Book Review

Atom-Probe Field Microscopy

M.K. Miller, A. Cerezo, M.G. Hetherington and G.D.W Smith
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The Field Ion Microscope was invented by E.W Müller in 1951. For the first time, the surface of a sharply pointed specimen could be observed on an atomic scale. In 1967, the inventor of field ion microscopy (FIM) extended the possibilities of the microscope in combining the instrument with a time of flight mass spectrometer. E.W Müller demonstrated that with such an instrument, namely the atom-probe, the chemical nature of individual atoms observed by FIM could be identified. Thirty years after the invention of the one-dimensional atom-probe, a new generation of apparatus extending these possibilities in the three dimensions of space was introduced by the authors (A. Cerezo, G.D.W Smith, Oxford and M.K Miller, Oak Ridge National Laboratory) and the FIM group of the University of Rouen. With this new generation of analytical microscopy, the small volume analysed within the material can be reconstructed in the three dimensions of space, on an atomic-scale.

This monograph, written by renowned specialists may be viewed as an updated extension of the book of M.K Miller and G.D.W Smith already published in 1989 (MRS, Pittsburgh, PA, 1989). Many new items are added, including a description of the different types of position sensitive detector designed in Oxford, Oak Ridge or in France and that are implemented to different variants of 3D atom-probes. A more exhaustive description of the statistical treatment of atom-probe data is also provided. This monograph is intended for specialists of Atom-Probe Microscopy as well as for non-specialists interested into application to materials. Special efforts are made for scientists new in the field.

The book starts with an historical background and a general introduction to Atom-Probe Field Ion Microscopy (APFIM). Hence, the different modes of evaporation (electrical pulses, laser pulse assisted, electron beam activated evaporation...) are first introduced and the different variants of atom-probe (AP) are described (high mass resolution AP, imaging AP, 3DAP). The second chapter is devoted to the physical basis of FIM, namely ionisation and evaporation of surface atoms in high field conditions (20-50 V/nm). The theory of contrast in FIM and the principle of high mass resolution spectrometry are then treated in the following chapters.

The description of the many statistical tools that can be used for the treatment of data (chap. 5) is carried out with clarity and includes most of the models developed not only by the authors but also by the other FIM groups active in the field (Universities of Göttingen, Göteborg, Rouen). Many examples are provided to the reader for an in-depth and a more operative training for the beginner. Some basic concepts used in statistics are recalled in separated plates included in the text. The clear and numerous examples illustrating the various methods introduced will be evidently of great help to the student.

The last chapters deal with the applications of Atom-probe Field Ion Microscopy to physical metallurgy and surface science. The authors show that the 3D atom probe is a powerful tool for the investigation of the early stages of phase separations and the identification of decomposition regimes (spinodal decomposition, nucleation and growth). Various examples drawn from literature also illustrate the role of atom probe microscopy in the study of intergranular segregation. Many colour plates illustrates the most salient results obtained by the laboratories working with 3D APFIM on both sides of the channel. A section is devoted

to intermetallics (NiAl, TiAl) and aluminium base alloys for aerospace applications. The specific problem related to the analysis of semiconductor and non-metallic materials is also treated. Pulse laser atom probe is shown here to be an interesting experimental approach for the study of III-V semiconducting materials, of metal-semiconductor interfaces as well as of GaInAs quantum wells. This last chapter also includes a review of investigations of high Tc superconductors and non-metallic materials including carbides, carbonitrides, graphite, glass. Thin films, surface segregation, oxidation as well as surface reactions and adsorption in the presence of reactive gas (H_2, O_2, N_2) are also important applications which deserved a review.

The book ends up by a text written by Richard P. Feynman who discusses the possible future directions. Among the numerous interesting issues raised, the question of the spatial resolution attainable with the 3D atom probe is of utmost interest. While the depth resolution is high enough to reconstruct the stacking sequence of planes within the analysed volume, the lateral resolution (at the specimen surface) is essentially limited to a few tenth of a nanometer because of the aberrations of the ion trajectories close to the surface. R.P. Feynman predicts that the development of quantum mechanical treatments of atoms at surfaces together with the application of molecular dynamics methods, should allow improved three-dimensional modelling of the process of field evaporation, therefore opening new perspectives for the original atomic lattice sites to be accurately reconstructed. Other outlooks related to the use of FIM techniques for the production of single atom sharpness points are also discussed. Hence, very sharp tips suitable for STM probes as well as for highly coherent electron sources for electron microscopy and electron holography applications may be produced. Also, the application of APFIM in the investigation of field emitter arrays for vacuum microelectronics and flat screen display is cited. The perspectives offered by the possible incorporation in future of miniature APFIM's into electron microscope are eventually reviewed.

In conclusion, there is no doubt that the recent emergence of 3D atom probe has opened a new era in the nanoanalysis world. This book provides an excellent source of information and references for scientists. One may regret the very little attention paid to the essential problem of the 3D reconstruction of the analysed volume from the native atom-probe data. Almost no information related to the exact protocol of reconstruction used and the related models developed is given to the reader. Despite this minor point, this very didactic monograph is a reference book both for graduate students entering the field and for specialists. I highly recommend scientists interested in field emission and material science to read it.

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