CAMECA®
SCIENCE & METROLOGY SOLUTIONS

AMETEK®

# Metals & Alloys

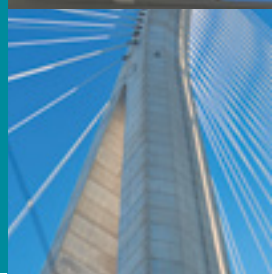






ANALYZE
OPTIMIZE
DEVELOP

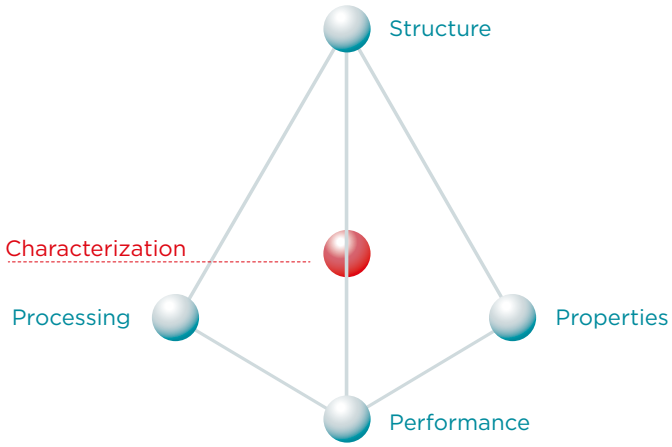






# The Critical Role of Material Characterization

Every facet of life is in some way determined or influenced by materials. From your cell phone to your toaster; from your car to your shoes; from your house to your coffee cup, materials pervade our everyday lives. Indeed, entire ages of human history are named after the material that characterized them: the Stone Age, Bronze Age, Iron Age, Silicon Age, and so on.



