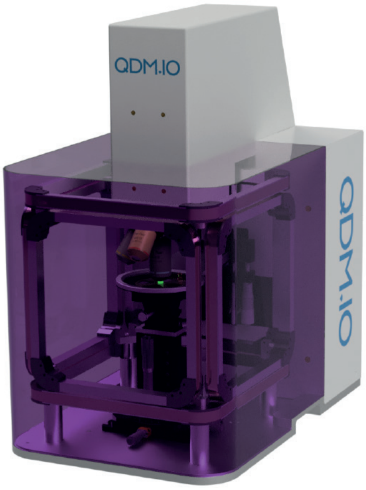
SPECTRUM

News from Quantum Design Europe

Edition 43 | January 2025

New measurement technology – Imaging with NV centers

Since the discovery of nitrogen-vacancy (NV) centers in the 1990s, they have increasingly developed from research objects to research tools. An NV center is a point defect in the crystal structure of a diamond. This quantum system has excellent stability even at room temperature, so that it is now widely used, e.g. as a qubit or as a component of a magnetometer.



A few years ago, the first measurement technology manufacturers began to equip scanning probe microscopes with NV centers in order to use them as magnetometers with high spatial resolution. The American manufacturer Q-CAT has chosen an innovative approach that opens up completely new measurement possibilities. Instead of positioning a single NV center on the tip of a cantilever, the Quantum Diamond Microscope from Q-CAT uses a sensor that contains a large number of NV centers. This allows an area of several millimeters to be measured simultaneously. For the first time it has become possible to image the magnetization in real time with an extremely high sensitivity that is otherwise only known from SQUID magnetome-

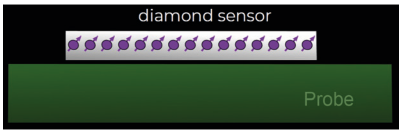


Fig. 1: A diamond chip with a large number of NV centers is placed over the sample.

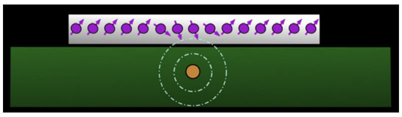


Fig2: The local magnetic field of the sample disturbs the NV centers.

» Page 2

Low energy XRF (LE-XRF) in semiconductor metrology with the Sigray AttoMap system Part 1 – Presentation of the system

Micro X-ray fluorescence (µXRF) has proven to be an invaluable analytical technique in the semiconductor industry as it enables non-destructive elemental analysis with high sensitivity for dopants and thin film thicknesses. µXRF is usually performed at high X-ray energies (> 5 keV) and is considered a measurement system for high atomic number (high Z) elements. However, it is often overlooked that µXRF is even more powerful at lower X-ray energies. In this article, we present some application examples of the AttoMap system at low energies for critical applications in semiconductor metrology.

Overview of the AttoMap-310

Performing µXRF at low X-ray energies offers significant advantages over conventional µXRF at higher energies. This includes orders of magnitude higher sensitivity to low-Z elements and even significantly improved sensitivity and shorter acquisition time for the lower energy (L and M lines) of high-Z elements, as the X-ray optics

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New measurement technology – Imaging with NV centers

» ters. Compared to a scanning SQUID, the technology offers significantly better spatial resolution. Not only is the field strength of the sample measured at a specific location, but also the local field vector. Applications are e.g:

- 2D materials
- Measurements of magnetic domains in moire magnetism

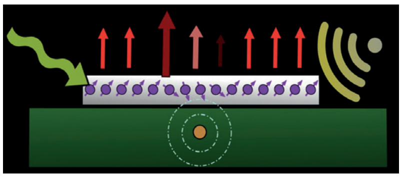


Fig3: The NV centers are excited with a green laser and microwaves and emit a fluorescence spectrum.

- Examination of Dirac liquids
- Photovoltaics
- Determination of current flows in PV components
- Electronic components
- Measurement of the magnetic fingerprint and analysis of individual components in integrated circuits
- Paleomagnetism
- Distribution of different minerals in a rock sample
- Determination of the detrital portion of speleothems
- Meteorite analysis
- Biomagnetism
- Single cell detection in blood
- Imaging of magnetic bacteria with sub-cell resolution

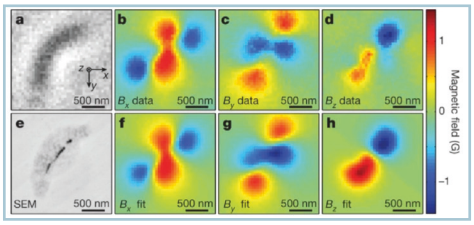


Fig4. The local magnetic field can be calculated from the fluorescence.

