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IMAGE ANALYSIS OF POLYCRYSTALLINE MATERIALS MICROSTRUCTURE

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ABSTRACT

The main sources of structure images of different materials are light- and scanning electron microscopes. The unsatisfactory quality and contrast for the automatic quantitative metallography needs often characterise these images. The most important causes of the poor quality of these images are uneven illumination of the whole specimen surface and preparation artefacts. Some new methods for these defects' elimination from scanning electron microscopy (SEM) images were presented in this work.

The accuracy of the final results of the quantitative structure evaluation depends not only on the quality of the acquired image as well as on procedures used for its binarisation and modification. Therefore problems of the detection of the structure elements in different materials were discussed. There are various ways to achieve it. In the scanning microscopy unconventional techniques of the image formation can be used. In some SEMs (for example Hitachi S-4200) it is possible to form digital images of the chemical elements distribution on the surface of the examined polished section (X-ray mapping). These images can be used after the appropriate logical and mathematical modifications to detect phases existed in analysed material. The examples of the application of these methods are presented.

Keywords: image processing, image analysis, scanning microscopy, microanalysis

INTRODUCTION

Modern scanning electron microscopes and X-ray spectrometers are applied while examining materials microstructure and non-planar surfaces obtained during materials properties tests. In this respect their following advantages should be mentioned:

- ultra high resolution combined with large depth of focus,
- high spatial resolution of X-ray microanalysis,
- possibility of revealing structural components of various chemical composition or crystallographic orientation.

SEM techniques are presently the basic research tools in investigations of advanced metallic, ceramic and composite materials with ultrafine grains as well as materials strengthened with sub-microscopic particles of dispersed phase.

In qualitative and quantitative analysis of materials microstructure the different SEM techniques as well as image processing and analysis methods are used. It results from essential difference in requirements: classical (qualitative) metallography tends to visualise all the existing structural constituents while in quantitative analysis only selected features, being currently analysed, should be emphasised. However in both cases the quality of acquired image of materials microstructure is of fundamental importance. Factors affecting the quality of SEM images (specimens' preparation methods, observation's techniques and parameters) were the subject of our earlier works (Cwajna, 1994; Cwajna et. al. 1996, Szala et. al. 1996). Digital form of images stored in the computer memory of modern SEM makes them especially suitable to various numerical transformations. They are applied for image enhancement as well as for image processing and analysis in quantitative metallography and fractography (Wojnar, 1997; Szala and Olszówka-Myalska, 1997; Szala and Richter, 1997; Szala and Roskosz, 1997; Coster et. al., 1997).

METHODS OF SEM IMAGES ENHANCEMENT

The most commonly used methods of SEM images enhancement are: brightness and contrast control, gamma modulation, grey level histogram equalisation, histogram normalisation and filters applied for smoothing, noise reduction, edge detection and sharpening. It was found, that grey level histogram equalisation leads in many cases to over-contrast of SEM images. Better results may be obtained by grey level histogram normalisation (Fig. 1).

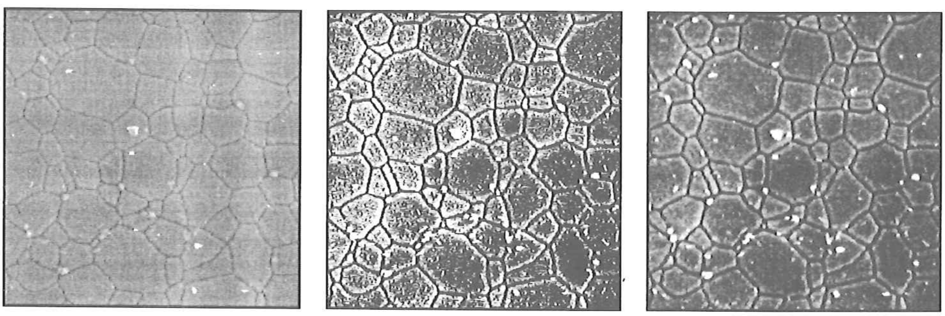

Fig. 1. SEM images of Y_2O_3. microstructure of initial image (left), the same image after histogram equalisation (middle) and the initial image after histogram normalisation (right).