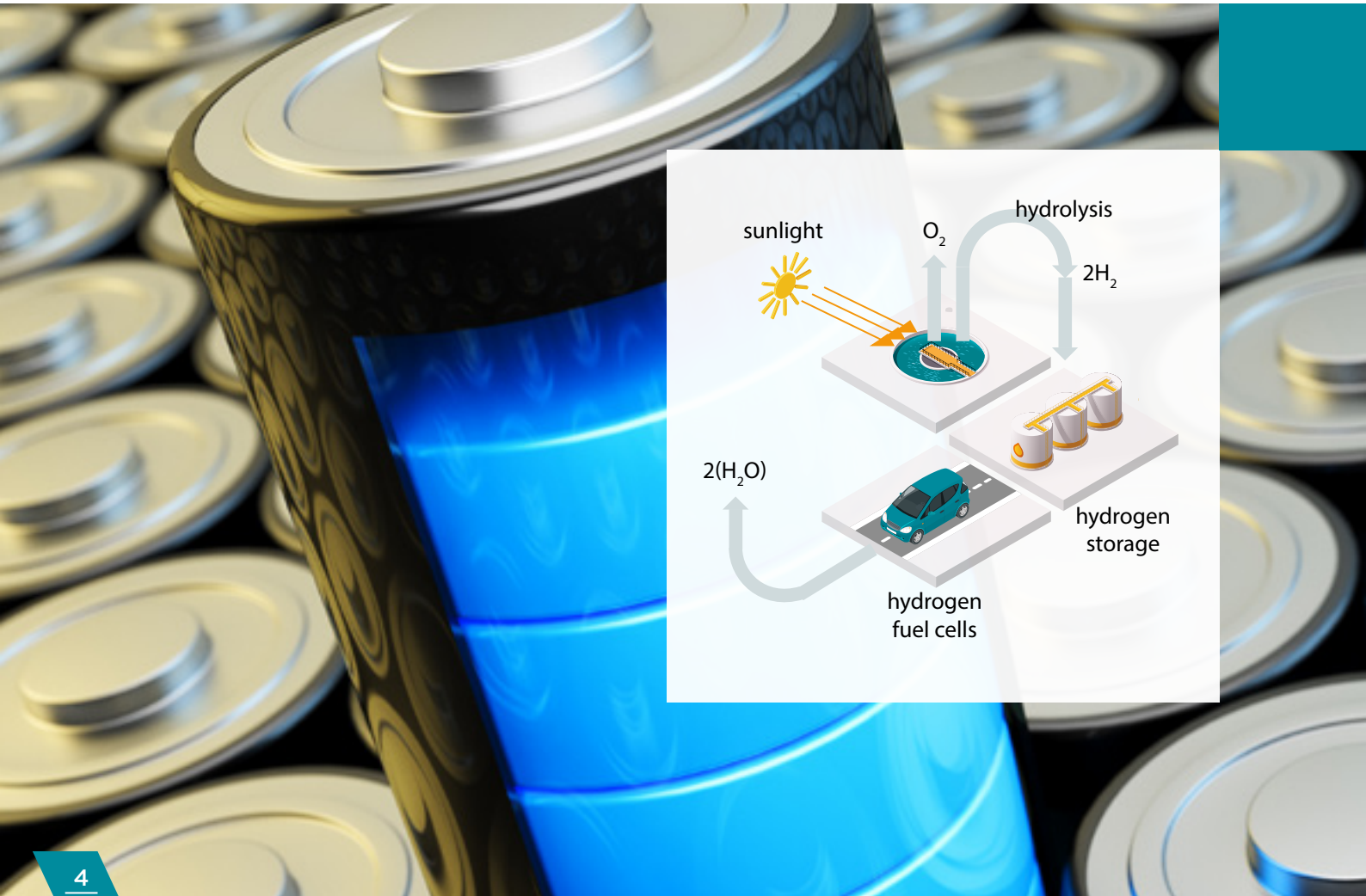

The classic materials science tetrahedron of "Structure, Processing, Properties, and Performance" has been recently modified to include the critical role played by materials "Characterization." The detailed knowledge of structure promotes learning and innovation of new materials with new properties.

To fully understand and improve the properties of materials, it is necessary to understand their structure and composition at a variety of spatial length scales. Bulk compositions vary on millimeter length scales; grain boundary segregation occurs on the micrometer scale (one part in a million meters); and precipitation and clustering occur on the nanometer scale (one part in a billion meters).

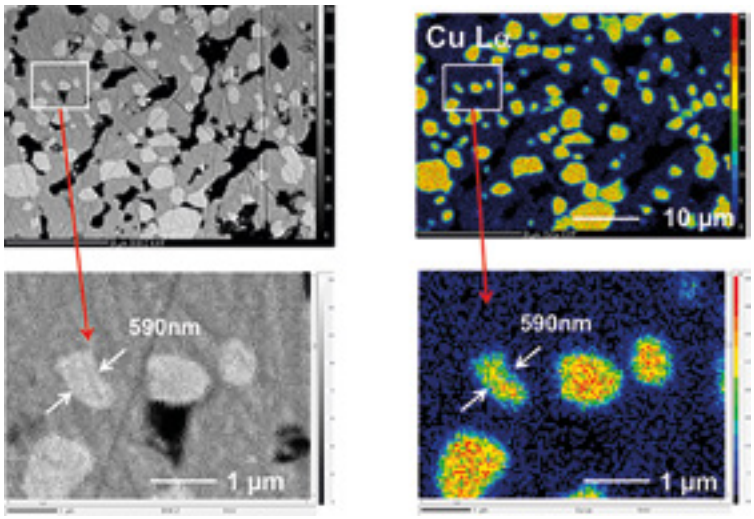
# Hydrogen Storage Alloys

A hydrogen fuel cell can convert stored hydrogen into electricity, and is used for variety of applications, from cars to space shuttles. Unlike fossil fuels, this conversion of hydrogen does not generate carbon dioxide. Gaining access to the microstructure details in hydrogen storage materials, including trace and minor elemental distributions, is important to understand and optimize hydrogen absorption properties.

**How can you determine microstructure details?** CAMECA has the answer.



# Hydrogen Storage Alloys




Sub-micron elemental mapping in MgPd hydrogen storage alloys.

*Sample courtesy of Dr. Eric Leroy, CNRS ICMPE Thiais, France.*





EPMA

## SXFive-TACTIS



The **CAMECA SXFive-TACTIS** uses a high-quality electron column optimized for x-ray microanalysis, and high-resolution secondary electron images with the choice of W/$LaB_6$ or field emission sources. It includes a new touch-screen interface with beginner and expert operation modes. The SXFive-TACTIS provides high-quality trace and minor element analysis for a wide range of materials applications (metals, alloys, and glass, for example). It can be fitted with up to five wavelength dispersive spectrometers and one energy dispersive spectrometer for high reliability and reproducibility.

