3D Surface Analysis in Scanning Electron Microscopy

Stefan Scherer

The scanning electron microscope is widely used in observing microscopic objects with a large depth-of-focus. Unfortunately no measurements concerning the 3D structure are possible. In this work a system is presented that allows to combine the advantages of the SEM with the capabilities of a surface analysis device. The pure software solution enables the user to perform measurements like profile analysis, roughness and waviness, area analysis and even the fractal dimension or volumes of impressions and uprisings can be calculated.

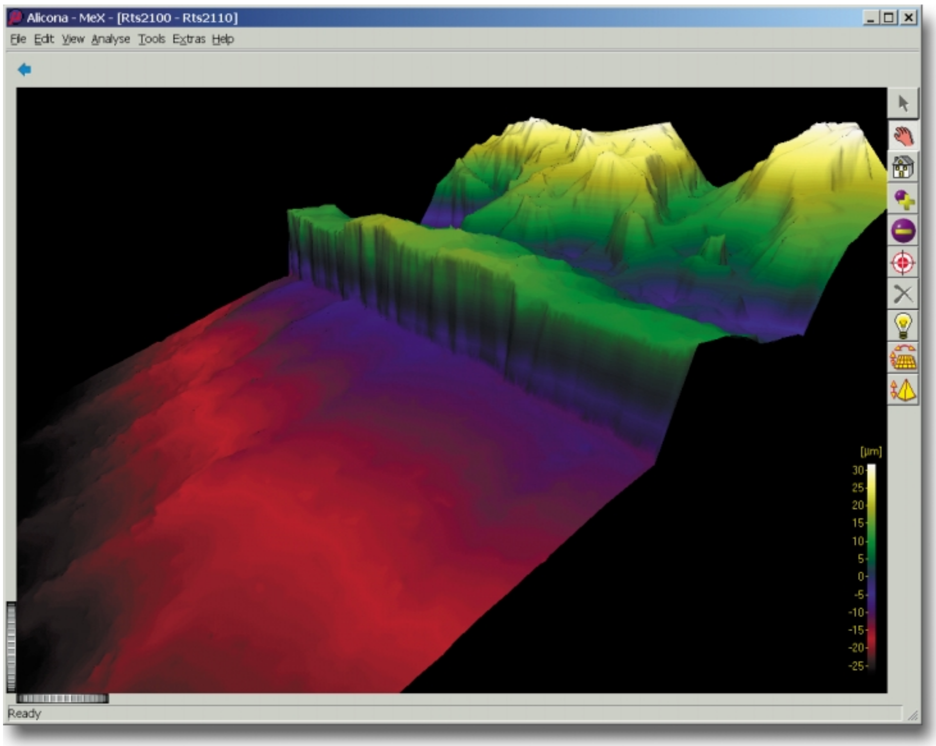

Fig. 1: Digital elevation model of the fractured surface of metallic glass at a pixel size of 0.2 µm. The depth is encoded as colour.

Introduction

The scanning electron microscope (SEM) provides large depth-of-focus and high-contrast images at a large variability in magnification. The user is pleased with a pretended three-dimensional impression of the observed surface. Nevertheless, the three-dimensional structure is mapped onto a two-dimensional image plane and does not allow direct depth measurements. In order to perform these measurements the microscopist has to apply another device like the AFM, CLSM or a profile meter. The drawback of this approach is obvious: the need for another device and the problem of relating the SEM image with the three-dimensional measurement. In the following a pure software solution to this problem is described in the application of fracture analysis.

MeX – a software tool for 3D reconstruction and analysis in SEM

From the vision point of view, surface reconstruction can be divided into two major tasks: geometric calibration and image matching. For geometric calibration the user has to capture two images under two distinct views. These are obtained by a simple eucentric tilting. The user provides the device parameters magnification, working distance and relative tilt angle. The tilt angle is the most sensible parameter concerning reconstruction error and thus recent research was drawn to auto-calibration. Latest results allow to only provide a rough estimate for the user parameter with an automatic and exact calibration. The principle task in image matching is to automatically identify points in the two images representing the same point on the specimen (homologue points). The three-dimensional surface point is represented by a two-dimensional window in one image which is "searched" in the other image. This searching is performed by calculating a correlation measure and finding its maximum. Conventional approaches use the well-known cross-correlation or normalized cross-correlation coefficient. It is proven to be optimal under linear grey-value transformations, but non-linear transformations frequently cause false correlations. And it is exactly these non-linear transformations that can be observed in stereoscopic SEM images. The user is faced with false and noisy results. The development of a new correlation measure, which can be classified as a rank-based technique, highly increases the robustness of the matching. Results of yet unknown quality can be achieved. Once the homologous points are identified, the three-dimensional coordinates of the surface are computed from the known calibration.