The advantages and drawbacks of these methods were described in an overview paper by Wojnar (1997). Generally, they give as a result naturally looking images with emphasised details, invisible in initial images.

The methods of fundamental importance as far as SEM is considered, are:

- acquisition using frame averaging necessary because of stochastic and dynamic changes of SEM images quality,
- obtaining of image formed from acquired images' pixels of minimal intensity, which enables artefacts elimination (Fig.2),
- application of smoothing filters (mean, median) and image normalisation (Fig.3) applied for elimination of the effects connected with movement of images during their acquisition,
- correction of uneven illumination (shade correction).

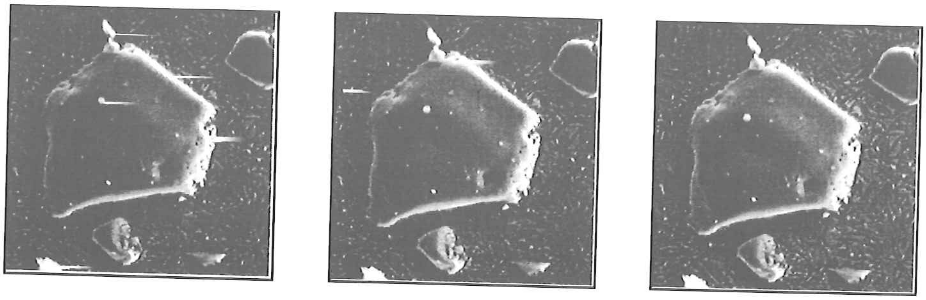

Fig. 2. Two randomly chosen images obtained with SEM and image being minimum of 10 consecutively registered images.

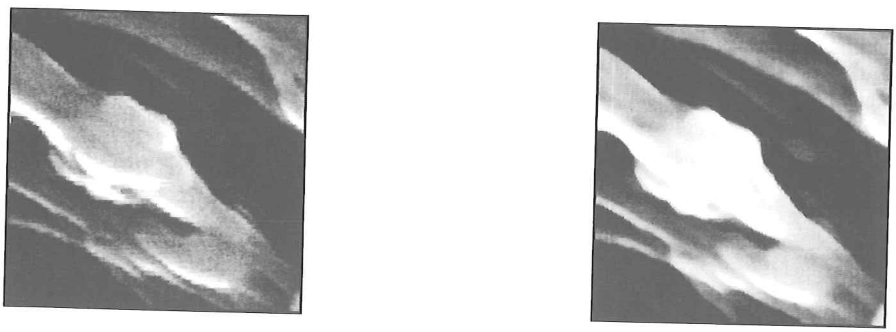

Fig. 3. Cotton fibre SEM image (left), its image after smoothing filter and histogram equalisation applying (right).

The described methods enable significant SEM images enhancement for qualitative materials microstructure assessment purposes. Obviously, in many cases they introduce additional noise, making detection of structural elements more difficult. Thus, for quantitative microstructure analysis they should be used with special care.

Proper selection of microscope accelerating voltage may help to obtain the SEM images of one-phase materials microstructure suitable for quantitative analysis, as shown in Fig. 4.

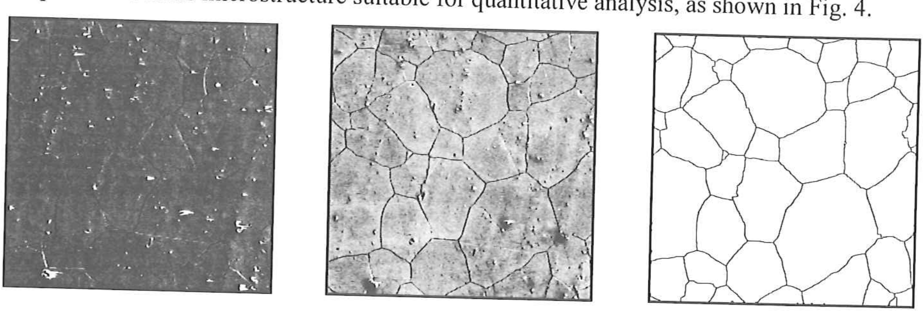

Fig. 4. SE images of austenitic steel microstructure recorded at accelerating voltage 15 kV (left); 5 kV (middle) and grain boundaries detected from middle image (right).

