doi:10.1017/S1431927614006035
Microsc. Microanal. 20 (Suppl 3), 2014

Automated Quantitative Materials Microscopy

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During the last 20 years major changes occurred in the field of computer based image processing and automation of microscopes. Today's hard- and software provides a variety of tools for consistent quantification of microstructures in materials microscopy. Quantitative determination of volume fractions of phases, grain size, defect size and morphology as well as texture, alignment or distribution of objects can be realized.
Condensation of data in microstructure quantification allows a better understanding, interpretation and comparison of data, assembled over an extensive time period (e.g. in quality assessment in production). The possibility to correlate data is of considerable benefit for the development of sustainable knowledge. Production parameters can be correlated with microstructure features to optimize material processing. The correlation of microstructure and the properties of materials or components can help to improve material properties based on a solid understanding.

However the full scope of quantitative microstructure analysis cannot be obtained without automation. For instance the measurement of geometry parameters or the identification of inhomogeneities in components requires the scanning of large areas and processing of big data volumes. Automated microscopy involves computer aided acquisition and processing of image data using a microscope equipped with scanning stage (motorized x, y) and autofocus (motorized z). Automation provides a more stable statistical coverage of results. Distributions of grain sizes for example can easily be generated with tens of thousands of grains being quantified automatically. Furthermore larger areas of parts can be scanned to visualize quantitatively inhomogeneities of components. Due to progress in hard- and software technology the scanning time could be reduced by a factor of ten within the last five years. The distribution of pores in powder metallurgic components is used as an example to demonstrate the importance of quantifying inhomogeneities in components.

For quantitative microstructure analysis materialographic preparation of high quality without preparation artifacts is essential. Examples for intelligent algorithms to detect the quality of sample preparation are shown. The measurement of intrinsic magnetic properties of hard magnetic phases (saturation magnetization and magnetic anisotropy) out of the pattern of magnetic domains is demonstrated. Using a hot stage, even temperature depending properties can be quantified. It is illustrated that the Curie temperature (T_C) can be measured using the microscope. Even anisotropies in sintered magnets can be analyzed quantifying the pattern of the magnetic domains. Metallographic quality control is shown for Li-Ion batteries. The geometry of the layout and the microstructure of the electrodes can be monitored. Quantitative microscopic determination of defects in ceramic components can be used to assess the reliability of ceramic components.
These examples show that a systematic quantification of the microstructure is extremely valuable to understand complex coherences of microstructure, processing and material properties.

References:

[1] The authors gratefully acknowledge Dagmar Goll, Johannes Herbst, Christian Weisenberger, Volker Knoblauch and Carl Zeiss Microscopy GmbH for their support

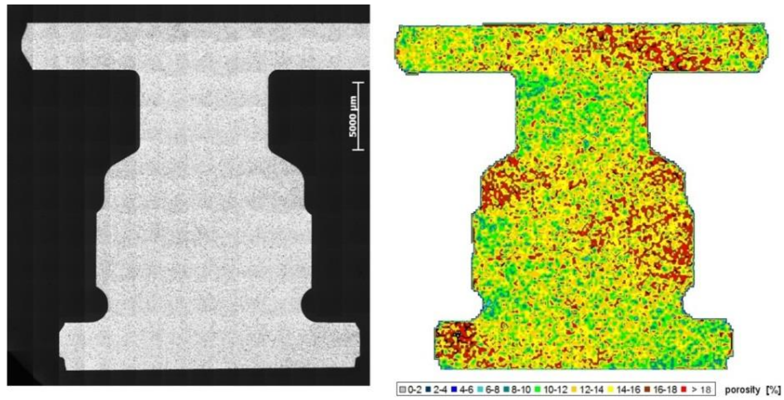

Figure 1. Powder metallurgic component, compacted axially. a) Bright field - 24x30 image tiles, b) porosity distribution (25000 image frames) in the component using post-image processing, red: high porosity region, green: low porosity region.

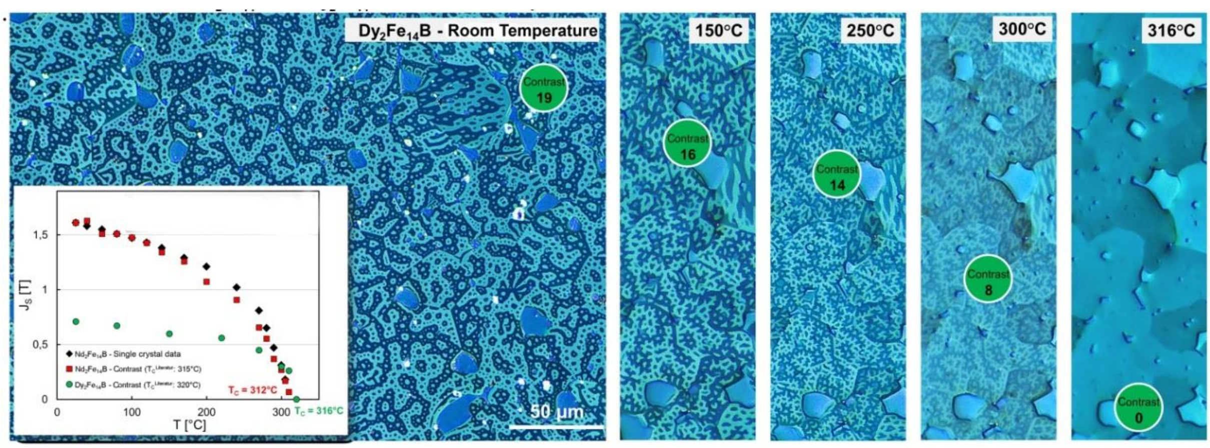

Figure 2. Domain structure of $Nd_2Fe_{14}B$ and $Dy_2Fe_{14}B$ using Kerr effect and hot stage. Temperature depending contrast is in good agreement with literature data of the saturation magnetization and T_C.

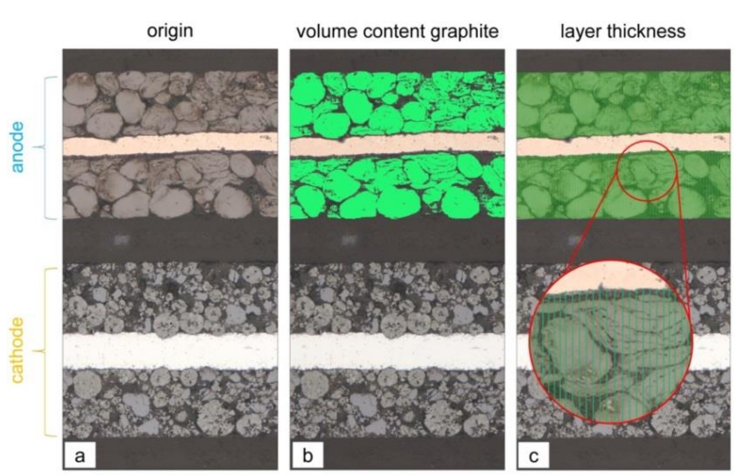

Figure 3. Electrodes of Li ion batteries. Measurement of volume fraction of electrode material (b) and layer thickness of electrodes (c) for quality assurance.

https://doi.org/10.1017/S1431927614006035 Published online by Cambridge University Press