neighbour
- Draw vectors joining these regions in the image plane

Figure 22 shows a binary image of which the nearest neighbours are to be calculated. The results are shown graphically in Figure 23, and the statistical analysis is shown in Figure 24.



Figure 22
Test image CPM2 containing clustered and semi structured regions.



Figure 23
Nearest neighbours detected and the lines drawn into the image plane

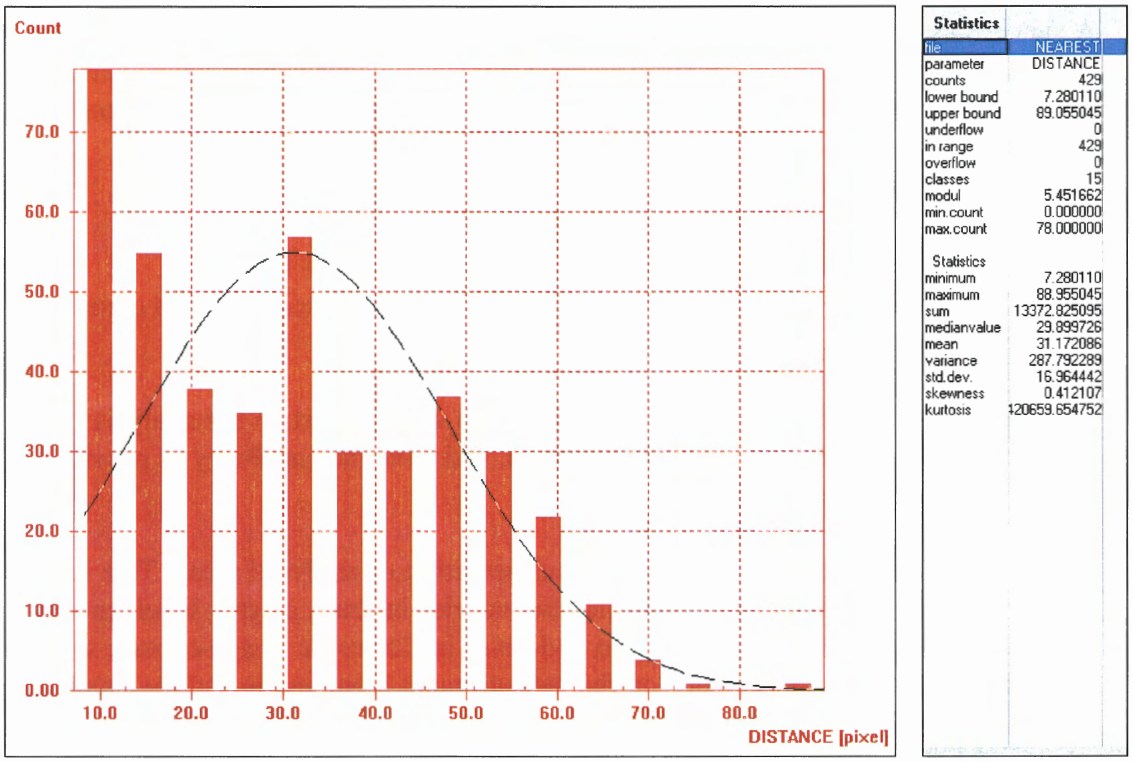


Figure 24

Statistical data obtained from the nearest neighbour measurements.

4.7 Image Edit Tools

Despite the advances made in AIAS software, unwanted artefacts can often be seen in the resulting binary image, or grain boundaries have not been clearly identified. These can often not be removed by changing the parameters in the image discrimination function. Some of these artefacts can often be removed by means of image processing functions such as the "scrap" function. However, in most cases, manually editing the binary image is the only option. This is done by the operator selecting the pixels that are to be removed and setting their value to binary 0, or adding missing pixels such as those representing grain boundaries and setting their value to 255. Not all AIAS allows the operator to make changes to an image at the pixel level.

5.0 Conclusions

A survey has been made of the capabilities of automatic and semi-automatic image analysis to provide detailed analysis of microstructural features relevant to hard materials, including ceramics, hardmetals and PM structural steels. Parameters studied included:

- Grain size/area distribution;
- Porosity size/area distribution;
- Grain shape, as described by feret ratio and number of facets;
- Microstructural homogeneity, in terms of detecting clustering and distribution of nearest neighbour distances.

The programming techniques have been shown to work, based on the analysis commands within the KS400 software system, and have the capability of providing discrimination between materials.

Most of the techniques require some manual selection of analysed areas. This is a result of features not having well-defined boundaries in terms of grey level contrast, resolution limits of the imaging system and noise in electronic image capture systems. The level of intervention depends on the measurement being made and the quality of the input image.

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DISCLAIMER

The use of KS400 image analysis software has been for demonstration of techniques and limitations, and is only treated as an example, NPL in no way endorses any particular software product.

Appendix A. KS400 Image Analysis Programs.

A.1 Image Calibration

```
# Set up colour camera for image acquisition, first image is of calibration graticule.
! tvselect "prgs"
tvlive
! tvwbalance 1
! tvsetup
tvframe 0,0,1024,772
tvinput 1
imgdisplay 1
imgRGB2grey 1,1

# Set up database and measurement parameters, calibrate system
! DBnew "database",1
! MSsetgeom
! MSsetfeat "POINTFEAT"
MSmeaspoint 1,"database",0,1,1,1,2,1

#Input image to be measured
Gclear 0
tvinput 1
imgRGB2grey 1,1
MSmeaspoint 1,"database",1,1,1,1,2,1
datalist "eqycd",0,0
Gclear 0
```

A.2 Reference Images

```
# Set up database and measurement parameters, calibrate system
! DBnew "database",1
! MSsetgeom
! MSsetfeat "POINTFEAT"
MSmeaspoint 1,"database",0,1,1,1,2,1

#Input image to be measured
Gclear 0
tvinput 1
imgRGB2grey 1,1
MSmeaspoint 1,"database",1,1,1,1,2,1
datalist "eqycd",0,0
Gclear 0
imgdelete "*"
! imgsetpath "c:/ks400/conf/eric/6cpz"
! imgload "c:\ks400\conf\eric\6cpz\calibration image.tif",1
imgprint 1,20,20,150,150,1,"25a"
imgdisplay 1
```

```
# calibrate image and check
MSsetgeom
MSsetfeat "POINTFEAT"
MSmeaspoint 2,"DATABASE",0,10,1,1,2,1,1
Gclear 0
# set up measurement parameters
MSsetfeat "REGIONFEAT"
! imgload "sample.tif",3

#  Discriminate grain boundaries by manual editing and rewrite into image
imgsave 3,"sampleaa.tif"
imgdisplay 3

#  Edit image to join up miss grain boundaries
! dislev 3,4,251,255,1
bindilate 4,5,6,1
binerode 5,6,5,1
Gclear 0
imgsave 3,"sampleaa.tif

# Select regions of alumina by region growing technique which are written into image
10, extract graphics and write back into original image 3 as grey level 100.
! reggrow 3,10,2,2,1,348,954,100,200,84
Gextract 10,128,255,11
imgdisplay 3
! Gmerge 3,100
Gclear 0
imgsave 3,"sampleaa.tif

# Select regions of zirconia by region growing technique which are written into image
10, extract graphics and write back into original image 3 as grey level 200.
! reggrow 3,10,2,2,1,348,954,100,200,84
Gextract 10,128,255,11
imgdisplay 3
! Gmerge 3,200
Gclear 0
imgsave 3,"sampleaa.tif

# Select regions of porosity by region growing technique which are written into image
10, extract graphics and write back into original image 3 as grey level 10.
! reggrow 3,10,2,2,1,348,954,100,200,84
Gextract 10,128,255,11
imgdisplay 3
! Gmerge 3,10
Gclear 0
imgsave 3,"sampleaa.tif
```

```
# Set up databases for measurement results
! DBnew "Alumina",8
! DBnew "Zirconia",8
! DBnew "porosity",


# Set up measurement parameters
MSsetframe
MSsetfeat "REGIONFEAT"


# Measure alumina
! dislev 3,15,100,151,1
binscrap 15,16,0,50,0
MSmeasmask 16,1,"Alumina",0,1,10

# Measure zirconia
! dislev 3,15,200,151,1
binscrap 15,16,0,50,0
MSmeasmask 16,1,"Zirconia",0,1,10

# Measure porosity
! dislev 3,15,10,151,1
binscrap 15,16,0,50,0
MSmeasmask 16,1,"porosity",0,1,10

# Review results and copy into Excel spreadsheet, powerpoint or word documents.
! datalist "Alumina",0,0
! datalist "Zirconia",0,0
! datalist "porosity",0,0
datahisto "ALUMINA","AREA",0,15,0.000000,100.000000,100.000000
datahisto "ALUMINA","DCIRCLE",0,15,0.065747,66.022400,318.000000
! datahisto "ALUMINA","NPOLY",0,15,0.289329,9.328000,115.000000
datahisto "ALUMINA","FERETRATIO",0,15,3.000000,30.100000,196.000000

datalist "ZIRCONIA",0,0
datahisto "ZIRCONIA","AREA",0,15,0.089911,0.919812,80.000000
datahisto "ZIRCONIA","DCIRCLE",0,15,0.067011,5.878640,114.000000
datahisto "ZIRCONIA","NPOLY",0,15,0.292098,2.746740,53.000000
datahisto "ZIRCONIA","FERETRATIO",0,15,3.000000,12.090000,102.000000
```