IMAGE ANALYSIS METHODS IN SCANNING ELECTRON MICROSCOPY

The shade phenomenon is observed practically in each image of materials structure recorded by SEM. Depending upon the extent of this effect correct detection of binary image can be difficult, if possible at all. The shading correction should be the first operation performed on the analysed image. The methods applied in light microscopy were presented in (Cwajna et al., 1994). Our experiences showed that the functional method is the most effective for SEM images (Szala and Richter, 1997).

The accuracy of the final results of the quantitative evaluation of materials microstructure depends first of all on the quality of the acquired image as the images obtained with procedures used for its modification and binarisation inherit the feature of initial image.

The superiority of SEM to light microscopes is connected with the possibility of different images application in selective evaluation of structural components: SE, BSE images and X-ray mapping. The special techniques of SEM are particularly useful in the examination of multiphase material microstructure. An example of SE and BSE images application for selective detection of former austenite grain boundaries as well as of MC and M_6C carbides in non-ledeburitic high-speed steel is shown in Fig. 5.

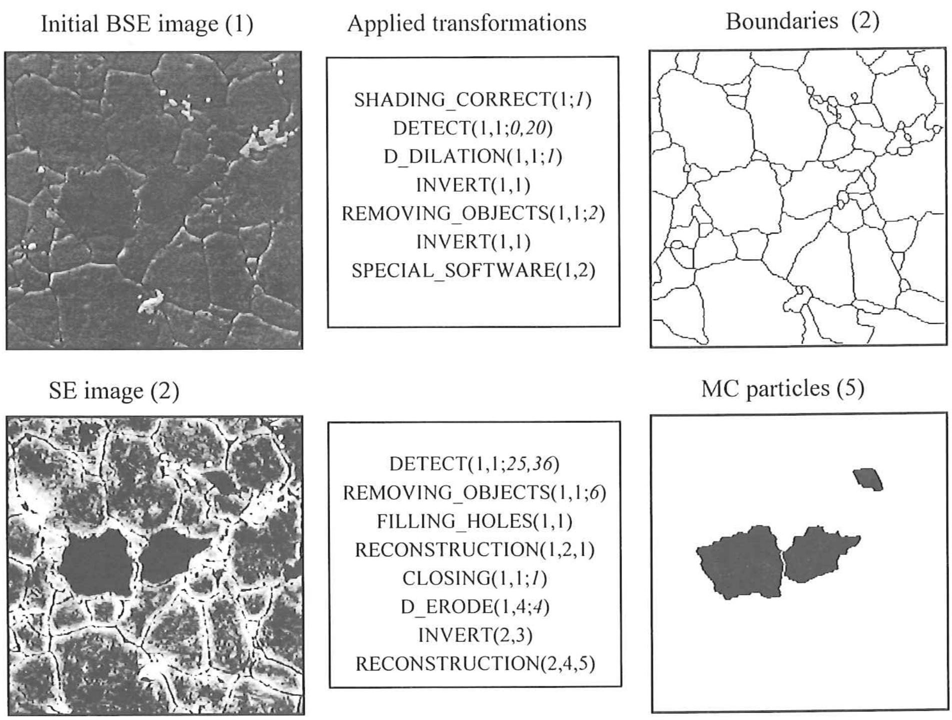

Fig 5a. Detection of austenic grains and MC carbides.

In ***X-ray mapping technique*** several digitalized distribution of chemical elements in the investigated area are obtained. These images are modified with the methods applied for numerical images (Fig. 6).

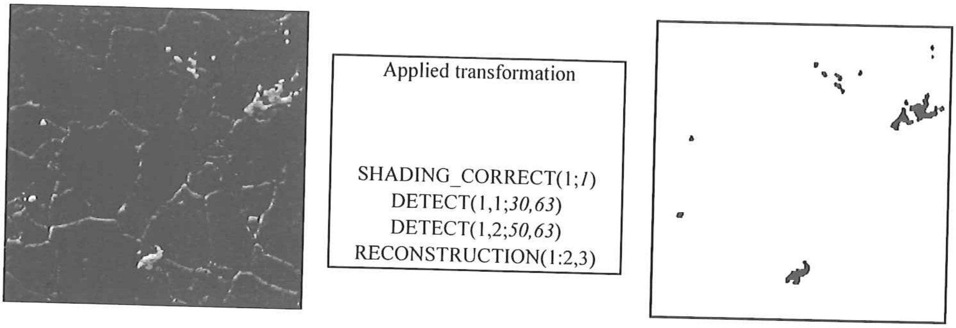

Fig. 5b. The detection of M_6C particles on the BSE image.

