Meet the Authors

Joonhong Ahn received doctoral degrees from the University of California, Berkeley (PhD, 1988) and the University of Tokyo (D Eng, 1989). He joined the faculty of UC Berkeley in 1995. His research deals with the performance assessment of advanced nuclear fuel cycles and the geological disposal of radioactive wastes. He led numerous joint research projects with institutions in Japan, South Korea, and the United States, and with the IAEA. He is currently conducting a joint research project with the Japan Atomic Energy Agency involving the analysis of criticality safety for the geological disposal of molten nuclear fuel in the Fukushima reactors.

Edward D. Blandford is a Stanton Nuclear Security Fellow at the Center for International Security and Cooperation at Stanford University and an adjunct research assistant professor in the Chemical and Nuclear Engineering Department at the University of New Mexico. His research interests include nuclear reactor thermal hydraulics, probabilistic risk assessment, performance-based regulation, and best-estimate code verification and validation. He received his MS (2008) and his PhD (2010) in nuclear engineering from the University of California, Berkeley. Prior to his graduate studies, he worked at the Electric Power Research Institute overseeing steam generator thermal hydraulics research and development activities.

Rodney C. Ewing is the Edward H. Kraus Distinguished University Professor in the Department of Earth & Environmental Sciences at the University of Michigan. He is also a professor in the Departments of Nuclear Engineering & Radiological Sciences and Materials Science & Engineering. Ewing's research focuses on radiation effects in minerals, ion beam modification of materials, the crystal chemistry of actinide minerals and compounds, and the "back-end" of the nuclear fuel cycle. He is the past president of the Mineralogical Society of America and the International Union of Materials Research Societies. He was recently appointed by President Obama to serve on the Nuclear Waste Technical Review Board.

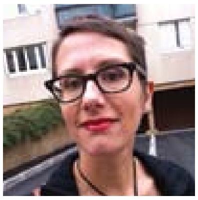
Bernd Grambow is a Professor of Excellence at the École des Mines de Nantes, France, where he holds the chair on nuclear waste disposal. He is head of the Subatech laboratory on high-energy nuclear physics, reactor physics and radiochemistry, a joint research unit at the IN2P3/CNRS, the Ecole des Mines of Nantes, and the University of Nantes. He is also director of the new French national CNRS-academic/industrial research network NEEDS (nuclear: environment, energy, waste, society). His scientific expertise is in radiochemistry, nuclear waste disposal science, geochemical modeling, radionuclide migration in the environment, chemical thermodynamics, and the dynamics of solid/liquid interfaces.

Hiroo Kanamori is the John E. and Hazel S. Smits Professor of Geophysics, Emeritus at the California Institute of Technology. He received his PhD in 1964 at Tokyo University. He works on the physics of earthquakes and its application to hazard mitigation through real-time technology.

Irène Korsakissok did her PhD thesis in the field of air-quality modeling. Her thesis dealt with multiscale modeling and uncertainties in atmospheric dispersion models. Two years ago, she joined the Institut de Radioprotection et de Sûreté Nucléaire (IRSN), where she is in charge of the local-scale atmospheric dispersion model used for operational purposes. She also works on local-scale meteorological preprocessors and model uncertainties.

Thorne Lay is Distinguished Professor of Earth and Planetary Sciences at the University of California, Santa Cruz. He received his PhD at the California Institute of Technology in 1983. He studies earthquake rupture processes, deep-Earth structure, and seismic wave propagation.

Yukio Masumoto is a principal scientist at the Japan Agency for Marine-Earth Science and Technology in Yokohama, Japan. He received a master's degree at Kyushu University and a PhD from the University of Tokyo on climate variations and large-scale air–sea interactions in the western tropical Pacific Ocean. After working at the University of Tokyo, he moved to the Japan Agency for Marine-Earth Science and Technology in 2010. His current research topics include climate variation modes in the tropics and their influences on global and regional climate systems, basin-scale and regional ocean circulation, and the prediction and predictability of these ocean/climate variations.



Anne Mathieu has been a research engineer at the IRSN for six years. After a PhD on the dynamics of the atmospheric boundary layer, she became an assistant professor at the Université Saint-Quentin en Yvelines. She joined the IRSN to work on local- and large-scale atmospheric dispersion during accidental releases. Her current work focuses on the development of methods for the reconstruction of accidental releases using environmental observations.

Takashi Murakami is a professor in the Department of Earth and Planetary Science at the University of Tokyo. His current research focuses on mineral–water–atmosphere interactions, including atmospheric evolution in the Precambrian, dissolution and weathering of minerals, and the formation and transformation of nanominerals and their effects on element transport. He has worked for the Japan Atomic Energy Research Institute, the University of New Mexico, the Australian Nuclear Science and Technology Organisation, and Ehime University. He is the past editor-in-chief of the *Journal of Mineralogical and Petrological Sciences* and is a vice-president of the Japan Association of Mineralogical Sciences.

