EDAX is excited to announce the Clarity™ Electron Backscatter Diffraction (EBSD) detector. It is the world’s first commercial EBSD-specific detector based on direct electron detection technology. Direct detection has made a significant impact in the microscopy community, and the Clarity™ is the culmination of efforts to bring this technology to EBSD collection. It provides patterns of the highest quality, as shown in Figure 1, and sensitivity with no detector read noise and no distortions for optimal performance.

Direct detection of electrons for collecting EBSD patterns is a return to its origins. The first experiments to detect EBSD patterns used photographic film. Electrons interacted directly with the film to produce high quality EBSD patterns, but this was slow for multiple patterns. This changed with the introduction of analog and then digital cameras coupled with a phosphor screen, which converts the electrons into light photons. This step allowed for the adoption of even better camera technology to improve the sensitivity and speed of data collection over the years. As a result, EBSD detectors have been developed to make pattern detection simpler, faster, more convenient. But the detection path that the signal must travel has some drawbacks. The electron to photon conversion is affected by the grain size of the phosphorescent material and film thickness on the screen and has conversion efficiencies and localized blooming of the signal. The requirement of high sensitivity means that the use of a lens system with the largest possible aperture is desirable and the trade-off is that small imaging artefacts are introduced because lenses are never perfect. For Hough-based indexing, such small imperfections do not matter, but they do limit the detail for quantitative analysis of the pattern. Direct electron detection removes all these steps and corresponding issues from the collection chain.
The Clarity™ EBSD detector uses direct detection to capture the backscattered electrons and does not require a phosphor screen or light transfer system. The technology is based on a CMOS detector that is covered by a silicon sensor across which a bias voltage is applied. The electrons generate several electron/hole pairs upon impact and the bias voltage moves the charge towards the underlying CMOS detector, where each event is counted. This method is so sensitive that individual electrons can be detected. Coupled with zero read noise, the Clarity™ provides unprecedented performance for EBSD pattern collection. Patterns comprised of less than 50 electrons per pixel can successfully be detected and analysed. But even this value is slightly misleading as the electron signal onto the EBSD detector is non-uniform and only the pixels in the middle of the pattern will reach this highest electron intensity. Additionally, the EBSD signal is a composite of both diffracted and scattered electrons, with only a small fraction of the detected electrons contributing to the bands in the pattern. A background correction is generally used to effectively remove the scattered electrons and enhance the diffracted signal to facilitate accurate analysis.

This level of sensitivity allows unprecedented analysis of beam sensitive materials. Direct detectors have recently been used for EBSD analysis of halide [1,2] and Methyl Ammonium Lead Iodide (MAPbI3) [3] perovskite solar cells. These materials do not produce useable and persistent EBSD patterns under typical beam currents. At low beam currents, high-quality EBSD maps were obtained that allowed investigation of the effects of grain boundaries, grain size, and crystal orientation on the performance of these materials. The Clarity™ can also be used to analyze traditional materials as well. The cover image shows a combined image quality (IQ) and Inverse Pole Figure (IPF) orientation map from a deformed iron sample showing significant plastic deformation.

The absence of a phosphor and optical lenses enables collection of extremely sharp EBSD patterns. Compared to a traditional pattern, the band edges are sharper with better contrast. Figure 3 shows EBSD patterns collected with the Clarity™ and the Hikari Super EBSD detectors. Averaged band profiles across sets of bands show higher contrast and more detail with the Clarity™, as shown in Figure 4. This sharpness enables detailed analysis of EBSD patterns and is ideal for cross-correlation investigations. Coupled with the ability to count the number of electrons in each pixel, these patterns are also useful for comparison with dynamic diffraction simulations of EBSD patterns. The measured information may help users better understand the subtleties of pattern formation, and lead to improved modeling and pattern matching.

When comparing direct detection patterns against phosphor/lens-based systems, it is easy to understand that the observed differences are indicative of the signal deterioration in the optic path. However, the direct detection EBSD patterns can also show a blurriness/sharpness deterioration towards the edges of the pattern. When this was observed with traditional detectors, it was thought that lens performance played a role in this sharpness degradation, but these comparative experiments show this is not true. This phenomenon is caused by the electrons reaching the perimeter of the detector having a longer electron pathway through the sample and experiencing additional dynamic diffraction effects, combined with increased interactions with lattice distortions.

