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Practical Metallography of Low Carbon Steels – New approaches in Preparation, Imaging and Analysis of Microstructures

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Steel, with its enormous variety of compositions, process routes and heat treatments as well as the resulting versatile mechanical properties, is interesting for a wide variety of applications. At the same time, steel is still in high demand as a material for research and continues to deliver new innovations. A paradigm shift has been taking place in the steel industry for some years now - from the experience-based process-property correlation to a microstructure-based material development. For this purpose, the microstructure is understood as the central information carrier that stores information on the various process steps across all scales and thereby determines the mechanical properties. Accordingly, the microstructure plays a central role in research, development and quality assurance. The appropriate tools for preparation, contrasting, quantifying and classifying, grouped under the term metallography, are therefore essential to sustainably guarantee the progress and innovative power of steel in particular and other materials in general.

The aim of the presented work is to provide new approaches and solutions in the field of microstructure analysis of low-alloyed steels (Figure 1).
Metallographic preparation is of utmost importance as the basis for every structural analysis. Accordingly, the main focus of the present work is on contrasting by means of chemical etchings by LePera and Beraha in order to work out and make visible the microstructure of low carbon steels with its partly very fine differences in the best possible way. In addition to technical concepts, the focus is also on understanding the reactions that take place during contrasting in order to significantly increase reproducibility. For these purposes, a setup will be presented to keep all critical parameters during etching constant. In combination with an insitu-flowcell, it is even possible to monitor and control the process of contrasting. [1], [2]

In the field of image processing, methodological work and new concepts of image registration, which is necessary when different methods for imaging are used, and segmentation, which is still done by thresholding mostly and thus causing a lot of artifacts, are presented. For these tasks, approaches to use correlative microscopy data to extract features for further analysis [3] as well as segmentation algorithms based on an “Active Contours without Edges” [4] approach will be shown.

The final goal of all these approaches is the microstructural analysis which consists of a quantification and classification. By combining different sources of information – summarized under the keyword correlative microscopy – it is shown that even complex microstructures can be evaluated qualitatively and quantitatively [5]. By machine learning methods based on Deep Learning [6] and Support Vector Machine [7] using texture and morphological parameters, promising tools will be presented to reach unbiased and objective classification results.

Based on these concepts, new standards in both research and quality assurance for the analysis of microstructures can be set.

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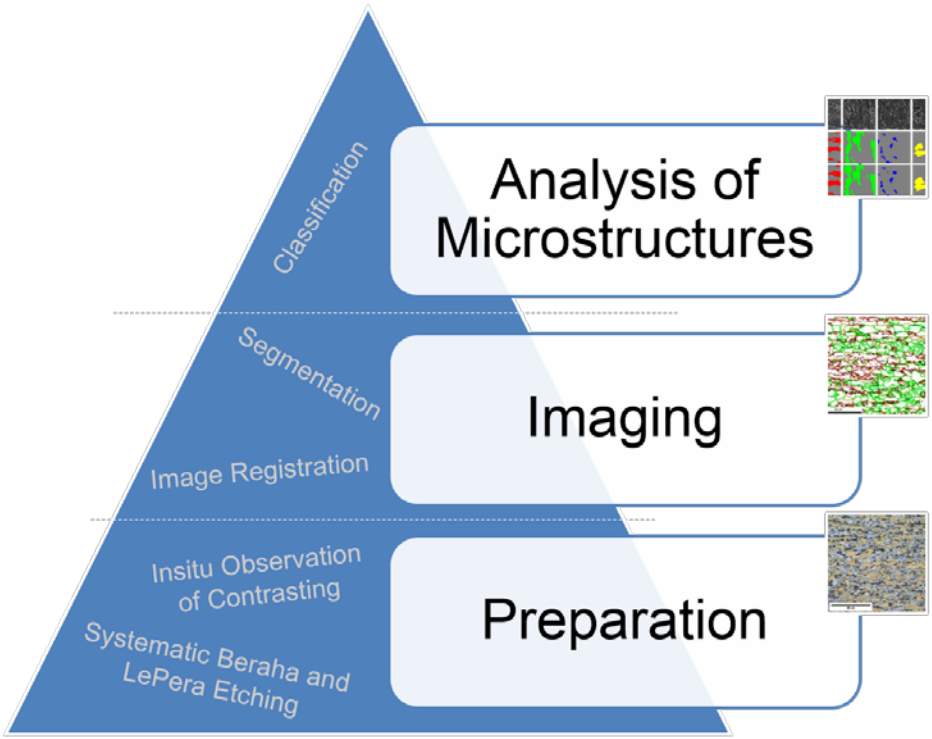

Figure 1. Approach to the systematic investigation of microstructures: Complex microstructures in steel can only be analyzed and classified using a solid preparation route and suitable imaging.