NUCAPT operates a 3D LEAP4000 XSi tomoscope, manufactured by IMAGO Scientific Instruments, featuring an ultraviolet (355 nm wavelength) laser pulsing at up to 1 MHz pulse repetition rate, local-electrode design, wide-angle field-of-view, and microtip array capability. Specimen datasets of $5 \times 10^8$ atoms are recorded routinely, corresponding to a specimen volume of $0.15 \times 0.15 \times 0.5 \, \mu m^3$.

**Facility Description**

Analytical Services

We analyze your specimens, atom-by-atom, at NUCAPT. We accept proprietary contract work and sponsored projects from universities, industry or government institutions. Please contact us for arranging a specific project and a quotation or project proposal.

Northwestern University Center for Atom-Probe Tomography (NUCAPT)

2220 Campus Drive
Evanston, IL 60208-3108

http://arc.nucapt.northwestern.edu

Prof. David N. Seidman, Founding Director
E-mail: d-seidman@northwestern.edu
Telephone: 847.491.4391

Research Prof. Dieter Isheim, Manager
E-mail: isheim@northwestern.edu
Telephone: 847.491.3575

Figure 1: (a) Teeth (arrow) of a chiton, a marine mollusk that chews rock, as seen in an optical microscope. (b) Atom-by-atom 3D APT reconstruction of organic fibers in a chiton tooth. The fibers are highly enriched in Na. A new level of complexity with how a chiton mineralizes its teeth around an organic scaffolding is revealed. L.M. Gordon and D. Joester Nature 469, 194-197 (2011).
3D Atom-Probe Tomography (APT)

An atom-probe tomograph creates a three-dimensional (3D) atom-by-atom direct space reconstruction of a specimen volume with subnanometer resolution, Figs. 1 and 3, thereby permitting chemical and microstructural analyses on an atomic scale in 3D, see also Ref. 1 and 3. This information is essential for understanding structure, properties, and genesis of biological materials.

In a 3D local-electrode atom-probe (LEAP) tomograph, individual atoms are evaporated from the surface of a microtip, Fig. 2, by a high electric field generated by applying a dc voltage, \( V_{dc} \), to the tip, and then transmitting a picosecond laser pulse on the tip (mode II), or a nanosecond high-voltage pulse, \( V_{pulse} \) (mode I), to the local electrode situated above the tip. The atoms are ionized and projected radially onto a position sensitive detector, Fig. 2. An image of the microtip’s surface is recorded at a magnification of \( >10^6 \) times. For each atom, its atomic mass, and thereby chemical identity, is determined from its time-of-flight.

Since the atoms are removed sequentially, one-by-one, from the surface, a 3D image can be reconstructed with a depth resolution of a single interatomic spacing. Fig. 1 (a) displays the magnetite teeth of a chiton, and (b) a reconstruction of organic fibers enriched in Na in a magnetite chiton tooth.

A computer workstation is utilized to compose and to view the reconstruction in 3D and to extract chemical information, such as local compositions and concentration profiles. Also, geometrical and topological information is obtained, such as fiber diameters or layer thicknesses, and the shapes of the features under investigation can be determined in 3D.

The detector efficiency is the same for all chemical elements in the periodic table. Thus, local chemical compositions can be derived quantitatively. Applications include for example the analysis of concentration gradients, interfacial regions. Fig. 3 displays concentration profiles and atomic distributions of Na in the cross section of an organic fiber analyzed by atom-probe tomography in a magnetite chiton tooth.

**Specimen Requirements**

Among the various techniques to prepare a sharp needle-shaped specimen suitable for APT, focused-ion beam (FIB) milling is today the most versatile one. To protect the sample from radiation damage due to the Ga\(^+\) ion-beam, protective sacrificial cover layers are first deposited on top of the material, for example, by ion-beam sputtering. A sharp microtip is then fabricated using the FIB, after selecting the region of interest and, if necessary, using a lift-out technique to position the specimen volume at the end of a commercially available microtip specimen holder. NUCAPT uses a FEI Dual-Beam Helios nanolab FIB for this purpose. Cryogenic techniques are currently implemented to keep organic materials frozen during specimen preparation and transfer.

The focused ultraviolet laser pulsing in the LEAP tomograph offers optimum evaporation conditions for specimens regardless of their electrical conductivity.

**Further Reading**