In summary, the Clarity™ direct electron detector provides unparalleled sensitivity and pattern quality for EBSD pattern collection and mapping. It enables the analysis of beam sensitive materials and provides quantified information about electron intensities onto the detector.

References:
2 Local Crystal Misorientation Influences Non-radiative Recombination in Halide Perovskites, Jariwala, Sarthak et al., Joule, 2019 in press https://doi.org/10.1016/j.joule.2019.09.001
Troubleshooting Indexing Problems on a Difficult Sample: A Look at Ice

EBSD on ice can be difficult for many reasons. Ice has a low average atomic number (or low Z value), causing weaker than average EBSD patterns, which can cause issues with data collection. This also means background and indexing parameters may need to be optimized to get the best results. Doing ice in the microscope can be tricky given the beam sensitive nature of the samples. While the collection and indexing parameters can be optimized live on the scope, this can take significant time, however post-processing of the data can help. This includes both pattern processing (NPAR™), as well as Hough Parameters.

With this in mind, a customer data set was received where they were asking for help on setting up data collection on ice. The data as received, showed large areas of no indexing, as well as speckling inside possible grains (Figure 1.)

With the lower symmetry nature of ice requiring more lines to get a unique solution, each good line matters. The solution to this problem is to set the Vertical Bias or the Rho Fraction to bias the Hough routine away from the bad areas.

The background was bad and over subtracting in some areas causing a complete loss of signal. This area was also causing incorrect lines to be detected by the Hough. These lines were then used in the indexing.

Figure 1. The data as received shows inconsistent results, but the interior of grains showed some consistency of results. This dataset is on the edge of being a perfect dataset with some changes.

Figure 2. Overall Image quality of the area shows that most of the sample has low Image Quality. This points to poor pattern contrast, which will need to be improved to get better results.

The background was bad and over subtracting in some areas causing a complete loss of signal. This area was also causing incorrect lines to be detected by the Hough. These lines were then used in the indexing.

Figure 3. Looking at high pattern quality areas of the sample show a cause of mis indexing in the interior of the grains. In the bottom of the pattern, the background is causing over subtraction and background leading to signal loss. This causes the Hough Transform to identify three incorrect lines (in red), which are being used by the indexing routine.

Figure 4. a) The pattern as received shows little signal. With the lack of contrast, the Hough can not find lines to even try to index this pattern. b) By using the background routines built into OIM Analysis™, the signal and the contrast of the signal are both increased. The initial background is still causing issues with signal loss in the bottom right quadrant. c) Using NPAR™, increases the signal levels and contrast that is occurring. Note the undersaturated area signal increase is strong enough to remove the issues caused by the bad background.
After the main problems were found and corrected for, the full dataset was rerun using the changed parameters (New background, NPAR™, and changes in the Hough to Vertical Bias and Rho Fraction). The final result of this data shows much more consistent indexing results over the full area (Figure 5).

After the indexing is done, it is best to revisit the IQ and Confidence Index (CI) maps to see what areas are still trouble spots and to quantify the indexing results. The IQ map in Figure 6 was made using both the patterns that were background reprocessed, as well as run through NPAR™. The IQ map shows greatly increased pattern quality visible grain structure. This improvement in pattern quality leads to the increase in the indexing results.

The final step is to double check the change in the indexing quality. CI maps and indexing statistics were compared before and after processing (Figure 7). It quickly becomes apparent that the CI values have increased significantly (from an initial average value of 0.2 to 0.8). Low CI datapoints still exist near grain boundaries, but this is expected. The number of indexed data points has increased from 41% to over 99%.

Data set courtesy of:
Andrew Cross, University of Pennsylvania
Jamie Ford, University of Pennsylvania
David Goldsby, University of Pennsylvania
Travis Hager, University of Pennsylvania
Dave Prior, University of Otago
In a recent demonstration of the Orbis micro-XRF system, a customer mentioned that they were having trouble measuring iodine in table salt with their current XRF system. This seems like a straightforward exercise, but upon further investigation, it was not.

The iodization of salt in the United States began about a century ago. Iodine is an important micro-nutrient for thyroid gland health. Certain portions of the American population had diets deficient in iodine and the iodization of table salt was chosen as a method to increase the level of iodine in the average American diet. The salt iodization process was inexpensive; salt does not spoil and estimates of table salt consumption were available.