A.3 Region

The following program was used to determine the effect varying POLYDIST had on the measured function NPLOY.

```
! imgload "c:\ks400\conf\eric\6cpz\IMAGE.tif",1
MSsetfeat "REGIONFEAT"
!.MSsetprop "POLYDIST",change the value here".
dislev 1,2,84,255
! MSmeasmask 2,1,"DATABASE",0,1,10
```

A.4 Ultimate Dilation

The following program was used for the ultimate dilation of regions ultimately dilated to determine their zone of influence.

```
# Ultimate dilation progam
#  Load calibration image, calibrate and set feature measurement
! imgload "c:\images for archiving\Calibration Image.tif",1
! MSsetgeom

#Set up measurement parameters
DBnew "Image",1
MSsetfeat "REGIONFEAT"

#  Load image and identify regions
! imgload "c:\images for archiving\Image for measuring.tif",1
! dislev 1,2,100,255,1
binscrap 2,3,0,20,0

#  Perform dilation and measure areas of influence
MSsetframe
binudilate 3,4,5,255
MSmeasmask 4,1,"Image",0,1,10
datahisto "Image","AREA",0,15,0.000000,100.000000,100.000000
datalist "Image",0,0
```

A.5 Porosity size and size distribution

Program used for the measurement of regions of porosity.

```
imgsetpath "c:\ks400\conf\images"
imgload "00000660.tif",1
imgdisplay 1

#  Calibrate Image
MSsetgeom
#  Check Calibration by marking of features
MSsetfeat "POINTFEAT"
MSmeaspoint 1,"database",0,1,1,1,2,1
datalist "database",0,0

#  Set up Measurement Features
MSsetfeat "REGIONFEAT"
MSsetprop "MINAREA",30

# Set up databases for each image and a total
DBnew "LDA1630",8
DBnew "lda1631",8
DBnew "lda1632",8
DBnew "lda1633",8
```

```
DBnew "lda1634",8
DBnew "lda1635",8
DBnew "lda1636",8
DBnew "lda1637",8
DBnew "lda1638",8
DBnew "lda1639",8
DBnew "lda1640",8
DBnew "lda1641",8
DBnew "lda1642",8
DBnew "lda1643",8
DBnew "lda1644",8
DBnew "lda1645",8
DBnew "lda1646",8
DBnew "lda1647",8
DBnew "lda1648",8
DBnew "lda1649",8
DBnew "lda1650",8
DBnew "lda1651",8
DBnew "lda1652",8
DBnew "lda1653",8
DBnew "lda1654",8
DBnew "lda1655",8
DBnew "lda1656",8
DBnew "lda1657",8
DBnew "lda1658",8
DBnew "lda1659",8
DBnew "lda1ttal",8

# Program repeated from this stage for each image
imgdelete "*.*"
Gclear 0

! imgload "00000659.tif",1
imgdisplay 1
scalint 1,2,0,255,5,250
lowpass 2,3,37,40
shadcorr 2,3,4,1,0
MSsetframe
! dislev 4,5,0,43,1

! MSmeasmask 5,1,"lda1630",0,1,10
datalist "lda1630",0,0

#  Set append to on after first measurement
! MSmeasmask 5,1,"lda1ttal",0,1,10

#  Copy Data to excel
datalist "lda1630",0,0
datalist "lda1ttal",0,0
datahisto "lda1630","AREA",0,15,0.000000,100.0
```

A.6 Dilation for Spatial Distribution

```
imgsetpath "c:/ks400/conf/eric/Lde1"
imgload "00000690.tif",5
imgdisplay 5

# Image processing operations for grey level images if binary image does not exist.
lowpass 5,6,49,25
shadcorr 5,6,7,1,0
! dislev 7,8,0,63,1
imgcopy 8,2

#Load existing binary image into image memory 2
MSsetgeom
! DBnew "Lde1a",3
MSsetprop "CONDITION",1
MSsetprop "FRAMEMODE",0
MSsetprop "SCALEX",1
MSsetprop "SCALEY",1
MSsetprop "REGIONFEAT","AREA,CGRAVX,CGRAVY"

binscrap 2,2,0,10,0
imgdelete 3
! MSmeasmask 2,1,"Lde1a",0,1,10
datalist "Lde1a",0,0
datahisto "LDE1A","1",0,15,0.000000,100.000000,100.000000
imgstatus 2, xdim,ydim,1,"Grey"
imgnew 3, xdim,ydim,1,"Grey"
imgdisplay 3

# Get centre of gravity for each region from database and draw single pixel into
image
! DBfirstline "Lde1a"
while 1
DBgetvalue "Lde1a","CGRAVX",CGX
DBgetvalue "Lde1a","CGRAVY",CGY
showwindow "Messages",1
write "CGX", CGX
write "CGY", CGY
imgdisplay 3

Gpixel int(CGX),int(CGY),11
Gmerge 3,255
Gclear 0
DBnextline "Lde1a"

if _STATUS==0: break
endwhile
```

```
bindilate 3,4,6,1
dislev 4,5,240,255,1
MSsetframe
! DBnew "Cogdilate",2
! MSsetfeat "FIELDFEAT"
! MSmeasmask 5,1,"Cogdilate",0,2,10
!
dilation=1
for y=dilation, y<100, y=y+dilation
bindilate 5,6,6,1
MSmeasmask 6,1,"COGDILATE",1,2,10
imgdisplay 5
datalist "COGDILATE",0,0
imgcopy 6,5
endfor
! datalist "COG",0,0
imgdelete 3
imgdelete 2
! datalist "COGDILATE",0,0
Gextract 3,128,255,11
imgdisplay 7
Nearest Neighbour
# demo of nearest neighbour function
# load 'nearest' function
fcnload "nearest.mcr"
# load and segment image
! imgload "Image.tif",1

MSsetprop "FRAMEMODE",1
MSsetprop "FRAMESTARTX",1
MSsetprop "FRAMESTARTY",1
MSsetprop "FRAMESIZEX",sizeX
MSsetprop "FRAMESIZEY",sixeY

imgdisplay 1
datalist "NEAREST",0,0
datahisto "NEAREST","DISTANCE",0,15,0.000000,100.000000,100.000000
# Call macro near_nb
near_nb 3,1,"nearest",0
datalist "nearest",0,0
```

A.7 Nearest Neighbour

Macro for determining the nearest neighbour distance between regions. Nearest Neighbour

```
# demo of nearest neighbour function
# load 'nearest' function
fcnload "nearest.mcr"
# load and segment image
```

```
! imgload "Image.tif",1

MSsetprop "FRAMEMODE",1
MSsetprop "FRAMESTARTX",1
MSsetprop "FRAMESTARTY",1
MSsetprop "FRAMESIZEX",sizeX
MSsetprop "FRAMESIZEY",sixeY

imgdisplay 1
datalist "NEAREST",0,0
datahisto "NEAREST","DISTANCE",0,15,0.000000,100.000000,100.000000
# Call macro near_nb
near_nb 3,1,"nearest",0
datalist "nearest",0,0
```

