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SCIENCE & METROLOGY SOLUTIONS

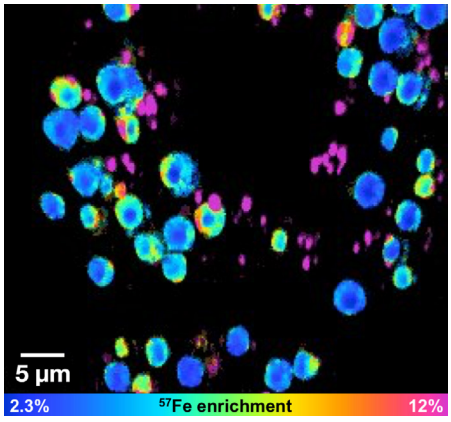
AMETEK
MATERIALS ANALYSIS DIVISION

Analyzing plant science processes with a CAMECA NanoSIMS at the University of Manchester

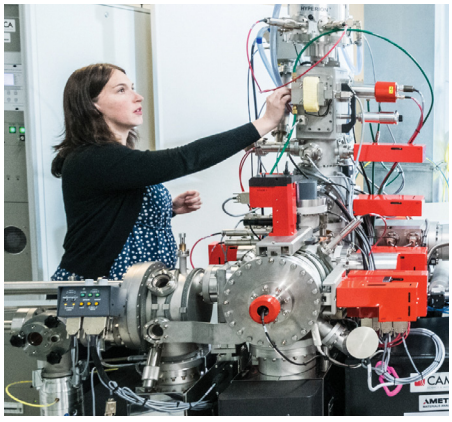
A SUCCESS STORY

CAMECA NanoSIMS 50L Advantages

- Unique high-performance ion microprobe/secondary ion mass spectrometer (SIMS)
- Utmost-precision isotopic & trace element analysis
- High spatial resolution (down to 50 nanometers)
- High sensitivity (ppm in element imaging)
- High mass resolution (M/dM)
- Parallel acquisition of seven masses
- Plant science
- Cell biology
- Materials research
- Environmental microbiology
- Geology and space science



NanoSIMS 50L ion ratio image of a wheat grain bran layer cell showing elevated ^{57}Fe in small hot spots (pink).



Dr. Katie Moore makes adjustments to the NanoSIMS 50L.

The Challenge

As populations climb and climates change, plant science grows ever more important. Because to keep everybody healthy, we must keep them fed.

Dr. Katie Moore, Lecturer in Materials Characterization in the Department of Materials at the UK's University of Manchester, is making crucial contributions to that effort. Like most materials scientists, she spends time analyzing materials used in manufacturing or construction. But since her doctoral studies at Oxford in 2008, she's also been helping nutrition scientists analyze *plant* materials.

For example, cereals can provide a critical source of dietary iron. But not enough to keep us healthy: a wheat grain just doesn't have enough iron that's easily bioavailable to our digestive system.

Could iron content be increased through biofortification? Not artificially adding iron to flour, but breeding wheat strains with elevated levels of iron? Finding the answers requires an understanding of the processes at work inside plants at the subcellular level.

The Instrument

Dr. Moore and her colleague Dr. Kexue Li, the lab's NanoSIMS Experimental Officer, apply a variety of analytical instruments to facilitate studies for their students and for investigators in diverse research areas. One vital tool: an advanced CAMECA NanoSIMS 50L ion microprobe.

This unique instrument optimizes secondary ion mass spectrometry (SIMS) performance at ultra-high lateral resolution and sensitivity. So it furnishes superior isotopic and trace element analysis in small regions of interest, with isotope ratio reproducibility of a few tenths of permil. Users say it delivers key performance metrics simultaneously that other instruments' techniques can only obtain individually.

Although no instrument can do everything — for example, a number of plant science problems require localizing zinc (Zn) and cadmium (Cd), but SIMS cannot ionize these elements well — Dr. Moore reports that the NanoSIMS 50L provides some crucial benefits.

"For my plant science/nutrition research," Dr. Moore says, "the main advantage is its high spatial resolution — which allows subcellular mapping — combined with high elemental sensitivity."

The NanoSIMS 50L was installed at Manchester in 2014, with a new oxygen (O) source added in 2018. "The spatial resolution when imaging with oxygen has improved from about 300 nanometers to 50 nanometers," she states. "That better resolution, greater beam stability, and reduced maintenance have been the biggest benefits."