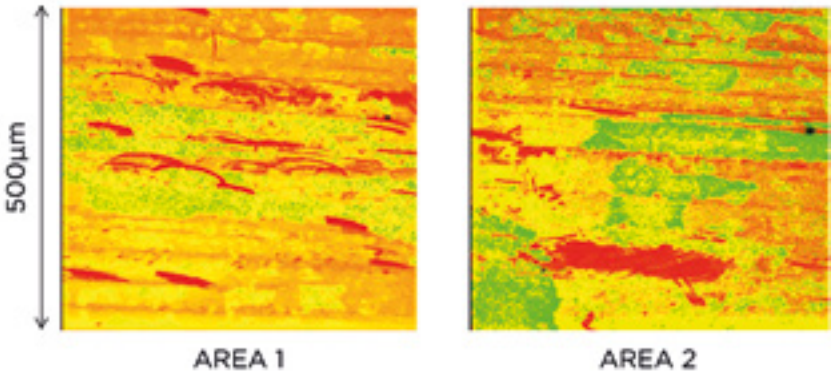
# Defects in Steel

Tinplate is a thin steel sheet coated with tin, resulting in a steel that exhibits an interesting set of properties: good cosmetic appearance, strength, stiffness, and corrosion resistance, among other traits. Tinplate is a well-known packaging steel, widely used for making different types of containers, such as food and beverage cans. It is of critical importance that the plated coating does not degrade during use. The tinplate surface is, in most cases, passivated with a chromium layer to stabilize the surface by preventing the growth of tin oxides.

**How do you know if the passivation layer is working?** CAMECA has the answer.

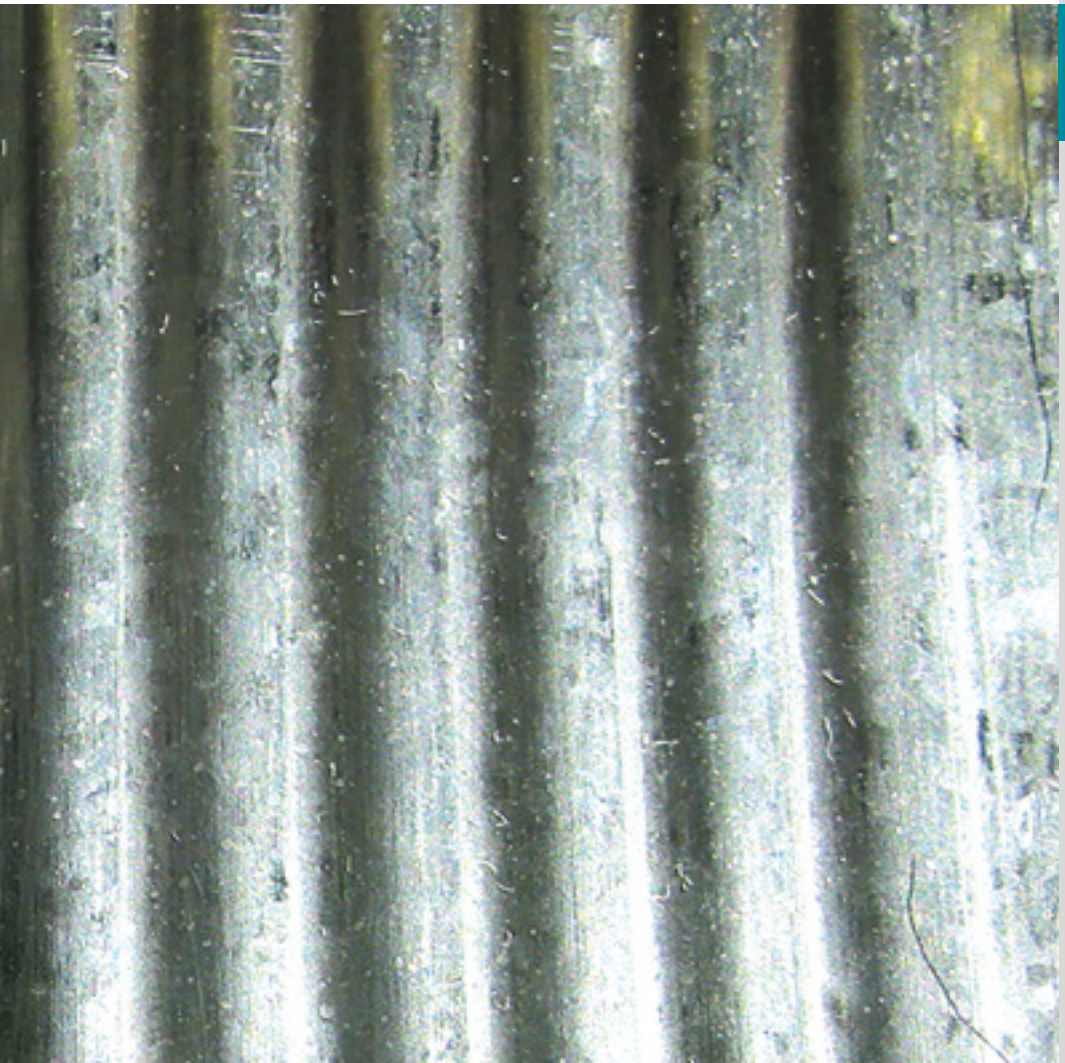


Beverage cans need defectless coating.