A.8 Nearest

This Macro is called from the Nearest Neighbour Macro. It finds the shortest distance between one region and another by sequentially looking at the database and calculating the distances to all the other regions and selecting the smallest value. As a visual aid, the macro also draws the distance vectors into the image.

```
# Nearest Neighbour
macro near_nb(MaskImage=2,DensImage=1,DataBase="nearest",append=0)
~Nearest Neighbour Measurement
~$inpimage
~$inpimage
~$dbase
~$logic

MSgetprop "REGIONFEAT",regionfeat
MSgetprop "DRAWFEAT",drawfeat
MSsetprop "REGIONFEAT","CGRAVX,CGRAVY"
MSsetprop "DRAWFEAT","DRCGRAV"
MSmeasmask MaskImage,DensImage,"temp",0,1,12
Gclear 0
MSdrawmask MaskImage,DensImage

DBstatus "temp",1,nl
cgx[nl]:=0.0
cgy[nl]:=0.0

DBfirstline "temp"
for n=1, n<=nl, n=n+1
DBgetvalue "temp","CGRAVX",x
DBgetvalue "temp","CGRAVY",y
cgx[n] = x
```

```
cgy[n] = y
DBnextline "temp"
if _STATUS == 0 : break
endfor

MSgetprop "UNIT",unit
MSgetprop "SCALEX",scalex
MSgetprop "SCALEY",scaley

if append == 0
DBnew DataBase,1
DBsetcolumn DataBase,1,"DISTANCE","Float",unit
endif

for n=1, n<=nl, n=n+1
min = 100000.0
for i=1, i<=nl, i=i+1
if i == n : continue
dx = cgx[n]-cgx[i]
dy = cgy[n]-cgy[i]
d = dx*dx+dy*dy
if d < min
min = d
nmin = i
dmin = d
endif
endfor
Gvector
int(cgx[n]/scalex),int(cgy[n]/scaley),int(cgx[nmin]/scalex),int(cgy[nmin]/scaley),11
DBaddline DataBase
DBsetvalue DataBase,"DISTANCE",sqrt(dmin)
imgdisplay 1

endfor

imgdisplay DensImage
MSsetprop "REGIONFEAT",regionfeat
MSsetprop "DRAWFEAT",drawfeat

endmacro
datalist "NEAREST",0,0
datahisto "NEAREST","DISTANCE",0,15,0.000000,100.000000,100.000000
```

The following image analysis subroutines were used in the example macros. They are from the KS400 image analysis software and therefore not necessary compatible with other software packages. However, they have been included to allow other users to understand how each stage of the image analysis macros were applied.

Appendix B. KS400 Image Analysis Functions

Bindilate

This function dilates structures in the input image.

The Dilate radio button of the Function list in the Morphology dialog box must be selected. Dilation has the effect of growing regions. Connections between regions may be generated and holes are filled. The image Input (binary image) is dilated for Count number of times using the structural element Shape.

Parameters:

Input	Input image
Output	Output image
Shape	Structural element used, 1...7
Count	Number of repetitions

Macro Command:

bindilate Input, Output, Shape, Count

These functions can also use grey value images as input images. In that case, the pixel is only checked for a grey value of 0 or not equal to 0. They are handled just like binary images: the output image will contain only the values 0 and 255.

binerode

This function erodes structures in the input image.

The Erode radio button of the Function list in the Morphology dialog box must be selected. Erosion has the effect of shrinking regions. Also small connections between regions and small regions itself will disappear. The image Input (a binary image) is eroded for Count number of times using the structural element Shape.
The following structural elements (numbered left to right from 1 to 7) are available:

Parameters:

Input	Input image
Output	Output image
Shape	Structural element used, 1...7
Count	Number of repetitions

Macro Command:

binerode Input, Output, Shape, Count

These functions can also use grey value images as input images. In that case, the pixel is only checked for a grey value of 0 or not equal to 0. They are handled just like binary images: the output image will contain only the values 0 and 255

binscrap
This function deletes or selects regions in a specified size range.

The Scrap radio button of the Function list in the Utilities dialog box must be selected. The operation deletes or selects regions on the basis of their total area in pixels. Regions with an area within the range MinArea to MaxArea are effected. To delete regions outside the range, the parameter Select must be active.

Parameters:

Input	Input image
Output	Output image
MinArea	Minimum region size in pixels
MaxArea	Maximum region size in pixels
Select	0 - Select the regions outside the size range
	1 - Deselect the regions within the size range

Macro Command:

binscrap Input, Output, MinArea, MaxArea, Select

binudilate
This function carries out a dilation without allowing regions to grow together.

The Ultimate Dilation radio button of the Function list in the Morphology dialog box must be selected. The function Ultimate Dilation works like a normal dilation, except that dilated regions do not grow together (holes are filled). A separating line of background pixels remains between the regions. The number of regions will remain the same. The operation ends after Count numbers of repetitions. To terminate the function automatically (regions cannot grow any more) set Count to 0.

Parameters:

Input	Input image
Output	Output image
Shape	Structural element used, 1...7
Count	Number of repetitions

Macro Command:

binudilate Input, Output, Shape, Count

These functions can also use grey value images as input images. In that case, the pixel is only checked for a grey value of 0 or not equal to 0. They are handled just like binary images: the output image will contain only the values 0 and 255.

datahisto
This function displays the measurement parameter from a database as a histogram in the Data Histogram window.

The histogram of the Parameter of the DataBase is calculated and displayed. The number of Classes can be entered as the value range of the parameter (MinParam, MaxParam). The maximum displayable frequency of distribution (ordinate) is MaxCount. This parameter range is ignored if Autorange is activated in the menu Options (see below). If the parameters MinParam, MaxParam or MaxCount are variables, they will get the corresponding values if Autorange is selected. The text string Title is used as the title of the diagram. Use the special character ("^") to display blanks.

Parameters:

DataBase	Data file to be displayed
Parameter	Name of the parameter
Print	1 - Print window 0 - Do not print window
Classes	Number of classes
MinParam	Minimum parameter value for the histogram
MaxParam	Maximum parameter value for the histogram
MaxCount	Maximum displayed distribution frequency
Title	Title text

Macro Command:

datahisto DataBase, Parameter, Print, Classes, MinParam, MaxParam, MaxCount, Title

datalist
This function displays the data from databases as a data listing. A file is selected from the list box DataBase. If the check box Print is activated, the values are also printed. When the check box Clipboard is activated, the values are copied to the clipboard. The file name (in this case database), database and size are shown in the title bar of the window. The file has three measurement parameters and 322 records. The first nine records are shown. Using the scroll bars you can move between the data records (vertical scroll bar) and the parameters (horizontal scroll bar). Using the short horizontal scroll bar you can move up and down in the file.

Parameters:

DataBase	Name of the database to be displayed
Print	0 - Do not print window
	1 - Print window
Clipboard	0 - Do not copy to the clipboard
	1 - Copy to the clipboard

Macro Command:

datalistDataBase, Print, Clipboard

Dbaddline

This function adds a line (record) to the end of a database.
To add data to a database a new line must be added first. This is only possible at the end of the database.To create a database use the function New (macro command DBnew). To write data to a database file use the function Set Value (macro command DBsetvalue).

Parameters:

DataBase	File name of database

Macro Command:

DBaddline	DataBase

Dbfirstline

This function sets the database pointer to the first line (record).
Before reading from or writing single values to a database the pointer must be set to a defined position. To read a value from a database use the function Get Value (macro command DBgetvalue). To write a value to a database use the function Set Value (macro command DBsetvalue). To advance to the next line (record) use the function Next Line (macro command DBnextline). After the function execution the global variable _STATUS shows if more data are available. When the _STATUS value is 0, the database does not contain any more data.

Parameters:

DataBase	File name of database

Macro Command:

DBfirstline	DataBase

Dbgetvalue

This function reads one value from a database.
The Value is read from the defined Column at the current line in the file DataBase. The line (record) can be set with the functions First Line and Next Line (macro commands DBfirstline and DBnextline). The value should correspond with the column type (float, int or string) definition. To write a value use the function Set Value (macro command DBsetvalue). The parameter Value must be a variable (from the same type used in the specified column) to receive the return value.

Parameters:

DataBase	File name of database
Column	Column number
Value	Return value from database

Macro Command:

DBgetvalue	DataBase, Column, Value

Dbnew

This function creates a new database file.
Normally the database files are created automatically by the measurement functions. To create a database according to the settings of the properties REGIONFEAT or FIELDFEAT use the function DBnewMS. For special purposes (e.g. storing text) it is useful to create a user defined database file. Data must be written with the function DBsetvalue. If the database file already exists, the file is completely overwritten. Use the function DBexist to test the existence of a database. The number of columns also is to be defined. To set the data type for each column use the function Set Column (macro command DBsetcolumn). The default directory for database files is C:\KS400\CONF\DATA. The directory can be changed with the function DBsetpath.

Parameters:

DataBase	File name of database
Column	Number of columns

Macro Command:

DBnew	DataBase, Column

Dbnextline

This function sets the database pointer to the next line (record).
Before reading from or writing single values to a database the pointer must be set to a defined position. To read a value from a database use the function Get Value (macro command DBgetvalue). To write a value to a database use the function Set Value (macro command DBsetvalue). To print to the first line use the function First Line

(macro command DBfirstline). After the function execution the global variable _STATUS shows if more data are available. When the _STATUS is 0 the pointer is at the end of the database.

Parameters:

DataBase	File name of database

Macro Command:

DBnextline	DataBase

Dbsetcolumn

This function defines the data type and name of a column in a database.
This function must be used, when a database was defined with the function New (macro command DBnew) to define entries of one record. The default String length is 15 characters. If more characters are needed, set the parameter Type to the desired length plus one. The maximum value for Type is 254. The column definition can be read with the function Get Column (macro command DBgetcolumn). Each column in a database can be redefined as long as there are no lines added to the database.