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Yasumasa Miyazawa is a senior scientist at the Japan Agency for Marine-Earth Science and Technology in Yokohama, Japan. He received a master's degree at Kyoto University and a PhD from the University of Tokyo on the predictability of the Kuroshio variations and mesoscale eddy activities around Japan. After working with a private company, he moved to the Japan Agency for Marine-Earth Science and Technology in 2004. His current research topics include numerical modeling of tide–wave–current interactions in the ocean, the implementation of data assimilation in numerical ocean models, and the utilization of simulated data products in societal applications.

Christophe Poinssot is the director of the RadioChemistry & Processes Department in the French Nuclear and Alternative Energies Commission (CEA). He was also appointed as a professor in nuclear chemistry at the French National Institute of Nuclear Science and Techniques and, from 2012, as a visiting professor in actinide materials at the University of Sheffield. After his PhD in material science from the Ecole Normale Supérieure of Paris, he joined CEA Saclay in 1999, where he launched and coordinated the research program on the long-term storage and disposal evolution of spent fuel. His main interests are the improvement of nuclear energy sustainability and the geochemistry of uranium minerals.

Denis Quélo has been a research engineer at the IRSN for five years. After a PhD in data assimilation of atmospheric chemistry, he joined the IRSN to develop an operational, large-scale atmospheric-dispersion model. His current work centers on impact studies related to accidental releases from nuclear facilities.

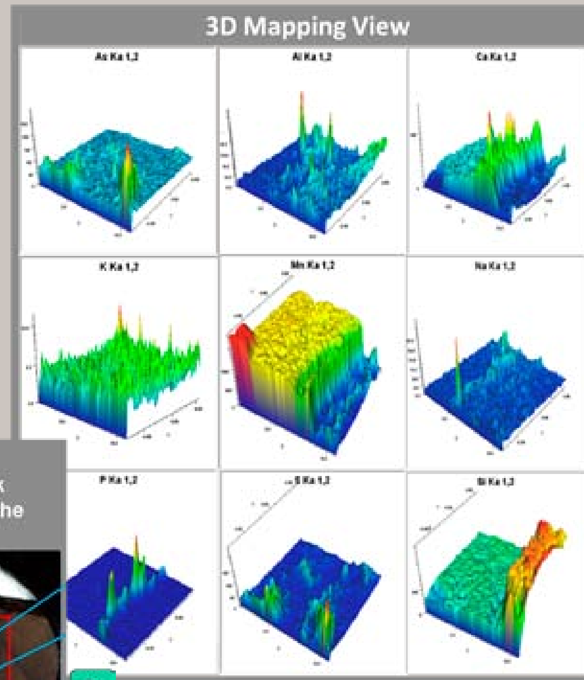
Jeroen Ritsema is the Henry N. Pollack Associate Professor at the University of Michigan. He received his PhD in 1995 at the University of California, Santa Cruz. His research is focused on the seismic imaging of Earth's interior, computational seismology, and Earth dynamics.

Yoshio Takahashi is a professor of environmental geochemistry at Hiroshima University, Japan. In 1997, he received his PhD in environmental radiochemistry from the University of Tokyo. He then became a research associate in the Department of Earth and Planetary Systems Science at Hiroshima University and became a full professor in that department in 2009. His research interest is primarily in speciation studies applied to environmental chemistry and geochemistry to understand the fates of contaminants, geochemical cycles, and the evolution of the Earth. He is currently participating in a project on the migration of radionuclides emitted during the accident at the Fukushima Daiichi nuclear power plant.

Daisuke Tsumune is a senior research scientist at the Central Research Institute of the Electric Power Industry, Japan. He received a master's degree and a PhD from Tohoku University, the latter on oceanic transport processes of artificial radionuclides originating from global fallout due to atmospheric weapons testing. His current research interests include tracer distribution and the transport mechanism of tracers, such as carbon, in the ocean; iron as a micronutrient; and artificial radionuclides originating from global fallout and from the Fukushima Daiichi accident. His goal is a better understanding of the role of oceans on climate and an assessment of oceanic pollution at the global scale.

Naohiro Yoshida is a professor in the Department of Environmental Chemistry and Engineering, a vice-director of the Inter-Departmental Organization for Environment and Energy, and an assistant vice-president at the Tokyo Institute of Technology. He is also the president of the Geochemical Society of Japan. He introduced the use of isotopomers, isotopic substituted molecules, as powerful tracers in the study of the cycles of materials of biogeochemical interest from the early Earth to present and future global change, life and biomedical diagnosis. He is currently involved in an intensive survey of radionuclide dispersal from the Fukushima Daiichi nuclear power plant.

WDXRF as an Investigative and Analytical Tool Using Small Spot/Mapping and UniQuant™



Process control, failure troubleshooting, and in situ identification are all now possible using a standard laboratory wavelength dispersive X-ray fluorescence (WDXRF) with the advent of small spot/mapping capability. Narrowing a sample surface-analysis area down to 0.5 mm to obtain the chemistry of an inclusion or irregularity has helped many a scientist solve problems that could only be solved through more complex techniques previously. The test results provided below were performed using the Thermo Scientific ARL PERFORM'X WDXRF.