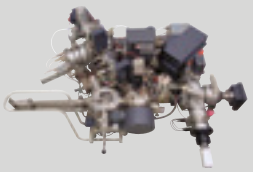

Red = $^{118}Sn$ Green = $^{52}Cr$ Yellow = both

The quality of the tinplate surface has been investigated using the ion imaging capabilities of dynamic SIMS. Defects on the sample correspond to the red areas (no Cr passivation layer on the Sn coating). Field of view: 500x500 µm2.



SIMS

## IMS 7f-Auto



Using the **CAMECA IMS 7f-Auto**, ion imaging of trace and major species can be obtained in metallurgical samples. Other strengths of the secondary ion mass spectrometry technique include unique depth profiling capabilities and high sensitivity (low detection limits). A large range of applications can be addressed: diffusion phenomena in polycrystalline samples, surface imaging analysis in alloys, study of inclusions, and segregation effects.

# Hydrogen Embrittlement Investigation

Hydrogen atoms easily diffuse into metals causing degradation of their mechanical properties. Known as hydrogen embrittlement, this phenomenon is not completely understood, yet it can lead to catastrophic failures in aircraft components, automotive fastening systems, high-strength structural steel plates and concrete reinforcing bars used in buildings... It is therefore of paramount importance to understand hydrogen trapping processes.

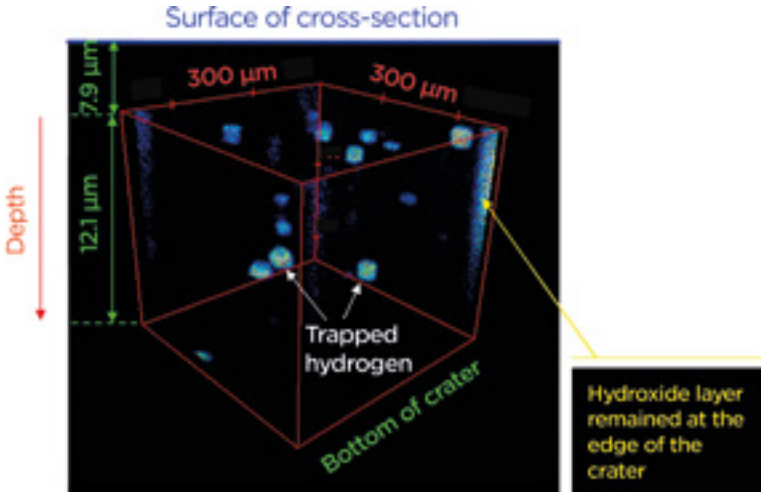
**How can you detect and visualize real hydrogen trapped at the intermetallic particles in alloys?** CAMECA has the answer.





Materials that are most vulnerable to hydrogen embrittlement include high-strength steels, titanium and aluminum alloys and electrolytic tough pitch copper.

# Hydrogen Embrittlement Investigation



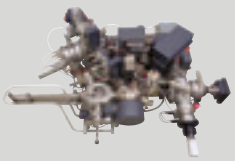

3D reconstructed SIMS ion image showing hydrogen trapped at inter-metallic particles in a practical aluminum alloy (6061-T6) exposed to high-pressure hydrogen gas (100 MPa, 200 °C for 300 hours).

*From: J. Yamabe, T. Awane, Y. Murakami, International Journal of Hydrogen Energy, Vol. 42 (2017), 24560.*



**SIMS**

## IMS 7f-Auto



For metallurgical applications, 2D mapping or 3D volume reconstruction of trace or major species is of great interest. Dynamic SIMS is widely used for the micro-characterization of metals and alloys, thanks to its unique advantages: low detection limits for all species including light elements, possibility to use isotopic tracers, depth profiling and ion imaging capabilities.

The **CAMECA IMS 7f-Auto** provides high lateral resolution imaging capabilities (down to sub-micron scale), allowing to visualize the distribution of elements or isotopes in three dimensions.