Parameters:

DataBase	File name of database
Column	Column number
Name	Feature name
Type	Feature type

Float - Floating point number
Int - Integer number
String - Text string
Unit Feature unit

Dbsetvalue

This function writes a value to a database.
The Value is written to the defined Column at the current line in the file DataBase. The line (record) can be set with the functions First Line and Next Line (macro commands DBfirstline and DBnextline). The value should correspond with the column type (float, int or string) definition. To read a value use the function Get Value (macro command DBgetvalue).

Parameters:

DataBase	File name of database
Column	Column number
Value	Value to write

Macro Command:

DBsetvalue	DataBase, Column, Value

Dbstatus

This function gets the size of a database.
The number of Columns and Lines (records) in the database is returned. The two parameters must be variables to get the return values.

Parameters:

DataBase	Name of database
Columns	Number of columns (features)
Lines	Number of lines (records)

Macro Command:

DBstatus	DataBase, Columns, Lines

Dislev

This function performs grey value segmentation.
The Interactive radio button of the Function list in the Threshold dialog box must be selected. Segmentation is especially used to generate binary regions. They are needed for measurement. Two threshold values determine which grey value range of the image Input is retained or deleted in the image Output. The threshold values Low and High are determined either by moving the borders in the grey value histogram or by using the scroll bars below. In addition, the Low, Center and High values can be set by making entries in the appropriate fields.

If the low (L) and high (H) values are to be moved together, the horizontal line in the histogram can be moved, or the center (C) scroll bar can be adjusted. The parameter Colour radio buttons Green and Blue/Red determine whether the pixels inside (Green) or outside (Blue/Red) of the grey value range [Low, High] are displayed in the appropriate colour:

If Green is selected, the pixels within the chosen range are overlaid with green, while the rest of the image retains its original grey values. The pixels with the grey values Low and Low+1 are defined in blue. The pixels with the grey values High and High1 are defined in red.

If Blue/Red is selected, the pixels with grey values within the range Low, High remain unchanged. Pixels with grey values lower than Low are overlaid with blue, those with grey values higher than High with red.

If the Invert option is selected, the area outside the selected range is chosen.

If the Binary option is selected all grey values within the range Low to High are set to white (grey value 255) in the image Output, the rest are set to 0. If the option is not selected, the grey values in the selected range remain unchanged and those outside are set to black (grey value 0).

If the image Input is a true colour image, the lightness channel is displayed in the histogram (the image is internally converted from RGB to HLS). For the segmentation of true colour images use the optional function ThresholdRGB (macro command dislevrgb).

Parameters:

Input	Input image
Output	Output image
L	Lower grey value threshold
H	Upper grey value threshold
Binary	0 - Selected pixels retain their original grey value 1 - Selected pixels are set to the grey value 255, the remainder to grey value 0

Macro Command:

dislev Input, Output, L, H, Binary

Endfor

This loop allows a code section to be repeated a specified number of times. The nesting level is limited to a value of 10.

Syntax: for (start value, condition, increment)
.
endfor
or for (start value, condition, increment): function

The condition is a logical expression, start value and increment are arithmetic or logical expressions.

Example: for i = 1, i < 15, i = i+1 : write i

```
for i = 1, i < 5, i = i+1
  imgdisplay i
  write "Image : ",i
  pause
endfor
```

endwhile

See "while"

Fcnload

Before a user defined macro function can be called, it has to be made known to the system. This is accomplished by calling this function.

Parameters:

file Macro file to load, the full path and extension of the file must be specified

Macro Command:

fcnload file

Syntax for Calling a User Defined Macro Function

This is accomplished by executing the function fcnload, e.g. fcnload "path/user.mcr", when USER.MCR is the file name, in which the macro function USERNAME has been defined. User defined functions are also added to the function list of the system if a macro file containing the defined functions is loaded. While the KS software is started the system is searching for the file USERINIT.MCR in the directory C:\KS400\CONF\MACROS. If the file exists it is automatically executed. The macro may contain any valid command line as any other macro. This initialization macro is useful to arrange a standard system status (e.g. opening or closing windows or setting the image and data directory).

Passing constants username 1,2,"abc",4
Passing variables username 1,2,"abc",d=4
or
username a=1,b=2,c="abc",d=4
or
d = 4username a,b,c,d

for

This loop allows a code section to be repeated a specified number of times. The nesting level is limited to a value of 10.

Syntax: for (start value, condition, increment)
.
.
endfor
or for (start value, condition, increment): function
The condition is a logical expression, start value and increment are arithmetic or logical expressions.

Example: for i = 1, i < 15, i = i+1 : write i

```
for i = 1, i < 5, i = i+1
  imgdisplay i
  write "Image : ",i
  pause
endfor
```

Gclear

This function sets all graphics plane pixels to one colour.
The graphics plane is filled with the selected Colour. The display device (Display or DisplayMDI window) can be changed with the function seldisplay.

Parameters:

Colour Colour for drawing the graphics plane, 0...15
0 - Transparent, clear graphics plane

1 - Blue	9 - Light blue
2 - Green	10 - Light green
3 - Cyan	11 - Light cyan
4 – Red	12 Light red
5 – Magenta	13 - Light magenta
6 – Yellow	14 - Light yellow
7 - Light grey	15 - White
8 - Dark grey	

Macro Command:

Gclear Colour

Gextract

This function copies parts of an image into the graphics plane.
The function Extract Graphic sets the graphics plane for all those pixels having grey values within the range from Low to High. The rest of the graphics plane is not changed. The colour of the graphics plane pixels is selected from the list box Colour. In true colour images the operation is carried out on the lightness channel of the internally converted image. The graphics plane can be selected with the function seldisplay.

Parameters:

Input	Image from which the graphics plane is extracted
Low	Grey value, lower limit of range
High	Grey value, upper limit of range

Colour Colour for drawing the graphics plane, 0...15
0 - Transparent, clear graphics plane

1 - Blue	9 - Light blue
2 - Green	10 - Light green
3 - Cyan	11 - Light cyan
4 - Red	12 - Light red
5 - Magenta	13 - Light magenta
6 - Yellow	14 - Light yellow
7 - Light grey	15 - White
8 - Dark grey	

Macro Command:

Gextract	Input, Low, High, Colour

Gmerge

This function copies the graphics plane to a grey value of an image.
The grey value of Image is set using the scroll bar (GreyValue). The function Merge Graphic changes the grey value of the pixels of Image, for which the graphics plane is set, to the grey value GreyValue. If the Image is of type "Colour" the parameter GreyValue is not available. The graphics plane is copied to the image channel maintaining the colour. Pixels for which the graphics plane is not set remain unchanged.

The graphics plane can be selected with the function seldisplay.

Parameters:

Image	Image to be changed
GreyValue	Grey value (if image type is "Grey")

Macro Command:

Gmerge	Image, GreyValue

Gpixel

This function sets a single pixel in the graphics plane and reads the cursor coordinates.
A single pixel in the graphics plane is set at the coordinates PixelX and PixelY with the defined Colour. If the pixel coordinates are outside of the currently displayed image, the graphics plane is not changed. While the dialog box is open, the pixel position can be defined interactively in the Display window. If the function is executed interactively from a macro (apply the character "!" as a prefix to the command line), the first mouse click on an image will end the function.

The graphics plane can be selected with the function seldisplay.

Parameters:

PixelX	Pixel position, X-coordinate
PixelY	Pixel position, Y-coordinate

Colour Colour for drawing the graphics plane, 0...15

0 - Transparent, clear graphics plane	
1 - Blue	9 - Light blue
2 - Green	10 - Light green
3 - Cyan	11 - Light cyan
4 – Red	12 - Light red
5 – Magenta	13 - Light magenta
6 - Yellow	14 - Light yellow
7 - Light grey	15 - White
8 - Dark grey	

Macro Command:

Gpixel PixelX, PixelY, Colour

Gvector

This function draws a vector in the graphics plane.
A line or vector is drawn in the graphics plane beginning at the start position StartX and StartY and ending at the position EndX and EndY. Drawing is done with the defined Colour. If the line does not fit entirely in the currently displayed image, only the visible part will be drawn. While the dialog box is open, the line can be defined interactively in the Display window.

The graphics plane can be selected with the function seldisplay.

Parameters:

StartX	Starting point of the line, X-coordinate
StartY	Starting point of the line, Y-coordinate
EndX	End point of the line, X-coordinate
EndY	End point of the line, Y-coordinate

Macro Command:

Gvector	StartX, StartY, EndX, EndY, Colour

If

Loops, conditions and submacros (Xmacro) can be nested a maximum of 180 times.
The nesting level is limited to a value of 10.
if-else-endif branching
The result of a condition can be used to branch within a macro.

```
Syntax:     if (condition): function
or      if (condition)
        .
        .
        endif
or      if (condition)
        .
        .
        else
        .
        .
        endif
```

The condition is a logical expression and can be used with or without parentheses.