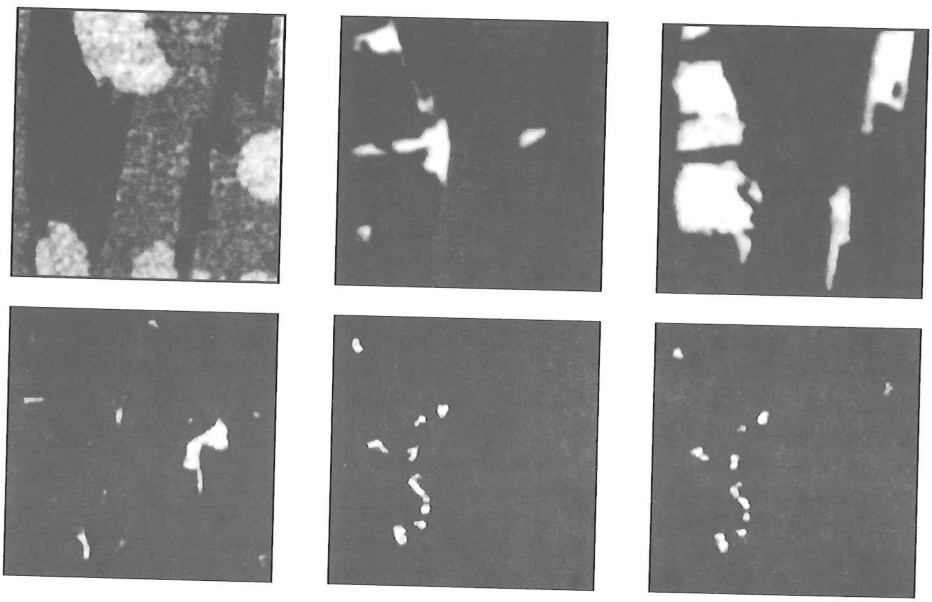

Fig. 6. Images showing distribution of : Fe, Si, Mg, Ca, Ce and La in ferroalloy.

Logical product of binary images representing microregions of certain content of chemical elements enables detection of phases occurring in an investigated (fig. 7).

CONCLUSIONS

The presented examples show that in scanning electron microscopy more effective methods of image preparation for automatic measurements and counting are available in comparison with light microscopy. BSE images as well as the images obtained with X-ray mapping technique performed with the application of worked-out programme are particularly useful for selective evaluation of structural components of multiphase materials.

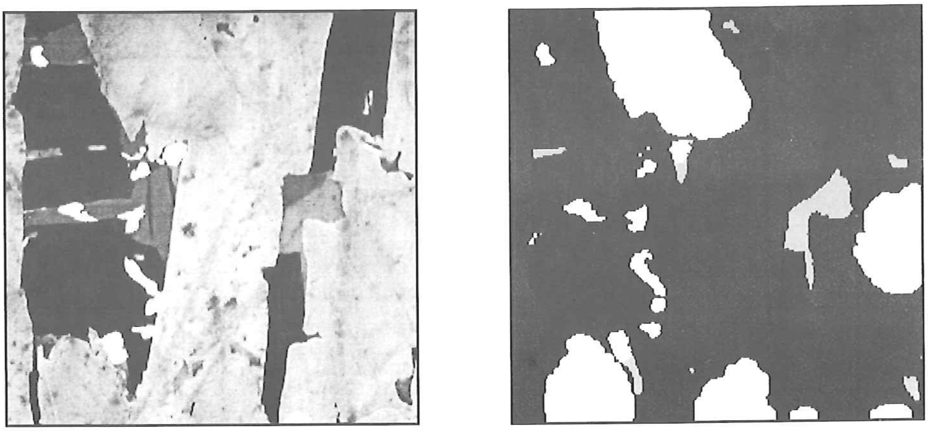

Fig. 7. Initial SE image of ferroalloy microstructure (left) and phases distribution (right).

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