# Oxide Formation at the Surface of Metals

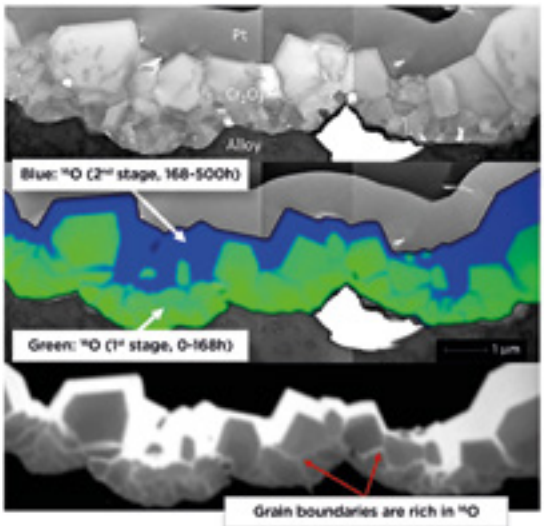
Metallic alloys are often protected by a surface oxide layer that resists corrosion. “Stainless steel” is a good example of a thin oxide layer that has been designed to protect bulk metal from corrosion or oxidation. Steels and other alloys made from iron are found in everything from cookware and cutlery to trains and bridges. Understanding the mechanisms of metallic oxide growth is fundamental in designing metal materials optimized for their properties and lifetime.

**How can you see the chemical details of these mechanisms?** CAMECA has the answer.



A TURBOJET ENGINE REQUIRES METALLIC ALLOYS TO BE STABLE AT HIGH TEMPERATURE IN CORROSIVE ENVIRONMENTS.

# Oxide Formation at the Surface of Metals




*From: Determination of the oxide scale growth mechanism using 18O-tracer experiments in combination with TEM and nanoSIMS. Hannes Falk-Windisch et al. in Materials Characterization 136 (2018) 128–133.*

Thermal oxide scale growth mechanism in a Fe-Cr alloy elucidated with a two stage isotopic oxygen labeling and subsequent NanoSIMS cross section mapping correlated with electron microscopy image.



A THIN SUPERFICIAL OXIDE LAYER DETERMINES THE CORROSION RESISTANCE OF METALLIC PIPES.

**SIMS**

## NanoSIMS 50L



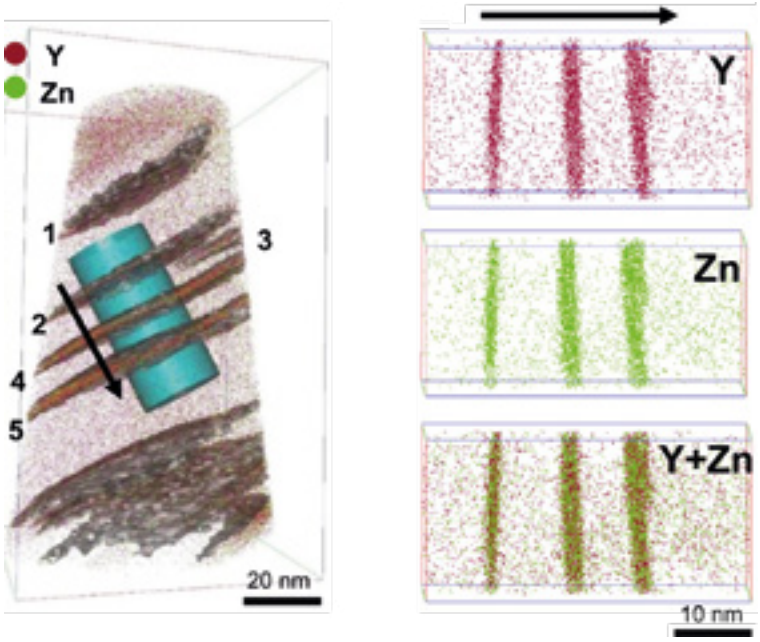
The **CAMECA NanoSIMS 50L** is a dynamic SIMS using a ~50nm spot size for both negative and positive secondary ions to produce high spatial resolution imaging capability. It has parallel detection of up to seven elements or isotopes and ultra-high sensitivity, combined with high mass resolving power and excellent lateral imaging resolution.

# Grain Boundary Analysis

In metals and other construction materials, strength and other macroscopic mechanical properties are pre-determined by chemical details occuring at a much finer length scale. Segregation of individual atoms to grain boundaries, for example, can substantially affect a material's strength.

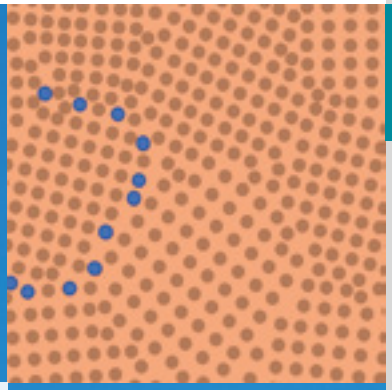
**How can you see individual atoms in three dimensions?** CAMECA has the answer.






Elemental maps of Y and Zn in a long period stacking ordered structure of a high Mg alloy.