Imgcopy

This function copies an image.
The content of the image Input is copied to the image Output. In addition the look-up table of the image Input is copied to the image Output.
The simplest way to copy images is the drag and drop method. Press the left mouse button when the cursor is positioned on an image in the Gallery (the appearance of the cursor changes). Pull the mouse to the output image inside the Gallery
, and then release the mouse button. The image is copied. If the recording mode of the Macro editor is activated, imgcopy is automatically inserted into the macro.

It is also possible to use drag and drop to copy images from or to the Display window. These actions are not recorded.

Parameters:

Input	Input image
Output	Output image

Macro Command:

imgcopy	Input, Output

imgdisplay

This function displays an image.
The parameter Image is displayed in the Display window, even if the window is closed. An image can also be displayed by drag and drop from the Gallery to any image window or to the Display window. The corresponding look-up table is loaded into the Display window along with the image.

Parameters:

Image	Image to be displayed

Macro Command:

imgdisplay	Image

imgdelete

This function deletes an image from memory.
After the function has been executed, the specified image does not exist any more in the memory/Gallery. Use the function Clear (macro command imgclear), if you only want to clear the contents of an image. If "" is selected in Image all images, except protected images which are present in the Gallery, are deleted.
An image can also be deleted by dragging from the Gallery or an image window, and dropping it in the waste basket of the Gallery. If the Macro editor is activated, the appropriate macro command is automatically inserted into the macro. If the Display window is not open, the image is displayed in the dialog box. To see the image in full size click with the right mouse button on it and select Big Display.

Parameters:

Image Image to be deleted or "" for all images

Macro Command:

imgdelete Image

imgload

This function loads an image file from a disk or network drive.
All image files in the current directory with the selected image format are displayed in the File Name list box. The image directory can be set with the function imgsetpath. The default path for images is C:\KS400\CONF\IMAGES. In this path the delivered images are located. The directories on the current drive are shown in the Directories list box. Another drive may be selected from the Drives list box. The image format is selected in the list box List Files of Type. Some of them store also the look-up table (LUT). The type work will list the content for the Gallery. The following types are supported:

Image Type	LUT	Extension
Work (Gallery)	yes	WOR
CZV (previous Kontron Elektronik)	yes	IMG
MAC, Mac Point	no	MAC
PCX, Zsoft Paintbrush	no	PCX
BMP, Bitmap	yes	BMP
TIFF, Tagged Image File Format	yes	TIF
JPEG, Joint Photography Expert Group (works with true colour images only)	---	JPG

If Preview is activated, the content of the selected image is displayed on the left side. The right image shows the content of the image in which the selected image is to be loaded. The name of the selected image is displayed above it. Information about the image is given in the lower right section of the dialog box.

Parameters:

Input	File name of the input image
Output	Name of the output image

Macro Command:

imgload Input, Output

imgnew

This function creates a new image.
This function is only used when a user-defined image size is needed. The dimension in X and Y might be of any rectangular shape. The size is calculated as follows:

Type "Grey": SizeX SizeY
Type "Colour: 3 SizeX SizeY

New images are initialized with a grey value of 0. Grey value images are displayed at 8 bits per pixel. True colour images are created as 3 8 bit per pixel. New grey value images are initialized with the look-up table "Grey".

The radio buttons Grey and Colour are only displayed in the dialog box, if the option True Colour is installed and configured.

Parameters:

Image	Image name
SizeX	Width of new image
SizeY	Height of new image
SizeZ	Set to 1 - Reserved for future use
Type	"Grey" - 8 bit grey value image
	"Colour" - 24 bit true colour image

Macro command:

imgnew Image, SizeX, SizeY, SizeZ, Type

imgRGB2grey

This function converts a true colour image to a grey value image.
The intensities of the three colour channels of the image Input are combined and written to the image Output.

Parameters:

Input	Input image (colour image)
Output	Output image (grey image)

Macro Command:

imgRGB2grey Input, Output

imgprint

This function prints an image on any standard Windows printer.
The quality of the printed image depends on the installed printer, and the settings of the Windows printer driver.
The dialog box offers the possibility to define the position and size of the image at the print page. Setting the check box ShowDialog before printing opens the standard Windows dialog for the printer settings after pressing OK or Apply. A title can be defined in the edit box Text.

If the Display window is not open, the image is displayed in the dialog box. To see the image in full size, click with the right mouse button on it and select Big Display.
If the parameter ShowDialog is active, the following dialog box appears:

imgsave

This function stores an image on a disk or network drive.
All image files in the current directory with the selected image format are displayed in the File Name list box. The image directory can be set with the function imgsetpath. The default path for images is C:\KS400\CONF\IMAGES.
The directories on the current drive are shown in the Directories list box. Another drive may be selected from the Drives list box. The image format is selected in the Save Files as Type list box.

The image format is selected in the list box List Files of Type. Some of them store also the look-up table (LUT). The type work will list the content for the Gallery. Following types are supported:

Image Type	LUT	Extension
Work (Gallery)	yes	WOR
CZV (previous Kontron Elektronik)	yes	IMG
BMP, Bitmap	yes	BMP
TIFF, Tagged Image File Format	yes	TIF
MAC, Mac Point	no	MAC
PCX, Zsoft Paintbrush	no	PCX
Bio-Rad (optional)	no	PIC
LSM, Zeiss (optional)	no	LSM
JPEG, Joint Photography Expert Group (works with true colour images only) ---		JPG

The image types TIFF and JPEG can save the image in compressed form. To define the type of compression the function imgpackmode must be executed.
The image which is to be stored is displayed on the left side. The selected image number is displayed above it. If Preview is selected, the current content of the image File Name if present is shown on the right. Information about the image is displayed in the lower right section of the dialog box.

Parameters:

Input Input image
Output File name

Macro Command:

imgsave Input, Output

imgsetpath

This function sets the path for the image directory.
The directory entered must already exist. A root directory cannot be assigned ("C:\").
The functions Load (macro command imgload), Save As (macro command imgsave), and imgenum use this directory. The function imggetpath returns the setting of the current directory.

Parameters:

ImagePath	Image drive and directory

Macro Command:

imgsetpath	ImagePath

imgstatus

This function displays information about an image.
Information about image size and type of the parameter Image is provided. An alternative way to get the same information is to press the right mouse button, when the cursor is positioned on an image in the Gallery and selecting Info.
All parameters are return values except for the parameter Image. The variables contain values after the execution of the function. The global variable _STATUS contains the size of the image in kB.

Parameters:

Image	Input image
SizeX	Width of image
SizeY	Height of image
Slices	Number of images (reserved for future use)
DataType	Image type ("GREY" or "COLOR")

Macro Command:

imgstatus	Image, SizeX, SizeY, Slices, DataType

lowpass

This function performs a Lowpass filter.
The Lowpass radio button in the Function list of the Smoothing dialog box must be selected. The grey value of every central pixel is substituted by the average of its surrounding neighbors. The neighbors taken into account are defined by a square. The affected pixel is the central pixel of the filter matrix. The noise in the image is reduced, but region edges become blurred, local maxima are leveled, the dynamic range is strongly reduced.

The size of the filter is set using the Size scroll bar. Even numbers are set to the next odd value. The Size defines the strength of the smoothing operation. The Count scroll bar determines the number of iterative operations.

Parameters:

Input	Input image
Output	Output image
Size	Size of the square to be averaged (3...49, only odd numbers)
Count	Number of repetitions (1...50)

Macro Command:

lowpass	Input, Output, Size, Count

Msdrawmask

This function draws geometrical features to the graphics plane.
All regions are tested against the defined conditions before the features are drawn. Conditions can be set with the functions Set Property, Set Frame Set Frame, and Set Condition (macro commands MSsetprop, MSsetframe, and MSsetcond).
The features to draw are defined in the property DRAWFEAT. This property can be set with the functions Set Property and Set Features (macro commands MSsetprop and MSsetfeat). All features beginning with the prefix DR will be drawn graphically. All other features will be represented as numbers at the ACPX and ACPY point of the regions.

The regions are defined with a MaskImage. The DensImage is needed for the densitometric measurement. The graphics plane is not cleared during function execution.

Parameters:

MaskImage	Binary image with regions
DensImage	Image for densitometric measurement

Macro Command:

MSdrawmask	MaskImage, DensImage

MSgetprop

This function gets a single measurement property.
The property values can be read and tested to check interactively defined settings. A predefined set with all properties can be read or written with the functions Load/Save Measurement File As (macro commands MSload and MSsave). Single properties can be set with the function Set Property (macro command MSsetprop). There are also functions to set a group of properties interactively (functions Geometric Calibration, Densitometric Calibration, Set Frame, Set Condition, and Set Features (macro commands MSsetgeom, MSsetdens, MSsetframe, MSsetcond, and MSsetfeat).