Keywords

3D Analysis, SEM, Fracture Analysis

Experimental results – applications in fracture research

Once an accurate and dense 3D digital description of the surface is available, consecutive analysis steps are possible. As an example, the evaluation of profile- and area roughness data is discussed. Nevertheless, the topography of almost any specimen can be reconstructed and analysed provided that the surface is visible in both images. The analysis was made on a fracture mechanics specimen of metallic glass (courtesy O. Kolednik, Erich SchmidInstitute for Material

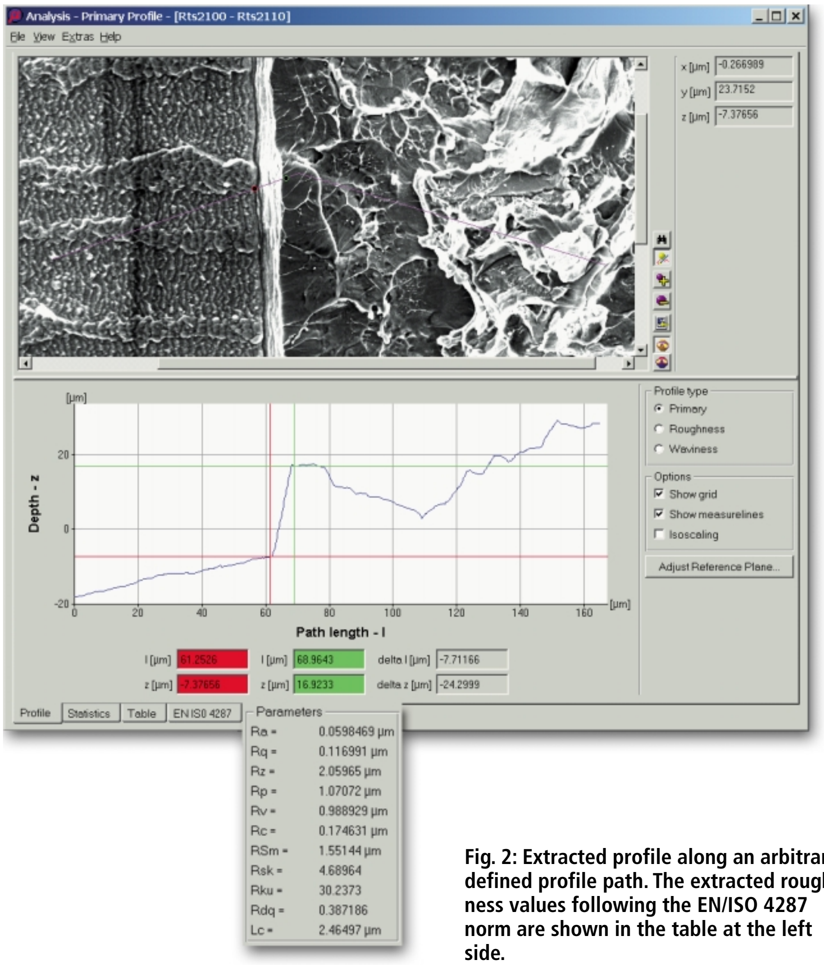

Fig. 2: Extracted profile along an arbitrary defined profile path. The extracted roughness values following the EN/ISO 4287 norm are shown in the table at the left side.

Science, Leoben). Additional analysis steps, such as volume measurements, fractal dimension, critical tip opening displacement and others are not discussed due to the limited scope of the presentation.

Conclusion

In this article a system for automatic surface analysis from SEM images was presented. Based on the input data from any conventional SEM a dense and accurate 3D digital description is obtained by the software program MeX. Consecutive analysis steps as profile extraction roughness or volume measurements are possible.

Dr. Stefan Scherer

Stefan Scherer holds a M. Sc. degree in Physics and a Ph.D. in Machine Vision. He has been working on 3D reconstruction from digital images for over 10 years now. He is co-founder and chief executive officer of Alicona Imaging GmbH.

Alicona Imaging GmbH
Parkring 2
A-8074 Grambach/Graz, Austria
E-mail: stefan.scherer@alicona.com
www.alicona.com