A surface stain or inclusion on a material can quickly be targeted and elementally defined, showing where it originated in the process. Minerals can be both identified and chemically imaged in 2- and 3-dimensional displays. Homogeneity testing of a coating over a large or small area, forensics testing on minute samples or scattered residue… the list goes on and on.

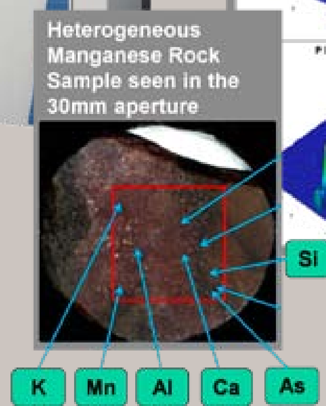
Elemental distribution for the examples mentioned above is easily displayed in an intensity format, and normally this would provide the required answer to the common question, "What is it?" But if concentration resolution is required, the operator may run into some trouble. How do you calibrate for a stain? What reference materials are readily available for a metal inclusion in a wire? How do you quantify components on a circuit board without removing them? This is where the second step to total small-spot analysis comes into play—UniQuant.

Small Spot/Mapping Description

Small-spot analysis is a rather easy concept to describe. The first step is for the XRF unit to image the sample surface. From this image it is possible, using the mouse, to click on areas of interest for analysis. For mapping, the operator selects one of a number of "shapes" and enlarges or contracts it to a size that best contains the area of interest. The sample is excited through the use of a primary X-ray beam. The secondary X-rays emitted are collimated through a 0.5 mm aperture. Small-spot analysis is a selection of one or more unique and individual points on a sample surface, each one producing a singular analytical result, whereas mapping is the joining of these individual points into a unified pattern to produce a 2- or 3-dimensional presentation along with intensity/concentration results for the selected area.

UniQuant Description

UniQuant uses the original factory calibration to determine concentrations in completely unknown samples. UniQuant is unique in its method of intensity measurements. Unlike other semiquantitative software programs, UniQuant uses a method known as peak hopping, instead of a continuous scan technique, to acquire the intensities for all measurable elements. The procedure of peak hopping allows for faster analysis by not wasting measurement time on any location where an element peak will not be found. UniQuant will measure every theoretical 2-theta angle for each element, including alternative lines for some heavier elements and background positions. By focusing the elemental counting times on peak locations only, UniQuant is able to provide more accurate results and lower detection limits compared to other scan-based semiquantitative methods. An interesting feature is that the counting time for each analytical line can be defined separately depending on the main interest of the analyst.



Mapping Example: Mapped Elements in a Geological Sample

Mapping imaging is a helpful way of better understanding a problem. The 2-D images can be viewed as individual element distributions or overlaid to give a more comprehensive correlation of the elements as a group. The 3-D images are single-element displays and can be rotated for a full 360-degree visualization or even a birds-eye view. While most maps are collected as intensity-only images, empirical calibrations can also be used to fully quantify the result. Geological samples can offer the most interesting and informative mapping images. In this example, one can see that the material is mostly Mn due to its uniform base and strong intensity response, but other elements are also present, with a large concentration of Si off to one side and the possible presence of a vein containing Ca, S, and P running through the center of the sampled area.

Conclusion

The examples presented here are only a fraction of the applications that many analysts are using today. The investigative capabilities of WDXRF have been shown to save thousands of dollars in process monitoring. With UniQuant, small samples are no longer a hindrance due to their size and a lack of calibrating materials. It is now possible to review coating thickness across a surface without the need of specialized instrumentation. Quantification using empirical calibrations on undersized or irregularly shaped materials is possible through the use of a standard laboratory WDXRF, even in situ.

Mapping/small-spot analysis brings many benefits especially when combined with a standardless routine such as UniQuant.

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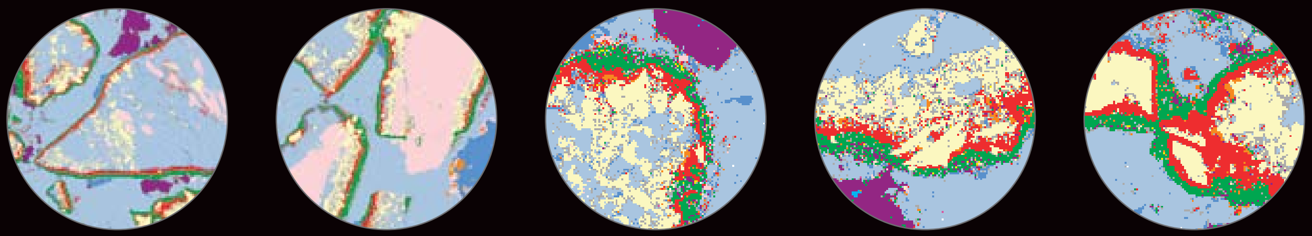
Image courtesy of Dr Hanna Horsch and Roland Schmidt, Hazen Research, Inc.

Mapping the world ... one micron at a time



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Uranium ore from the Schwarzwalder Mine, in Ralston Buttes district, Jefferson County, Colorado, USA, mapped by QEMSCAN®. The image shows an atoll-like texture with veins mineralized by uranium-thorium (red), and lead (green) bearing phases.

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