The parameter Value must be a variable to get the return value.

Parameters:

Property	Name of the property
Value	Variable, which gets the values

Macro Command:

MSgetprop	Property, Value

MSmeasmask

This function carries out an automatic or a selective measurement.
All regions are tested against the defined conditions before they are measured. Conditions can be set with the functions Set Property, Set Frame, and Set Condition (macro commands MSsetprop, MSsetframe, and MSsetcond).
The regions are defined with a MaskImage (regions must be separated by black pixels with grey value 0). The DensImage is needed for the measurement of densitometric features. The results are written to a DataBase file. It is possible to Append data if the selected features are the same as those in the existing DataBase. The Mode defines if the region features (property REGIONFEAT) or the field features (property FIELDFEAT) are to be measured.

The difference of Region Select and Region Reject takes place in the interactive Mode only. Region Select means, no regions are selected when the dialog is started (the user has to select regions). To select all regions at the beginning choose the Mode Region Reject. Executing the function in the non-interactive mode will measure in both terms all regions. Field will calculate the field specific features of the selected regions. Selection or deselection of regions is not possible in this Mode.

Class defines to which class the selected regions should belong. The class selection is only useful while defining a new classifier (refer to Teach Classifier, macro command MSclassteach). To define the class members the feature CLASS must be included in the property REGIONFEAT. The table shows all measurement values if the cursor is placed on a region. The left image (MaskImage) shows the valid regions, marked with a contour. A red coloured contour means, that the region is not selected. A selected region is marked by a green contour or the Class colour if the feature CLASS is a member of the feature list. The right image (DensImage) shows the selected regions in the corresponding class colour. To display the images in full size double click at them or click with the right mouse button on them and select Big Display from the context menu. Clicking on a region will change its status (selected, not selected).

Parameters:

MaskImage	Mask image defining the regions
DensImage	Image for densitometric measurement
Database	Name of database
Append	0 - Values are written to a new database 1 - Values are appended to the database
Mode	0 - Region Select: No regions are selected in the interactive mode. Features defined in the property REGIONFEAT are measured. 1 - Region Reject: All regions are selected originally in the I interactive mode. 2 - Field: All selected features defined in the property FIELDFEAT are measured
Class	Membership of selected regions

Macro Command:

MSmeasmask MaskImage, DensImage, DataBase, Append, Mode, Class

Msmeaspoint

This function measures point specific measurement features.
Points are defined interactively in the graphics plane of the Display window. If the Display window is not open, the image is displayed in the dialog box. To display this image in full size double click in it or click on it with the right mouse button and select Big Display from the context menu.
The results are written to the DataBase file. It is possible to Append data if the current features are the same as those in the existing DataBase.

The following four point features can be measured. Feature solution is defined by the property POINTFEAT.
The AREA feature can be measured in two ways:

- Polygon: The user clicks on the corners of the polygon. Pressing the right mouse button closes the contours.
- Freehand: The contours are drawn with the left mouse button pressed. The contour is closed when the left mouse button is released if Autoclose is selected.

The DISTANCE feature (length) can be measured in three ways:

1 Vector: The user clicks on the beginning and ending points of the vector.
2 Line: holding the left mouse button down and clicking along the points of a polygon line draws a line. Pressing the right mouse button terminates the drawing.
3 Calliper: A straight line is first defined by clicking on two points. Perpendicular to this line another line is drawn (drop line) to the current cursor position and its length is measured. The ending point is set with a mouse click.

The MEANDIST feature can be measured in two ways:

1 Vector: The user clicks on the beginning and ending points of the vector.
2 Calliper: A straight line is first defined by clicking on two points. Perpendicular to this line another line is drawn (drop line) to the current cursor position. The ending point is set with a mouse click.

According to the settings of the special properties, the grey values along the defined straight line are read in the following way: There are PROFILES parallel profile lines with a spacing of SPACE read and averaged. After this averaging during reading each grey value along the profile line is smoothed using a window with WINDOW predecessing and WINDOW successing grey values. This averaged profile is used to calculate derivatives and to detect extremas in the profiles. THRESHOLD determines how many of the detected extremas are rejected. A low value will result in many extremas and vice versa. The MODE property defines the kind of extrema that will be detected, as described above.

Finally the mean distance between all detected extrema is calculated as the measurement parameter MEANDIST.

The ANGLE feature can be measured in three ways:

1 Angle 2P: The user clicks on the beginning and ending points of a line. The angle between this line and a horizontal line in the starting point is calculated.
2 Angle 3P: The user first clicks on the base point of the angle, then on a point on each side of the angle.
3 Angle 4P: The user clicks on the beginning and ending points of two lines. The angle is measured at the real or imagined intersection of the two lines.

The COUNT feature counts and marks the points clicked on. The right mouse button terminates the point definition. Three markers are available:

- Square
- Cross
- Circle

OK and Apply are only available if the complete feature set has been measured.

You can get an image from the Gallery at any time and continue the measurement in the new image using drag and drop.

Reset clears all lines and measurement values of the current measurement. Undo clears one measurement value after the other in reverse order of their creation.

Next branches to the measurement of the next measurement feature. The result of the ignored measurement is given the value -1.0. By pressing the Skip button, the previously measured parameter is presented for measurement again and all other parameters are skipped and receive the value -1.0.

Frame and measurement conditions have no effect on this function.

Parameters:

Image	Image to measure
DataBase	Name of database
Append	0 - Values are written to a new database 1 - Values are appended to a database
Colour	Graphics plane colour for drawing
Area	1 - Polygon: Region contours are drawn by clicking on the polygon corners 2 - Freehand: Region contours are drawn with pressed mouse button
Meandist	Mean distance between detected extremas in grey profiles 1 - Vector: A line between two points 2 - Caliper: Perpendicular distance to a base line
Distance	1 - Vector: A line between two points 2 - Line: A polygon or continuous line 3 - Caliper: Perpendicular distance to a base line

Angle	1 - Angle 2P: Two point measurement
	2 - Angle 3P: Three point measurement
	3 - Angle 4P: Four point measurement
Count	1 - Square: Mark point with a square
	2 - Cross: Mark point with a cross
	3 - Circle: Mark point with a circle

Macro Command:

MSmeaspoint	Image, DataBase, Append, Colour, Area, Meandist, Distance, Angle, Count

Mssetfeat

This function sets the measurement features for all measurement functions.
The function determines the features of the region which are to be measured.
A redefinition of measurement features must be done before executing a measurement function (Automatic Measurement, Interactive Measurement, Point Measurement, or Draw Features). If no user definition was done, the settings from the "default" property file are taken. They are loaded automatically when the KS software is started. Feature settings can also be done with the function Set Property (macro command MSsetprop). Before the measurement, check or set all conditions and calibrations (functions Geometric Calibration, Densitometric Calibration, Set Frame, Set Condition, and Set Features, and the property MINAREA).

To store the whole set of conditions, calibrations and feature properties use the function Save Measurement File As (macro command MSsave). To load a property set use the function Load Measurement File (macro command MSload).
To read a predefined feature list select a file from the list box FromFile. To add features from other files to the current selection activate the Append check box.
The parameter Property defines which feature set is currently edited. All feature properties can be edited in one dialog session. After setting one of them, select a different one from the list box. Below the two described parameters is the feature table. This table shows the settings for the currently selected feature set.

Feature is the name of the feature definition. Any user-defined string can be entered. It must include alphabetical characters and numerical digits only and must start with a character. Unit is the name of the feature unit. This name may include any character. If the word UNIT is entered, it is substituted by the property UNIT. If the word DENSUNIT is entered, it is substituted by the property DENSUNIT. These properties can be changed with the functions Set Property, Geometric Calibration, or Densitometric Calibration (macro commands MSsetprop, MSsetgeom, or MSsetdens).

Expression shows the name of the features used by the system. This can also be a combination of system and user defined feature names and global variables. In this case the names of global variables must start with the underline character. Any arithmetical or logical expression and operation can concatenate them. The expression syntax is defined at the beginning of this section.

The maximal length of an expression is 128 characters. Per Property up to 100 features can be defined.

Pressing the Check button can check the names and Expression syntax. This is also done by selecting a different Property or pressing the OK button. If there are errors the line pointer will indicate the first one. The Cut button cuts the current line from the feature table. It can be restored with the Paste button to any position. The Insert button will insert an empty line before the marked position. To clear all feature definitions of the currently selected Property press the Reset button.

The lower half of the dialog box shows all available system features. The very left column shows group names. The single features of the selected group are listed in the middle column. Some standard features with a graphical representation are listed in the third column. Pointing with the mouse on any feature name (second or third column) will show a short description below the columns. Clicking on any feature name will add it to the feature selection of the current Property.

The function works in the interactive mode only (the dialog box is always opened).