The Work

Recently, Dr. Moore, Dr Sadia Sheraz, and their plant science collaborators studied the temporal uptake and distribution of trace amounts of iron (Fe) into wheat grain, combining NanoSIMS's other advantages with the ability to detect isotopes. Could overexpression of a vacuolar iron transporter increase the amount of iron carried into the starchy endosperm (the part of the grain used in white flour)? They fed wheat plants with isotopically labeled iron, ^{57}Fe, to see how their iron uptake and subcellular distribution changed compared to control grains.

"Mass interference of ^{57}Fe with ^{56}Fe^{1}H was one of the biggest challenges," she says. "And the low concentration of the isotope meant we had to image for a long time. Also, the wheat grain is quite large for NanoSIMS imaging, so we had to consider how best to sample it to get a representative result.

"We mapped the distribution of ^{57}Fe in wheat grain with the NanoSIMS 50L. Adjacent microtome sections were Perls' stained to show the presence of iron, and imaged with an optical microscope. Isotopic ratios of ^{57}Fe/^{56}Fe were extracted from vacuolar regions within cells."

The Results

Much iron in wheat can't be absorbed by our digestive tract because it's waylaid by binding to phosphorus-containing compounds called phytates. However, with NanoSIMS imaging, the researchers found features with very high levels of ^{57}Fe — hot spots of iron — in the bran layer cells not associated with phosphorus (P).

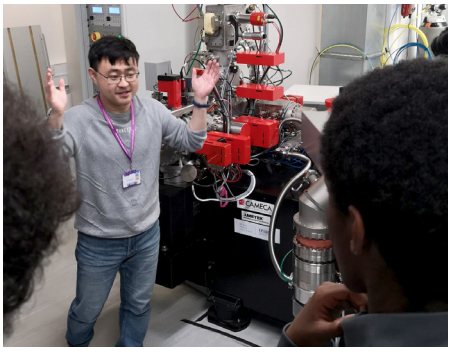
"That was unexpected," says Dr. Moore, "and new! This implies that the iron detected had only recently entered the cell — with isotope labeling and the NanoSIMS we can take a snapshot of the flux of iron and start to understand transport mechanisms. Eventually we may be able to select a wheat variety that has got natural overexpression of this vacuolar transporter. Obviously our collaborators are pretty excited."

The Future

Besides these plant studies, Dr. Moore is working on new materials science investigations of hydrogen (H) pickup and embrittlement mechanisms in zirconium (Zr), steel, and nickel (Ni) alloys, using the NanoSIMS 50L to map deuterium. In the presence of hydrogen, these alloys may become brittle — with catastrophic potential in environments such as the nuclear and oil & gas industries.

"The instrument's unique ability to localize hydrogen and deuterium at the scale of the microstructure is essential to understanding hydrogen embrittlement," she says.

NanoSIMS offers a lot of potential in plant/nutrition science research. "It comes down to working with excellent collaborators," Dr. Moore concludes, "and defining the right analytical questions that are really of interest in plant science right now."



Talking to students, Dr. Kexue Li outlines the scope of NanoSIMS capabilities.

About the Lab

The University of Manchester in Manchester, United Kingdom, is the country's largest single-site university, with a rich history of education and research. Its NanoSIMS Laboratory sits in the Department of Materials at the university's Photon Science Institute, under the auspices of the Henry Royce Institute. It facilitates advanced analysis for researchers from the university and from other institutions worldwide, in subjects from materials science and plant science to cosmochemistry, geology, and biology.

About CAMECA

CAMECA is a world-leading supplier of microanalytical and metrology instrumentation for research and process control. Our instruments measure elemental and isotopic composition in materials down to atomic resolution. Advanced CAMECA technologies include secondary ion mass spectrometry (SIMS), atom probe tomography (APT), electron probe microanalysis (EPMA), and low-energy electron-induced X-ray emission spectrometry (LEXES). We address challenging characterization needs in diverse markets, from materials sciences, life sciences, geology, and cosmochemistry to environmental, nuclear, and semiconductor research.

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www.cameca.com

Corporate Headquarters
29 quai des Grésillons – 92622 – Gennevilliers Cedex – FRANCE
cameca.info@ametek.com – Tel + 33 1 43 34 62 00
www.cameca.com

Regional Contacts
www.cameca.com/contact/international-distributors