*From: Compositional evolution of long-period stacking ordered structures in magnesium studied by atom probe tomography. Kim, J.-K., Guo, W., Choi, P.-P. & Raabe, D. in Scripta Materialia 156 (2018) 55–59.*



Schematic diagram of interfacial segregation of atoms in a fine grained material.

APT

## LEAP 6000 XR™

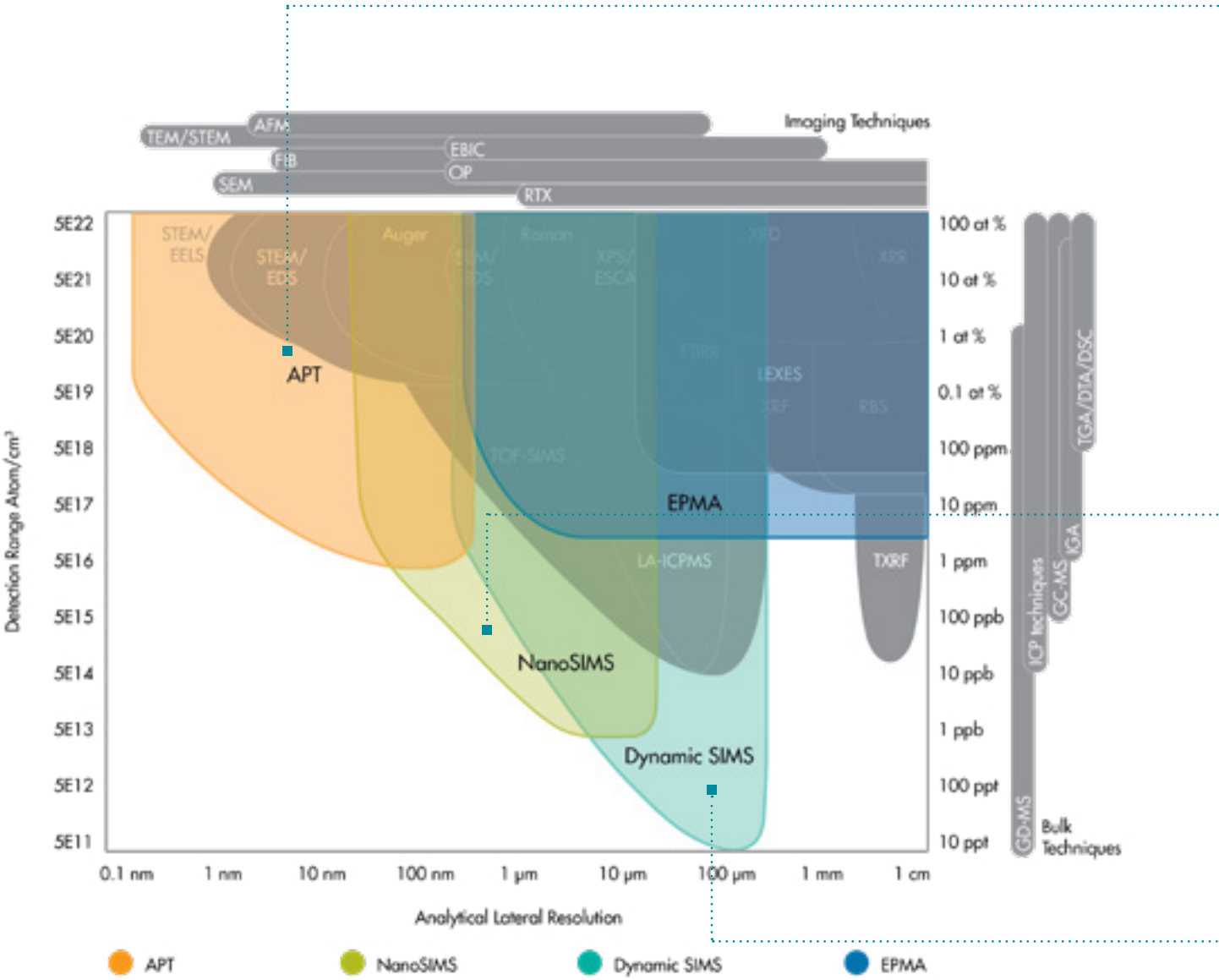


Atom Probe Tomography (APT) provides quantitative compositional analysis with sub-nanometer spatial resolution in three dimensions. It is especially suited for characterizing composition variations from microscale to sub-nanoscale.

- **EIKOS-UV™**, the Atom Probe for core APT applications;
- **LEAP 6000 XR™**, with a UV laser enables high productivity and a wide variety of applications.