A few weeks prior to the customer demo, iodized table salt was purchased from a local grocery store. The ingredients list showed iodine in the form of potassium iodide at about 45 ppm iodine. This was consistent with what can be found via web searches. A pile of salt grains was pressed onto a piece of carbon tape and measured with the Orbis system using a 2 mm spot size. The system was equipped to measure down to 30 μm spot sizes, small enough for individual grains, but 2 mm was chosen to avoid any potential issues with grain to grain variations. The presence of iodine was confirmed via the I(L) series and quantified using the I(L\(\alpha\)) line at 3.937 keV (Figure 1).

A few weeks later during the customer demonstration, a variety of customer supplied samples were measured and a request to measure table salt was made by the customer at the end of the session. The same table salt sample was measured again in the Orbis, only to discover that the iodine signal was no longer present (Figure 2). Peak fitting and quantification results showed no iodine at all. Given that solid I\(_2\) is known to undergo sublimation, it was speculated that the iodization level in the salt was somehow not stable. The customer confirmed that in previous attempts, he had measured table salt from shakers in the company cafeteria where the residence time of the salt in the shaker was unknown.

Further web searches indicated that indeed, the iodization level of salt has a certain shelf life depending on many factors including temperature, humidity, impurities in the salt, the chemical form of the iodine bearing additives, and product packaging. For example, in the form of potassium iodide, the iodide is oxidized by contact with oxygen and atmospheric moisture and the resulting iodine then undergoes sublimation. In various regions of the world, iodized table salt is formulated to improve its shelf life based on the characteristics of the table salt and the general environment, i.e. desert, tropical, etc.

In this case, the iodine level had dropped to near or below detectable limits after about three weeks of being left out in atmospheric conditions. The grains of salt ranged in size from about 100 to 500 μm in characteristic dimensions, which posed a basic question.
To what characteristic depth was XRF measuring? Was there possibly any iodine left in the largest crystals? This depth can be estimated based on the emission range of the fluorescent signal energy as the exciting X-ray energy always has to be greater than the measured signal. (The physics are a bit different for electron excitation, where the answer is determined by electron penetration depth into the sample.)

XRF measurement depth can be estimated from the Beer-Lambert equation for the absorption and transmission of light:

$$I = I_o e^{-\mu \rho x}$$

*Equation 1.*

Where
- $I_o$ = incident intensity
- $I$ = transmitted intensity
- $\mu$ = mass absorption coefficient (cm$^2$/gm)
- $\rho$ = density (gm/cm$^3$)
- $x$ = path length (cm)

The mass absorption coefficient (MAC) describes how readily the $I(L\alpha)$ signal line at 3.937 keV will be absorbed by the NaCl matrix. The total MAC of a matrix as a function of fluoresced photon energy can be described as follows:

$$\mu_{\text{matrix}}(E) = \sum_i (\omega_i \times \mu_i(E))$$

*Equation 2.*

Where
- $\mu_{\text{matrix}}(E)$ = matrix MAC for analyte photon with E energy
- $\omega_i$ = weight fraction of individual matrix element “i”
- $\mu_i(E)$ = MAC for element “i” for analyte photon with E energy

For NaCl, there are two MACs describing how Na and Cl each absorb the 3.937 keV photon. The easiest way to get the full matrix MAC is to back calculate it from the Beer-Lambert equation using any web-based calculator describing X-ray absorption/transmission characteristics modeling the signal photon traversing the sample matrix to the detector, such as: http://henke.lbl.gov/optical_constants/filter2.html.

By inputting the sample matrix formula (including trace elements if desired), and an arbitrary matrix path length, one can get the calculated result for $I/I_o$ and then rearrange Equation (1) to solve for the NaCl matrix MAC by inputting the previously used path length and the known density of table salt. The result is: $\mu_{\text{NaCl}}(3.937 \text{ keV}) \sim 540$ cm$^2$/g. Rearranging Equation (1), one can solve for the signal path length through the sample traversed by the fluoresced photon to the detector as a function of $I/I_o$:

$$x_{\text{NaCl}} = \frac{\ln(I/I_o)}{(-\mu_{\text{NaCl}}\rho_{\text{NaCl}})}$$

*Equation 3.*

The XRF Emission Depth, $d$, would typically be defined as normal to the sample surface and should also consider the take-off angle (TOA) of the detector defined from the sample surface as shown in Equation (4).

$$d_{\text{NaCl}} = x_{\text{NaCl}} \times \sin(\text{TOA})$$

*Equation 4.*

Table 1 shows the XRF Emission Depth as a function of the signal transmission ratio, $I/I_o$, with a nominal detector TOA of 50°.