Parameters:

Property	Active property in the dialog box

Macro Command:

MSsetfeat	Property

Mssetframe

This function sets the size and characteristics of the measurement frame. Quantitative measurements probably require a correction of the truncation effects at the borders of the image. Only regions, which meet the frame condition, are measured. All measurement functions test the frame condition. The frame is displayed in the Display window. The position and size of the frame can be set by entering the values in the corresponding edit boxes or interactively. To do so move the mouse on the frame line, press and hold the left mouse button, move the line and release the mouse button.

The frame mode and the parameters StartX, StartY, SizeX, SizeY, CenterX, CenterY, and Radius are measurement properties (FRAMEMODE, FRAMESTARTX, FRAMESTARTY, FRAMESIZEX, FRAMESIZEY, FRAMECENTERX, FRAMECENTERY, FRAMERADIUS). They can also be set with the function Set Property (macro command MSsetprop). It is possible to read properties from a predefined property set (file). To do so select the desired file from the list box FromFile. When a new value is defined it is always written to the <current> property set. All measurements are done with the properties defined under <current>.

If the Display window is closed the dialog box will include a zoomed window of the current image. Calibration must be done in this window. For a better control display the image in full size. Click with the right mouse button on the image and select Big Display from the context menu.

The following modes are available for selecting the regions to be measured:

Measurement without measuring frame. All regions are measured.
Regions which are inside the frame but do not cross or touch it are measured.
Regions, which are inside the frame and those, which cross or touch it are measured.
Regions, which are inside the frame and those, which cross or touch it on the top or right are measured.
Regions, which are inside the frame and those, which cross or touch it on the bottom or left are measured.
Regions which are inside the circular frame but do not cross or touch it are measured.
Regions, which are inside the circular frame and those, which cross or touch it are measured.

The function works in the interactive mode only (the dialog box is always opened).

Parameters:
none

Macro Command:

MSsetframe

MSsetgeom

This function sets the calibration for geometric measurement.
When the geometric measurement values should appear in real units (not in pixel) a calibration is needed. This is done interactively.

- Display an image with regions of known size (or a scale).
- Open the dialog box of this function.
- Select the desired Unit from the list box.
- Enter the known size (DistancesX and DistancesY) for a region.
- Size the frame in the Display window to the outline of the selected region. To do so move the mouse on the frame lines, press and hold the left mouse button, move the line and release the button. The values ScaleX, ScaleY, and Ratio will be calculated automatically.
  Click on the OK button.

To store the settings use the function Save Measurement File As (macro command MSsave). The parameters Unit, DistanceX, DistanceY, ScaleX, and ScaleY are measurement properties . They can also be set with the function Set Property (macro command MSsetprop).

It is possible to read properties from a predefined property set (file). To do so select the desired file from the list box FromFile. When a new value is defined it is always written to the <current> property set. All measurements are done with the properties defined under <current>. When the Display window is closed the dialog box will

include a zoomed window of the current image. Calibration must be done in this window. For a better control display the image in full size. Click with the right mouse button on the image and select Big Display from the context menu.

Parameters:
none

Macro Command:
MSsetgeom

MSsetprop

This function sets a single measurement property.
Before measuring an image the properties have to be defined. It is a good idea to define always the complete set to guarantee that all properties have the needed values. A predefined set with all properties can be read or written with the functions Load/Save Measurement File As (macro commands MSload and MSsave). Single properties or values can be read with the function Get Property (macro command MSgetprop).

There are also functions to set a group of properties interactively (Geometric Calibration, Densitometric Calibration, Set Frame, Set Condition, and Set Features (macro commands MSsetgeom, MSsetdens, MSsetframe, Mssetcond, and MSsetfeat). It is possible to read the value of the selected property from a predefined property set (file). To do so select the desired file from the list box FromFile. When a new value is defined it is always written to the <current> property set. All measurements are done with the properties defined under <current>.

When the function is used interactively all properties can be changed (select a property and enter a new value). When the function is used in a macro only one property can be changed at a time. To extend a current property value use the following syntax: MSsetprop "REGIONFEAT",",,PERIM" (double comma at the beginning of the value string). In the lower area of the dialog box (below the parameter Value) a short description of the selected property is displayed.

Parameters:

Property	SCALEX	Horizontal scaling factor
	SCALEY	Vertical scaling factor
	UNIT	Geometric unit
	DISTANCEX	Horizontal scaling distance
	DISTANCEY	Vertical scaling distance
	DENSTABLE	Densitometric transformation table
	DENSFACTOR	Densitometric transformation factor
	DENSOFFSET	Densitometric transformation offset
	DENSUNIT	Densitometric unit
	FRAMEMODE	Frame condition mode (0...6)
	FRAMESTARTX	Upper left corner of rectangular frame, X-coordinate (in pixel)
	FRAMESTARTY	Upper left corner of rectangular

	frame, Y-coordinate (in pixel)
FRAMESIZEX	Width of frame (in pixel)
FRAMESIZEY	Height of frame (in pixel)
FRAMECENTERX	Center of circular frame, X-coordinate (in pixel)
FRAMECENTERY	Center of circular frame, Y-coordinate (in pixel)
FRAMERADIUS	Radius of circular frame (in pixel)
MINAREA	Minimum area of regions (in pixel)
CONNECT	Connectivity of the regions (4 or 8)
CONDITION	Measurement condition
REGIONFEAT	Region features
FIELDFEAT	Field features
POINTFEAT	Point features
DRAWFEAT	Draw features
NSPACE	Line spacing for chord measurement (1...)
NFERETS	Accuracy of feret based parameters(2...128)
POLYDIST	Accuracy of polygon approximation (0...)
WINDOW	Derivative window size
PROFILES	Number of parallel, averaged profiles
THRESHOLD	Threshold in % (0 ... 100)
SPACE	Space between parallel, averaged profiles
MODE	Gradient Mode: 0 - all 1 - positive 2 - negative 3 - valleys 4 - hills
NFD	Number of Fourier descriptors (1...20)
NTEXLEVEL	Grey resolution for texture measurement (2...64)
TEXDISPL	Displacement for texture measurement (1...64)
DEAGSTEP	Circular deagglomeration step
Value	Value for selected property

Macro Command:

MSsetprop Property, Value

reggrow

This function carries out interactive segmentation based on the region growing process.
Region growing is useful when a few regions in an image have to be segmented interactively. Segmentation is especially used to generate binary regions. They are needed for measurement. Neighborhoods are examined during the growing. The parameters SeedX and SeedY define the start point of growing. They can be defined interactively by clicking with the cursor on the image Input. For a better control double-click on the image Input of the dialog box to see it in full size. Regions are detected if they meet certain conditions (Connection, Low and High or Tolerance).

Two processes are used:

- Fixed grey value (Mode = 1: Greyvalue):
-

  The grey values of the growing region must be within the range of Low and High. The histogram is used for the grey value range definition (see the Threshold - Interactive description). Moving the cursor within the image Input will show the current pixel value in the histogram. If the image Input is a true colour image the lightness channel is displayed in the histogram (the image is internally converted from RGB to HLS).

- Average and tolerance range (Mode = 2: Meanvalue):

  The average value is determined constantly during growth from the starting point. Other neighborhood pixels are only selected as part of the region if their grey value is within the average ± tolerance value.

The parameter Colour defines the graphics plane colour to be used within the image Input for region indication. The parameter Connection defines the neighborhood pixels of the region border, which are examined. This can be four or eight connected pixels. If the Binary option is selected the segmented pixels are set to white (grey value 255) in the image Output, the rest is set to 0. If the option is not selected, the original grey values are copied to the image Output.

The previous action can be canceled with Undo. Clear deletes all previous results. The marking colour can be set with Colour.

Parameters:

Input	Input image
Output	Output image
Mode	1 - Greyvalue: Fixed grey value threshold 2 - Meanvalue: Average+tolerance
Connection	1 - 4 connected neighborhood 2 - 8 connected neighborhood
Binary	0 - Retain original grey values 1 - Set segmented pixels to 255
SeedX	Start pixel, X-coordinates
SeedY	Start pixel, Y-coordinates
L	Lower grey value threshold, only Mode 1
H	Upper grey value threshold, only Mode 1
Tolerance	Maximum allowed difference between the average grey value of the region and neighborhood pixels, only Mode 2

Macro Command:

reggrow	Input, Output, Mode, Connection, Binary, SeedX, SeedY, L, H, Tolerance

Example:

```
imgdelete "*"
```

scalint

This function allows interactive changes of the contrast of an image.
The Interactive radio button of the Function list of the Contrast dialog box must be selected. A grey value range in the image Input is scaled to another range of the image Output. Both ranges can be edited interactively. This function is used to achieve a better view of an image, or to scale a range of grey values to single value for a special coding in an image. The function does not improve the result of the linear segmentation function Threshold (macro command dislev).

