The TOMO Project – Integrating a Fully Functional Atom Probe in an Aberration-Corrected TEM

Joachim Mayer[1,2*], Juri Barthel[1], Ashok Vayyala[1], Rafal Dunin-Borkowski[1],
Maarten Bischoff[3], Hugo van Leeuwen[3], Stephan Kujawa[3],
Joe Bunton[4], Dan Lenz[4], Thomas F. Kelly[5]

[1] Ernst Ruska-Centre, Forschungszentrum Jülich GmbH, Jülich, Germany
[2] Central Facility for Electron Microscopy, RWTH Aachen University, Aachen, Germany
[3] Thermo Fisher Scientific, Eindhoven, The Netherlands
[4] CAMECA Instruments, Inc., Madison, WI, United States
[5] Steam Instruments, Inc., Madison, WI, United States.
*corresponding author: j.mayer@fz-juelich.de

In the present contribution, we want to introduce the TOMO microscope which will be based on a combination of two well-known but fundamentally different materials analysis techniques in one device: a state-of-the-art atom probe will be integrated into a high-performance TEM. This plan represents a revolutionary step towards atomic-precision analysis and has not previously been realized. The first important advantage results from the almost complete complementarity of the techniques, which we will be able to apply to the same object simultaneously [1-4]. In a correlative approach, the segregation of a specific element to a defect or any other microstructural feature in a given matrix phase can most sensitively be analysed with the atom probe technique. However, the atom probe cannot deliver atomically resolved information on the atomistic structure and the local bonding situation, which in a complimentary way can be given by HRTEM/STEM and EELS. Although experimental workflows exist in which an APT needle is first characterised by TEM, reliable results can only be obtained for the thinnest part of the needle, but not for defects which will only be exposed after further ablation of the needle. On the other hand, the standard method of reconstruction of the APT atomic positions assumes that the apex shape of the needle is hemispherical. If the apex is not spherical, then errors in atom positioning result. In the presence of dislocations, twin boundaries, stacking faults, grain boundaries or multiple phases in the sample, grooving occurs which leads to an alteration of the trajectories and thus to artefacts in the final APT tomograms, see also Figure 1. The TOMO instrument, which will be installed at the Ernst Ruska-Centre in 2024, will benefit from the almost complete complementarity of the techniques, which can be applied to the same object simultaneously. The expected synergistic gain obtained by combining the technologies results from the fact that it will be possible to observe the shape of the tip apex during an experiment and thus correct atom trajectories for greater spatial precision. Furthermore, the true electric extraction field can then either be calculated from the image of the tip shape or it can be measured directly in the electron microscope by holographic techniques. For the first time, the TOMO instrument will permit the determination of the types and locations of millions of atoms in a volume of several hundred thousand cubic nm, down to each individual lattice position, in one measurement. The three-dimensional distributions of functional elements can be studied to almost the single-atom level, while linking it to atomic structures with picometre precision and electronic structures with sub-eV resolution. The structures and defects of relevant material systems like nanoelectronic components, compound solar cells or catalytically active nanoparticles, for example, can be imaged and analysed in parallel. In addition, the segregation of light elements such as H, Li or O to active defects and interfaces can be examined, leading to novel insights into a wide variety of structural materials, energy storage systems and functional elements [5].

References:

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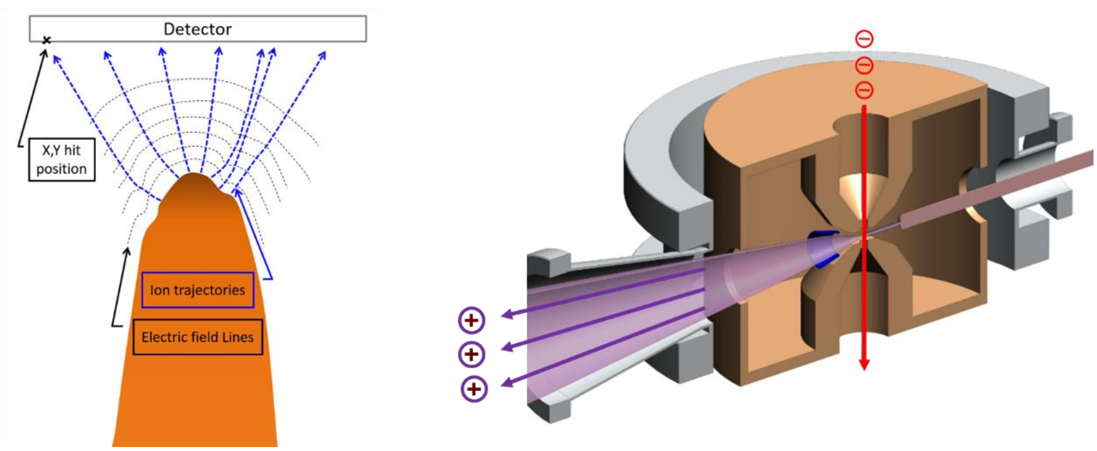

(a) (b)

Figure 1: (a) Effect of the apex shape on the APT results of a multiphase sample: schematic drawing of how the electric field line geometry influences the ion trajectories and registration positions on the two-dimensional detector. (b) Schematic drawing of the integration of the APT needle in the centre of the pole piece lens of the TOMO-TEM. UHV conditions and temperatures below 35 K will be ensured by a completely new column and stage design.

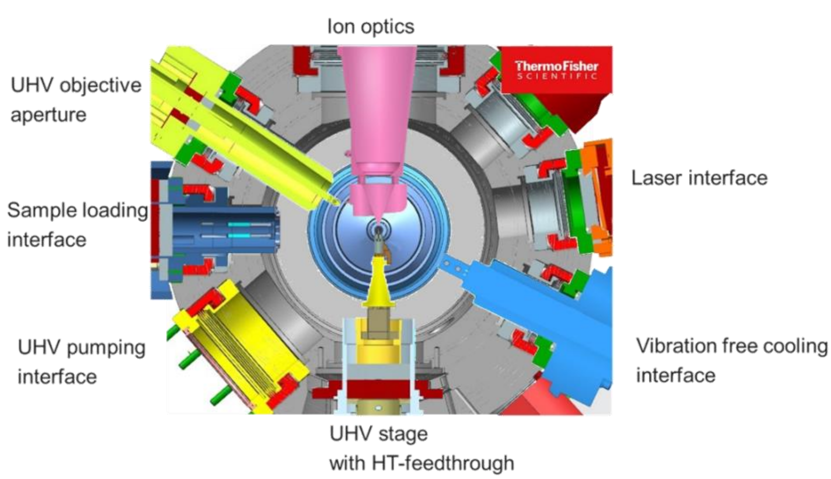

Figure 2: Schematic outline of the arrangement of the main components in the objective lens octagon.