<table>
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<th>$I/I_o$ [%]</th>
<th>Path Length, $x$ [μm]</th>
<th>Emission Depth, $d$ [μm]</th>
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<tr>
<td>10</td>
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<td>15</td>
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</table>

*Table 1. XRF Emission Depth as a function of the signal transmission ratio, $I/I_o$.*

The definition of the characteristic XRF path length and emission depth is somewhat arbitrary, as it depends on how one defines the signal transmission ratio, $I/I_o$. Typically, the characteristic path length has been defined as the length over which 99% of the signal has been absorbed. Hence:

$$x_{\text{NaCl}} = \frac{\ln(0.01)}{(-\mu_{\text{NaCl}}\rho_{\text{NaCl}})} \sim 40 \mu m$$

*Equation 5.*

It is interesting to note from Table 1, that at 50% of the critical emission depth, the XRF signal is undergoing 90% absorption.

Coming back to the original analysis, it is possible that iodine was still present at the core of the larger 500 μm grains of salt. Further analyses could be done on cross-sectioned grains or pulverized grains to make that determination. It would be possible to measure cross-sectioned grains of NaCl using the 30 μm spot size on the Orbis to study how readily iodine is lost as a function of depth into the NaCl grain, but that is a study for another day.
X-ray spectrometry in Scanning Electron Microscopes (SEMs) has routinely been used for decades. EDAX is proud to be a pioneer in this technology with one of the first Energy Dispersive Spectroscopy (EDS) systems designed for SEM applications. The qualitative and quantitative analysis of the measured raw data (the spectra) requires the utilization of complex non-linear models, which were developed over time and further progress is still being made today.

The fundamental physics to consider are the X-ray generation depth and self-absorption of generated X-rays in samples, which both depend on the geometry. Geometry influences the final quantitative matrix-correction used to calculate the concentrations, it is also required for the bremsstrahlung background calculation and line-series overlap deconvolution (the element line-series differ in ratios, which is also due to the absorption situation). Therefore, one can say that the geometrical situation influences, in a crucial way, the entire shape of the spectrum (the measured data), which includes the bremsstrahlung background with absorption jumps, the line ratio of peak series, and the total emitted (and measured) count ratios between different element line-series. The ‘understanding’ of the measured spectra can then be quite complex and everything that is visible with spectra and what is calculated from spectra evaluation depend on the correct geometry calculations (proper geometry modeling). One example of complexity is a Monacite spectrum (Figure 1). The element line series of La, Ce and Pr are highlighted with different colors, to show their proportions (after deconvolution).

Even though this point is very crucial for the evaluation of all the X-ray data, there can still be some confusion with geometry definition and angles.

Early on, the “Take-off” angle was defined and introduced as a basis for X-ray model geometry understanding, with the first Electron Probe Microanalysis (EPMA) systems, the Electron Microprobes. Simply, one can say that this angle is defined to be the angle of (mean) X-ray exit direction from a sample, similar to the way an aircraft or rocket launch is defined. It is the angle between the X-ray direction to the center of the detector and the sample surface. Logically this take-off cannot exceed a maximum of 90°, which is when the X-rays are emitted from a sample perpendicular to the surface (in other words, the detector axis is perpendicular to sample surface). With the basic "Electron Microprobe", there was no ability to tilt the sample. Therefore, the “Take-off angle” (TOA) was defined by the design of the entire instrument. It characterized the absorption situation in samples biunique and was equal to the “Elevation angle” (EA).

As it is now possible to tilt the specimens in SEMs, the TOA is usually calculated as the sum of EA and “Tilt angle” (TA) in simplified cases if the detector azimuth position is zero (perpendicular to the tilt axis). Until this point, the TOA is still representative for the real X-ray excitation and absorption situation. Roughly, this is indeed the case if small tilt angles are used, only small deviations (mistakes) will be in all calculations. But with a more careful look, one can see this is not the fact and big deviations will occur with high tilt samples.

Example 1:

In Figure 2a, the normal setup in a SEM (two-dimensional, simplified for the case of “Azimuth angle” (AA) is zero). The TOA is the sum of EA and TA. It is assumed that another SEM setup with a bigger "elevation angle", just EA = EA + TA, then one can twist Figure 2a with the "tilt angle" and with a second setup the TOA will be the same in case the sample is not tilted (Figure 2b). Both setups have identical TOA independent of the tilt of the electron beam. But as one can see very easily, the absorption situation in the sample would only be the same, if the electron column is also tilted. But this is not the reality.

