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HoMMage

Hysteresis Design of Magnetic Materials for Efficient Energy Conversion

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Zoom information:
Meeting-ID: 683 5582 3655
Kenncode: 437188

Development and applications of ELAVO 3D – an EBSD-based large volume 3D microstructure analysis system

Abstract:

Most microstructures of crystalline materials are inherently 3-dimensional (3D) and this 3-dimensionality influences many of their structural and functional properties. Examples are chemical and mechanical properties of grain boundaries, transition of deformation structures through a 3D-grain structure, or interconnectivity of phases or voids influencing conduction properties or mechanical strength. Nevertheless, most tools for microstructure analysis, e.g. classical light-optical microscopy, electron backscatter diffraction (EBSD)-based orientation microscopy or, usually also, transmission electron microscopy observe only 2-dimensional sections of the material and most properties are discussed based on this 2-dimensional knowledge. Often researchers think of 3D grain boundary planes as being lines separating areas of different grains from each other, of slip planes as being line-type features in a deformed structure, so called "slip lines", or of potentially interconnected pores as being separated individual holes in a 2D microstructure.

The request to better understand microstructures has triggered many attempts to establish 3D microstructure observation systems. They are either based either on serial sectioning, or on projection imaging using some sort of transmissive radiation, usually hard x-rays but also electrons. The latter projection-based systems are highly interesting because they are non-destructive, but usually they are limited either in spatial resolution or in observable volume and, frequently, by the limited access to synchrotron radiation. The serial section techniques usually employ an ion or LASER beam, or mechanical and chemical polishing for controlled removal of layers of material. After each removal the microstructure is observed usually by an SEM-based technique (SE, BSE, EBSD, EDX). Subsequently, software is employed to reconstruct the 3-dimensional microstructure from the individual section images or maps. Although these techniques are destructive, they enable 3D measuring all the microstructural and compositional details known from the respective 2D techniques.

After having developed a Ga+-ion beam based system for serial sectioning in conjunction with EBSD/EDX mapping, we recently developed a system based on mechano-chemical polishing for sectioning. This fully automated system allows observation of very large volumes of a sample, in the range of a cubic millimetre, with spatial resolution in the micrometre to sub-micrometre range. The polishing system creates perfectly flat and artefact-free surfaces which allow, besides EBSD and EDX-based mapping, also the measurement of properties, e.g. corrosion, local electrical conductivity, mechanical properties via hardness indents, etc.. It therefore builds a bridge between the microscopic world of 3D-microstructures and the macroscopic world of average properties.

In the presentation I will introduce the construction of our system ELAVO 3D, discuss the challenges that had to be overcome, compare the system with other competing developments and present a few applications, particularly from investigations on additively manufactured (AM) metals and from a study on grain boundary corrosion of a stainless steel. Most of the data are evaluated using our in-house produced 3D microstructure software QUBE.

Large parts of the system have been developed, and many applications have been run by my postdoctoral co-workers Shao-Pu Tsai, financed by Nippon Steel. The software QUBE has been developed by Peter Konijnenberg partly financed by Bruker Nano. New applications to AM metals have been contributed by my post docs Sravya Tekumalla and Zhongji Sun.

About the speaker:

Dr. Stefan Zaefferer studied physical metallurgy at the University of Clausthal-Zellerfeld in Germany. His PhD thesis was concerned with the investigation of deformation mechanisms in titanium alloys using TEM and dedicated self-written crystallographic software (known to some as "TOCA"). After his PhD he went for several to the University of Paris-XII and to Kyoto University. After a short stay at Darmstadt he became group leader at the Max-Planck-Institut für Eisenforschung in Düsseldorf, Germany. Since 2009 he is lecturer ("Privatdozent") in materials characterization at the University of Aachen (RWTH Aachen). His main research interest are the investigation of mechanisms of microstructure formation and the development of new techniques in electron diffraction, in both, TEM and SEM. His latest work is related to the development and application of electron channelling contrast imaging for direct crystal defect observation in the SEM, and to 3D microstructure observation using EBSD-based tools. These techniques have been applied to study various aspects of microstructures and properties of a range of different metals and alloys.

SZ has written or coauthored several book-chapters and about 150 peer-reviewed journal papers. He holds a couple of awards on materials science.