The Input histogram shows the grey value distribution of the image Input. The horizontal axis represents the grey values from 0 to 255. The vertical axis represents the pixel count. The selected range is marked by the borderlines in the histogram. There are three ways to change the range: clicking and dragging the borderlines with the mouse, entering a new value in the appropriate text boxes, or clicking on the buttons. If Input is a true colour image, the histogram will show the lightness channel of it (it is internally converted to HLS format).

The vertical scale of the histogram is set using the scroll bar, and is set at 13% in the example. The units are percents of the maximum grey value distribution. This setting has no influence on the function.
The Output histogram is used to define the grey value range, used with in the image Output.

Parameters:

Input	Input image
Output	Output image
LowIn	Lower grey value of image Input
HighIn	Upper grey value of image Input
LowOut	Lower grey value of image Output
HighOut	Upper grey value of image Output

Macro Command:

scalint Input, Output, LowIn, HighIn, LowOut, HighOut

shadcorr

This function corrects shading using a shading reference image.
The main causes of shading in an imaging system are:

Irregular lighting
Vignetting by the optical system
Irregular sensitivity of the camera sensor

First the reference image is acquired. The conditions (focal length, lens, focus, lighting) must not be changed during acquisition of the image Reference and the image Input. The reference image should contain as little noise as possible. If a camera with a macro lens acquires the images, a white region (paper) can be used to create the reference image. In case of a microscope with transmitted illumination, an

empty area of the slide can be used as a reference image. In case of microscope with reflected illumination a clean polished surface of the region can be used.

If a reference image cannot be acquired, it can be generated with a filter function (functions Smooth - Lowpass, Smooth - Median, macro commands lowpass, median), using a large matrix size. If the Add option is activated, an additive correction is carried out, and the brightness of the image is affected. If the Multiply option is selected, a multiplication correction is carried out, and the contrast of the image is affected.

The image Output can be adjusted by a constant grey value Offset, if the resulting image is too light or too dark. Negative values are set to 0, and values exceeding 255 are set to 255.

Parameters:

Input	Input image
ShadRef	Shading reference image
Output	Output image
Mode	1 - Multiplied correction, using multiplication
	2 - Additive correction, using addition
Offset	Grey value offset of output image, -255...255

Macro Command:

shadcorr	Input, ShadRef, Output, Mode, Offset

showwindow

This function switches the various windows, bars, boxes and menus on or off. This assures a certain layout of the system.

Parameters:

Window	Define the window to open or close
	Display
	Graphic
	Gallery
	Splitter
	Magnify
	Messages
	ToolBox
	Editor
	MenuBar
	ToolBar
Show	Selected status:
	0 - Close window
	1 - Open window

Macro Command:

showwindow	Window, Show

tvframeinput

This function gets an image from the input device using defined position and size of the image section to be stored.
The dimensions of video images are limited implicitly by TV standards (PAL, NTSC) and explicitly by the hardware of the frame grabber. This function sets the position and size of the image digitized within these limitations. The function uses the settings as defined with tvsetup.
For a detailed description please refer to the Frame Grabbers User's Guide.

Parameters:

Image	Name of the image into which the acquired image will be stored
StartX	Left margin of frame
StartY	Upper margin of frame
SizeX	Width of frame
SizeY	Height of frame

Macro Command:

tvframeinput	Image, StartX, StartY, SizeX, SizeY

tvinput

This function acquires an image from the selected frame grabber.
A live image is displayed, if the function is executed in the interactive mode.
If the Display window is not open, the image is displayed in the dialog box. To see the image in full size click with the right mouse button on it and select Big Display.
Depending on the currently selected frame grabber or camera driver, the dialog box shows different parameters that can be adjusted.
The following parameters can be set in any case:

Live	0 - The Display window shows the contents of Image 1 - The Display window shows a live image
FastLive	0 – Live display using the Bus Copy mode 1 - If the currently selected frame grabber / camera supports the OnlineMode property, a live image is displayed in a fast mode
Unit	Milliseconds Seconds Minutes

When using a camera that supports variable exposure times, Unit is used to determine, if the subsequent value Exposure is measured in milliseconds, seconds, or minutes.

Exposure Exposure time in Units
Supported range is 0...10000, when Milliseconds is selected, 0...1000, when Seconds is selected and 0...30, when Minutes is selected. Note: an exposure time of e.g. 2 seconds will be displayed as 2000 milliseconds. Focus, if Live is set to 1 and FastLive is set to 0, a focus value is calculated and shown. It is used to easily check if the image is in focus or not. The Display window shows a small rectangle, which

specifies the size and the region where the focus values are calculated. The current focus value is shown as a green slider, whereas the maximum value, that was measured, is shown as a red marker in the slider field. Handling: move the rectangle to the region that shall be focused and modify the focus with the appropriate button on your microscope. The ultimate foucs is reached, when the green bar has maximum size.

A click in the focus slider left of the red maximum marker will set the marker into the center of the slider, clicking with the right mouse button will show a context menu, which allows to modify the parameters for calculation of the focus value.
Linear, Square Root, Autoscale, Average, Refresh

Depending on the type of frame grabber/camera, the following parameters will be shown:

Monochrome input:	RefLow, RefHigh, Lower and upper reference value adjustment of brightness and contrast of the image (range 0.0...100.0)
Composite video:	RefLow, RefHigh, Lower and upper reference value adjustment of brightness and contrast of the image (range 0.0...100.0)
Saturation, Hue	Range 0.0...100.0
RGB input:	RefLowRed, RefHighRed, RefLowGreen, RefHighGreen, RefLowBlue, RefHighBlue, Lower and upper reference value adjustment of brightness and contrast of the image (range 0.0...100.0) in each colour channel

Parameters:

Input Name of the image into which the acquired image will be stored

Macro Command:

tvinput Input

tvlive

This function displays a live camera image.
For a detailed description please refer to the Frame Grabbers User's Guide.

Parameters:

none

Macro Command:

tvlive

tvsetup

This function defines the configuration of the selected frame grabber (e.g. synchronisation or camera type).
The list of setup parameters depends on the selected frame grabber. For a detailed description please refer to the Frame Grabbers User's Guide.

Parameters:
none

Macro Command:
tvsetup

tvwbalance

This function carries out a white balance for a colour image.
In order to reproduce colours as accurately as possible, a white balance has to be carried out for the colour signal. This ensures the correct representation of primary colours in the image. Two reference colours must be selected or defined in the non-balanced original image (reference image). The white and black points are generally determined interactively (double-click on the left image of the dialog box to display the original size).

To define the white reference point, select the White radio button in Reference Values, and click on a white point in the reference image. The black reference point is defined in the same way. The reference points just defined are then displayed using the two Output RGB colour values. They normally take the values 255, 255, 255 for white and 0, 0, 0 for black. If necessary, new values can be entered, or the Output Values can be changed by clicking on the Define button in the Colour dialog box. Pressing the Apply button carries out the white balance and displays the corrected image in the right window. The check box Activate is the only parameter for this function. If it is activated, the resulting colour transformation is active and applied to all true colour images, captured by the function Input (macro command tvinput).

Parameters:

Activate	0 - The transformation for the colour capture is not active
	1 - Activates the transformation for every captured image

Macro Command:

tvwbalance	Activate

tvselect

This function defines the frame grabber to use all camera functions.
Only frame grabbers which are configured in the KS software can be selected. The check box Live switches the online display on or off. For a detailed description please refer to the Frame Grabbers User's Guide.

Parameters:

Camera	Frame grabber name

Macro Command:

tvselect	Camera

Write

This function is used to write text to the message window.
Syntax:

```
write (arg1, arg2,...,arg6)
```

Example:

```
write "@"   #clear the message window
write "Result: ",res
```

read
This function is used to enter the value of a variable through a dialog box.
Syntax:

```
read (var, text)
```

#
Indicates a non-executable step within the program, usually used for writing comments within the program. However, it is sometimes used to stop a step of a program from being executed whilst debugging the system.

!
Allows the operator to input values into statements interactively instead of using the program default values.

Conclusions

A survey has been made of the capabilities of automatic and semi-automatic image analysis to provide detailed analysis of microstructural features relevant to hard materials, including ceramics, hardmetals and PM structural steels. Parameters studied included:

- Grain size/area distribution;
- Porosity size/area distribution;
- Grain shape, as described by feret ratio and number of facets;
- Microstructural homogeneity, in terms of detecting clustering and distribution of nearest neighbour distances.

The programming techniques have been shown to work, based on the analysis commands within the KS400 software system, and have the capability of providing discrimination between materials.

Most of the techniques require some manual selection of analysed areas. This is a result of features not having well-defined boundaries in terms of grey level contrast, resolution limits of the imaging system and noise in electronic image capture systems. The level of intervention depends on the measurement being made and the quality of the input image.

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