We can learn from this example that the TOA only represents one part of the absorption situation, the trajectory orientation of the emitted X-rays vs. the sample surface.
A second part depends on generated X-ray depth distribution (generation distance from sample surface). This part depends on the electron beam incidence angle in relation to the sample surface. And it is assumed in Figure 2b to be the same as in Figure 2a. But in reality, with the Figure 2b setup and no tilt (same TOA), the electron column stays perpendicular to the horizon and therefore the real depth distribution is deeper than Figure 2b suggests. Finally, despite both cases having the same TOA, the geometry for the entire X-ray excitation and the absorption physics are actually different!

Example 2:
One can imagine that with the usual high-tilt case used in Electron Backscatter Diffraction (EBSD), the TOA based models run out of order completely, because the TOA model does not consider the depth distribution, which is much reduced with a large slope sample. A usual EBSD tilt situation is with TA = 75°. If assuming a normal EA = 35°, then the TOA calculates 75° + 35° = 110°. By definition, the TOA is never > 90°, so it can be determined that the final TOA = 70°. So, does it mean in cases with an EA = 35°, that the TA = 75° has the same X-ray characteristics as a TA = 35°? It is easy to understand that this is not true. With the TA = 75°, the excitation of X-rays is much closer to the sample surface than with the other case, but both have the same TOA. The final emission of X-rays is much higher in the “high-tilt”, 75° case, than with the 35° condition, even though the absorption path orientation is the same (represented by TOA). It is because the generation depth is closer to the surface with a 75° tilt.

The TOA depicts only one aspect of the final X-ray emission situation, the absorption of X-rays, which are generated in the depth. The second aspect, the actual depth distance from surface, cannot be considered by TOA. This is another example showing that a TOA based metric is not a complete base model for X-ray physics in a sample and therefore it is not suited for correction models with tilted samples.

Consideration of two independent angle parameters EA and TA is necessary, to get the complete picture of the geometrical situation with X-ray emission from a sample (with AA being zero). TOA is a derived value, one can calculate the TOA from EA and TA. But it is not possible to get the complete geometrical picture from one angle parameter (TOA) alone.

EDAX is using another geometrical model in place of the classical TOA geometry base. First with TEAM™ EDS spectra evaluation, which is properly, geometrically defined with taking tilted samples into consideration: “Improved EDS Performance at EBSD Geometry” [1]. There was the statement: “An EDS quantification model, termed eZAF, which incorporates a blend of the most advanced models with recent and more precise atomic mass absorption coefficients, was used to quantify…”

The vast majority of the high-tilt situation improvement with EDS spectra evaluation was that eZAF replaced spectra evaluation algorithm without using a TOA founded geometry calculation, compared to legacy software models.

EDAX spectra evaluation algorithms have been using the following geometrical formula since the TEAM™ EDS software was introduced:

Absorption path of X-rays = depth of X-ray production in material * geo
(Equation 1)

The ‘depth of X-ray production in material’ is the depth distribution of generated X-rays inside the sample material with electrons perpendicular to the horizontal plane surface incidence.

\[ geo = \frac{\cos(TA)}{\sin(TA) \cdot \cos(EA) \cdot \cos(AA) + \cos(TA) \cdot \sin(EA)} \]
(Equation 2)

The parameters are: TA is the tilt angle; EA is the elevation angle and AA is the azimuth angle (angle between the perpendicular of the specimen stage tilt axis and the real detector position).

For no tilt cases, the formula transforms into a very simplified version, also in a 3-dimensional view:

\[ geo = \frac{1}{\sin(EA)} \]
(Equation 3)

And this is exactly the case for old Microprobes, where no tilt was possible normally, one could use the TOA = EA. Equation 3 also represents cases with AA = 90°, if the detector is in a position parallel to the tilt axis. Then any tilt is meaningless (if a simplified assumption is made that the X-ray emission is from a point-source and there is no divergence; in reality, this is only if the detector area is very small and the detector is far away from the sample).