# Broad Solutions to your Analytical Needs

CAMECA makes products tailored to the characterization of materials at all length scales, from millimeters to nanometers, and can provide a complete solution to your materials characterization challenges. From bulk composition with ppm sensitivy to nanometer scale atom clusters, you can find your characterization solution at CAMECA.



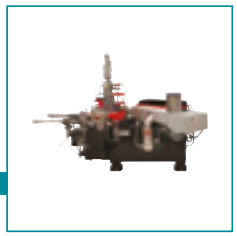
# Broad Solutions to your Analytical Needs



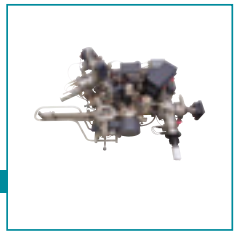
LEAP 6000 XR™



Invizo 6000™



NanoSIMS 50L



IMS
7f-Auto

# User Testimonials

*We have been using a CAMECA SX 100 EPMA unit with four wavelength dispersive spectrometers since 2008. The equipment has analyzed wide variety of solid samples such as minerals, metals, alloys, composites, and concretes. […] It's a robust and smart machine.*

Prof. Biswajit Mishra, Indian Institute of Technology, Kharagpur, India

*In the summer of 2017, a CAMECA SXFive was installed at the Syracuse University Electron Microprobe Laboratory user facility. Installation and commissioning were performed over a three-week period. We were immediately able to perform a wide range of sophisticated analyses, which is a testament to the skilled engineers and the highest quality analytical instrumentation. In the 15 months since commissioning, the instrument has run practically nonstop to serve a wide range of users with diverse analytical needs. […] We routinely use the instrument to perform major and minor element analyses of materials, but it truly excels at performing trace element analyses at concentrations down to the 5- to 10-ppm level for many elements. Light element backgrounds are very low and stable, which makes it possible to routinely perform accurate analyses of carbon, nitrogen and oxygen. The robust nature of the instrument, oil-free pumping system, and highest quality spectrometer design of the SXFive defines the state-of-the-art in electron probe microanalysis.*

Prof. Jay Thomas, Syracuse University, USA

*As a scientist interested in interfacial phenomena, the LEAP® 5000 has provided a transformative microscope in quantifying elemental behavior across of a variety of material surfaces. This has enabled new understanding of material's chemical structure and its effect in controlling properties, wether that be electrical, magnetic, optical or mechanical.*

Prof. Gregory B. Thompson, University of Alabama, USA

*Our LEAP® gives us fundamental understanding of atomic interactions between alloying elements in microalloyed steels. Particularly the clustering behaviors of light elements detected must lead to development of a new class of low-alloy steels by controlling heterogeneity contained in a classical metallic solid solution.*

Prof. Tadashi Furuhara, Institute for Materials Research, Tohoku University, Japan

*Our IMS 7f instrument was just being installed when the 3rd November 2011 earthquake happened. Despite seismic intensity of 7 and subsequent nuclear plant trouble, our university being located 100 km from Fukushima, CAMECA staff could solve the vibration related molecular pump issues and perfectly install the instrument. Since then, the Tohoku University IMS 7f has proven to be a robust machine, stable over time and incredibly versatile. We use it successfully for a wide variety of challenging microanalytical tasks such as characterization of diffusion in solid materials for fuel cells, depth profiles for multi layers in electric devices, behaviors of additional elements in steels or ceramics, dating in geoscience, isotopes analysis in biology...*

Dr. Takamichi Miyazaki, Tohoku University School of Engineering, Japan

*As a materials scientist focused on understanding the role of microstructure and environment in materials performance, the unique microchemical information attainable using the NanoSIMS is providing unique insights into hydrogen-assisted fracture that cannot be obtained via other analytical techniques. Our research using NanoSIMS has demonstrated the localization of hydrogen in the plastic zone ahead of fatigue cracks in austenitic stainless steel. NanoSIMS is the perfect complement to advanced analytical electron microscopy and atom probe tomography, as it provides essential information concerning elemental segregation at spatial resolutions necessary for correlation with the general microstructure.*

Dr. Greg McMahon and Prof. Grace Burke, Materials Performance Centre, University of Manchester, United Kingdom