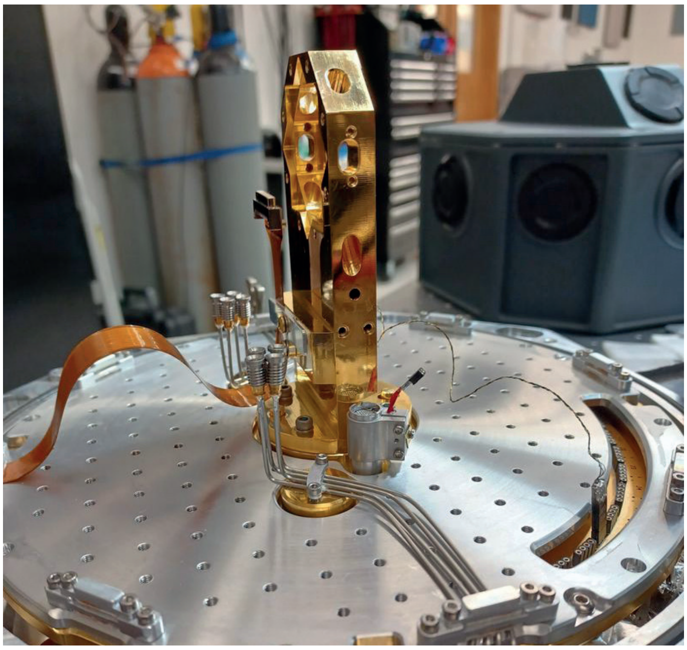
We will be presenting an application on this topic later in the isue. Stay tuned on page 11.

Please contact us
materials@qd-europe.com

Customized projects at Montana Instruments

Our long-standing partner in the field of optical cryostats, Montana Instruments, has been known for customized solutions since its foundation. The adaptations complement their user-friendly cryostats with closed cooling circuits and low vibrations and round off their product portfolio in the high-end range. The cryostats can be integrated into the optical setup directly after installation and there are no more adjustments to make before starting the measurement.

The options that Montana Instruments offer for the individualization of their cryostats are now shown with real-life projects on a separate subpage of their website [1].



The depicted examples include permanent magnets that are integrated into the cryostats to apply a small magnetic field to the sample, or the combination with stronger electromagnets that have a field strength of 1 to 2 Tesla.

There are solutions for ion traps in a Cryostation s200 and a chamber with ultra-high vibration stability. There are also solutions for placing 3-inch wafers in the sample chamber for optical investigations.

All of this is provided by a dedicated team of Montana Instruments engineers to enable the customer's research application. A design and cost estimate will be prepared in close cooperation with you.

Check out Montana's website for inspiration. Then challenge our specialists and discuss your requirements with us.

[1] https://www.montanainstruments.com/custom-engineering

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cryo@qd-europe.com

Low energy XRF (LE-XRF) in semiconductor metrology with the Sigray AttoMap system Part 1 – Presentation of the systemrents

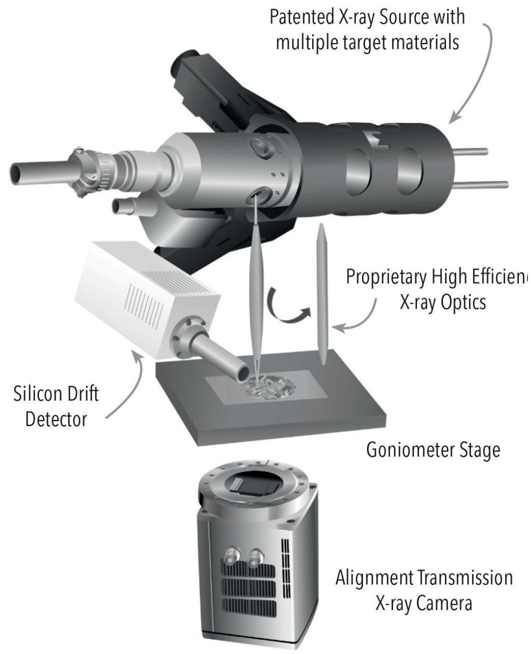
» increase with the square of the wavelength. Despite the numerous advantages, the main bottleneck with low energy µXRF is the low brightness of X-ray sources that produce low energy X-rays and the significant challenges in manufacturing X-ray optics for lower energies. The AttoMap-310 utilizes Sigray's patented X-ray source design, which uses actively cooled diamond to achieve high power loading, and its highly efficient axially symmetric X-ray optics. The system has been rapidly adopted by the semiconductor industry [1] for a wide range of elemental analysis applications including:

- Aluminum, for work function adjustment in transistors
- Fluorine, a residue from processing (e.g. etching)
- Germanium used in SiGe structures for gate-all-around applications and as a metrological endpoint for etching
- Molybdenum nitride, which is often used as a thin film in gate electrodes and in memory applications

Other applications include boron, titanium nitride, oxygen and zirconium oxide.