However, not everything has been taken into consideration. The formulas used are only proper in cases where the geometry is exactly in the designed ideal analytical position, the sample “working distance” (WD) is exactly at the point where the detector axis is striking the electron beam at sample surface. In practical cases this is often not true, actual WDs are not exactly at the intersection point:
The correct detector elevation is important for accurate quantification as the matrix correction has a strong dependence on this parameter.” [2]

Therefore, it is necessary to distinguish an “actual elevation angle” (or “effective elevation angle”) from the nominal angle, the “designed elevation angle”. Equations (2) and (3) used EA nominally, as if the operator really measured exactly at intersection point WD what is usually the ideal WD. If there are deviations, then the absorption in the sample differs. The “actual elevation angle” is required to calculate the base geometry values:

“Typically, the optimal sample position is located on the electron-beam axis at an optimal working distance. At this distance, the effective-elevation angle equals the nominal elevation angle. … The difference between the effective elevation defined by the actual working distance and the nominal elevation as defined by the intersection of the detector axis and the optic axis. The effective evaluation angle can be calculated from the actual working distance given the optimal working distance, the nominal elevation angle, and the nominal sample-to-detector distance.” [3]

The EDAX spectra evaluation models and algorithms follow this citation. The “actual elevation” angle is always used, which is normally different from the “nominal elevation”. But Figure 3 also shows two other effects in cases where the WD is not exactly in the optimal position:

1. There is a deviation between the detector axis and incoming X-rays, a “detector input deviation angle”.
2. The “detector sample distance” is changing, different from the nominal.

Indeed, the elevation angle changes and the effects of no perpendicular X-ray entrance into the detectors do not produce huge absorption deviations in many analytical cases, compared to other error components. But it matters more the closer the detectors are to sample. In general, and more in cases where detectors are close to the sample, the change of “detector sample distance” is affecting the solid angle (the total fraction of all emitted X-rays compared to all the directions emission). In many cases, this change can be in the order of magnitude of several %. In all cases, it is required to calculate and carefully consider if an absolute view is performed with X-ray spectrometry, e.g. with eZAF results that are not normalized based on reference measurements. It is also very important for full “standards-based quantification”, in this case even with normalized results. The solid angle change does not affect the PeBaZAF model results, which are not normalized, because characteristic radiation and bremsstrahlung have practically the same change in solid angle, and the effect cancels out.

Summary
The “take-off angle” parameter is no longer a good metric for X-ray data evaluation in the SEM. More appropriate geometry models have been used by EDAX since the release of TEAM™ EDS software. Consequently, in its new software platform (APEX™), EDAX will expose the parameters which are actually used, and which describe the geometry situation better and uniquely: the “actual elevation angle” and “tilt”. The TOA value being displayed was a concession on a decade long legacy geometry model, people were used to it, but it is not state-of-the-art. The experiences with the high-tilt EBSD parallel measurements, have shown that the old quantitative model, where TOA is used for base geometric consideration, would fail and it is required to be replaced by the geometry view, as the new eZAF [1] was developed for this with the first internal working name of “HiTiltZAF”.

References
2020 Worldwide Events

February 3-7
Asia-Pacific Microscopy Conference (APMC) Hyderabad, India
February 5-7
Semicon Korea Seoul, South Korea
February 23-27
The Minerals, Metals & Materials Society (TMS) San Diego, CA
March 1-5
Pittcon 2020 Chicago, IL

To help our present and potential customers obtain the most from their equipment and to increase their expertise in EDS microanalysis, WDS microanalysis, EBSD/OIM™, and Micro-XRF systems, we organize a number of Operator Courses at the EDAX facilities in North America, Europe, Japan, and China.

March 17-19
The Japan Institute of Metals and Materials (JIM) Tokyo, Japan
March 31-April 3
Analytica München, Germany
April 21-22
Royal Microscopy Society (RMS) EBSD 2020 Sheffield, United Kingdom
April 23-24
2020 FIB SEM User Group Meeting Laurel, MD

February 3-7
Asia-Pacific Microscopy Conference (APMC) Hyderabad, India
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Semicon Korea Seoul, South Korea
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2020 Worldwide Training

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Europe

EDS Microanalysis (APEX™ EDS)

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EDS Microanalysis (TEAM™ EDS)

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EBSD OIM Academy

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Japan

EDS Microanalysis (APEX™ EDS)

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EDS Microanalysis (TEAM™ EDS)

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North America

EDS Microanalysis

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</tr>
<tr>
<td>October 19-20</td>
<td>Draper, UT</td>
</tr>
<tr>
<td>November 17-19</td>
<td>Mahwah, NJ</td>
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</table>