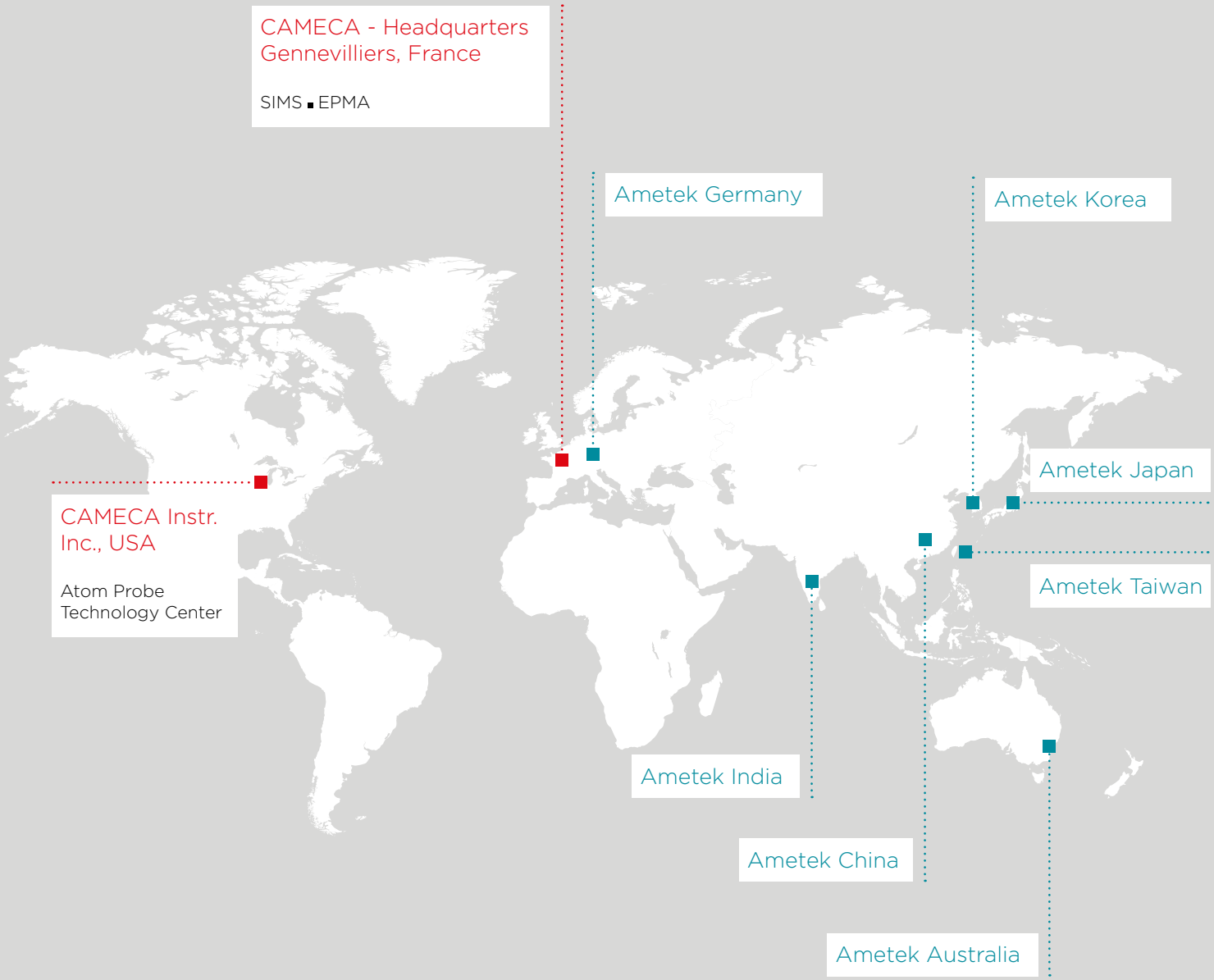
# About CAMECA

CAMECA started in France in 1929 as a manufacturer of movie theater projectors, before rapidly evolving into a provider of scientific instrumentation for the international research community and in-fab / near-fab metrology solutions for the semiconductor manufacturing industry. From its inception, CAMECA has been renowned for its precision mechanics, optics and electronics.

Since pioneering Electron Probe MicroAnalysis (EPMA) in the 1950's and Secondary Ion Mass Spectrometry (SIMS) in the 1960's, CAMECA has remained the undisputed world leader in these techniques while achieving numerous breakthrough innovations in complementary techniques such as Low energy Electron induced X-ray Emission Spectrometry (LEXES), and Atom Probe Tomography (APT).

Operating under ISO 9001 certification, CAMECA controls not only the technology, but all aspects in the design, manufacture, installation, and servicing of products. Located near Paris, France (CAMECA headquarters) as well as in Madison, Wisconsin, USA, our plants are state of the art facilities, using best practices for clean room production, computer networking, electron and ion optics simulation, and advanced CAD.

CAMECA is a business unit of AMETEK, Inc., a leading global provider of electronic instruments and electromechanical devices, as part of the AMETEK Materials Analysis Division.




R&D and production center, Sales and service

Sales and service

# World Leader in Elemental & Isotopic Microanalysis


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Life Science


Material Science


Metals & Alloys


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