EBSD OIM Academy

<table>
<thead>
<tr>
<th>Event</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>March 24-26</td>
<td>Draper, UT</td>
</tr>
<tr>
<td>July 8-10</td>
<td>Mahwah, NJ</td>
</tr>
<tr>
<td>October 21-23</td>
<td>Draper, UT</td>
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Pegasus (EDS & EBSD)

<table>
<thead>
<tr>
<th>Event</th>
<th>Location</th>
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</thead>
<tbody>
<tr>
<td>July 6-10</td>
<td>Mahwah, NJ</td>
</tr>
<tr>
<td>October 19-23</td>
<td>Draper, UT</td>
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China

EDS Microanalysis

<table>
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<tr>
<th>Event</th>
<th>Location</th>
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<tr>
<td>March 3-5</td>
<td>Shanghai (ACES)</td>
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<tr>
<td>June 2-4</td>
<td>Shanghai (ACES)</td>
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<tr>
<td>September 1-3</td>
<td>Shanghai (ACES)</td>
</tr>
<tr>
<td>December 1-3</td>
<td>Shanghai (ACES)</td>
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</tbody>
</table>

TEAM™ EBSD OIM Academy

<table>
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<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>February 25-27</td>
<td>Shanghai (ACES)</td>
</tr>
<tr>
<td>May 12-14</td>
<td>Shanghai (ACES)</td>
</tr>
<tr>
<td>September 22-24</td>
<td>Shanghai (ACES)</td>
</tr>
<tr>
<td>December 8-10</td>
<td>Shanghai (ACES)</td>
</tr>
</tbody>
</table>

*Presented in English
#Presented in German

Please visit http://www.edax.com/support/training-schools for a complete list and additional information on our training courses.

Visit edax.com for the latest news and up-to-date product information.
The Nanoscale Characterization Facility (NCF) in the Singh Center for Nanotechnology is a central user facility at the University of Pennsylvania. The NCF houses state-of-the-art tools for electron and ion beam analyses for Penn, other universities, and industry users in the Philadelphia area. It offers users access to Scanning Electron Microscopes (SEMs) and Transmission Electron Microscopes (TEMs). The facility includes an integrated sample preparation laboratory with complete sample coating and plasma cleaning capabilities, as well as cryogenic TEM sample preparation equipment, and a suite for offline image and data analysis.

The facility is open to all users and all samples, including 6,000 year-old bricks from Archaeology, nanoporous gold foils from Materials Science and Engineering, synthetic polymersomes from Chemistry, Antarctic ice cores from Geology, and novel root canal materials from the Dental School. Due to the many different samples types, the facility’s systems need to be flexible and able to handle whatever is thrown at them.

“We chose EDAX due to the easy-to-understand workflow of the TEAM™ and APEX™ software packages, which are a great fit for our users – experienced and brand-new SEM drivers alike,” stated Staff Scientist, Dr. Jamie Ford. “Having EDAX Energy Dispersive Spectroscopy (EDS) detectors and APEX™ installed on all of our SEMs (FEI Quanta ESEM, JEOL 7500F HR-SEM, TESCAN S8000X Plasma FIB) simplifies training and makes combining datasets from different tools seamless.”

Most of the users at the NCF are interested in qualitative maps. One example is determining if metal/polymer/metal multilayer structures are in the correct order with the correct thickness. TEAM™ and APEX™ help with this, allowing users to get their beam set to the correct spot and start collecting maps within five minutes.

“The EDAX equipment and software has been indispensable in the qualitative regime when we have to verify the stoichiometry of films deposited in the Nanofabrication Facility,” said Dr. Ford.

The users at the NCF are also use Electron Backscatter Diffraction (EBSD) to solve a number of materials problems. Some examples include analyzing the grain structure of copper films in substrates for graphene growth, correlating the orientation of deposited hexagonal boron nitride flakes with their optical properties, and determining the grain size and orientation of ice and solid CO₂.

For more information about the Nanoscale Characterization Facility at the University of Pennsylvania, please visit: https://www.nano.upenn.edu/resources/nanoscale-characterization/.

Figure 1. Data from one of the NCF’s outreach programs. High school students anneal dimes at a range of temperatures between 500-1000°C, cross-section them, polish them, and use EDS to determine the diffusion of Ni from the NiCu cladding into the bulk Cu.