AttoMap-310 micro X-ray fluorescence microscope (µXRF):

Sigray's AttoMap-310 µXRF enables rapid analysis of both low atomic number elements (low Z) down to boron (B) and low energy fluorescence lines (e.g. L and M lines) of high atomic number elements. Its unprecedented performance is made possible by several key innovations in critical X-ray components, including:



1) Patented X-ray source with multiple targets
Sigray's X-ray source allows users to select up to five different X-ray target materials to tune the incident X-ray energy, maximizing sensitivity by up to two to three orders of magnitude. Targets include Sigray's patented ceramic X-ray source targets, which offer significantly higher power loading and higher brightness compared to conventional X-ray target materials such as aluminum. Particularly advantageous targets for semiconductor applications are Sigray's SiC X-ray targets, which produce an ultra-bright Si line that avoids excitation of the Si fluorescence of the substrate/wafer, and a calcium-based target for high-efficiency Sn/Ag ratio measurements. Other targets are Au, Cr, Cu etc.

2) Proprietary X-ray optics
Unlike conventional µXRF systems that use polycapillary optics, the AttoMap-310 utilizes Sigray's proprietary axially symmetric X-ray optics. This optic provides higher performance at low X-ray energies and can be designed to deliver >99% of an X-ray beam within a 40 µm test field (or focused on a small 3-5 µm achromatic X-ray spot). Sigray optics also allow the detector to be placed much closer to the sample than polycapillary optics, resulting in much greater fluorescence detection.

3) Goniometer table (θ-2θ)
The sample stage and SDD of the AttoMap-310 can be rotated to achieve near grazing incidence angles on samples to maximize the sensitivity of low energy X-rays. Rotation angles can also be adjusted to remove diffraction peaks in Si wafers.

4) Vacuum housing
The AttoMap-310 utilizes a vacuum chamber that achieves <10E-5 Torr and is designed to allow ultra-low concentrations of carbon and oxygen at the request of semiconductor customers.

In the next part of our series on low-energy X-ray fluorescence (LE X-ray fluorescence) in semiconductor metrology, we present initial measurement results for aluminum, fluorine, germanium and molybdenum nitride samples.

Source: 1st Microscopy Today 2023 Awards. https://academic.oup.com/mt/article/31/5/12/7273061

Please contact us
imaging@qd-europe.com

Four-point surface resistance measurements at different temperatures

Sheet resistance measurements are a versatile tool for research and industry. Important examples are the electrical characterization of new materials, the monitoring of thin film processes and the determination of the homogeneity of semiconducting and conducting thin films. Traditionally, these measurements are carried out at room temperature. New applications such as solar cells or quantum technologies sometimes require significantly wider temperature ranges.

Using a combination of a cryogenic probe station and the M81-SSM (Synchronous Source Measurement System), our partner Lake Shore was able to demonstrate that measurements are possible in the fringe areas of modern applications.

One possible configuration for four-point sheet resistance measurements is the linear arrangement of four contacts with uniform distances between the measuring tips. If the measuring tips are small and the layer to be measured is thin compared to the substrate, the sheet resistance can be determined with

$$R_{SH} = \frac{\rho}{t} = \frac{\pi}{\ln(2)} \frac{V}{I}$$

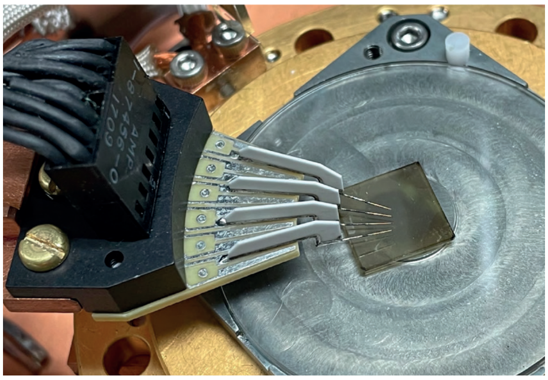


Fig. 1: Probe station with a multi-contact wedge (MCW) probe arm. The sample is mounted on an insulated sample holder.

V is the voltage drop and I is the applied current through the external contacts. Complex contact structures are considered in [1].

A Lake Shore CRX-4K with a Multi-Contact Wedge (MCW) probe arm can be fitted with a suitable measuring tip to ensure that the measuring tips are at a fixed distance from each other (Fig. 1). This configuration has the advantage that several contact surfaces can be measured quickly with one measuring arm without the individual tips shifting against each other. Reliable and reproducible measurement results can therefore be provided.

The electrical measurements are carried out with Lake Shore's M81-SSM. The current is applied to the outer contacts with the BCS-10 (Balanced Current Source) and the voltage drop at the two inner contacts is measured with the VM-10 (Voltage Measure). The BCS-10 module has an output for common mode rejection. This output is connected to input B of the VM-10 in order to reduce interference signals caused by earth currents or other interference in the measurement setup. For further details see [2].

Lake Shore's MeasureLINK™ software is used for logging, temperature monitoring and implementing a current reversal protocol to reduce thermoelectric effects.

The chosen example shows the measurement of the temperature-dependent sheet resistance of a 10 μm thick silver-platinum layer (Heraeus C4729). At room temperature, a value of 4.35 mΩ/□ (ohm per square) was determined for the sheet resistance, which is consistent with an expected sheet resistance of ≤ 5 mΩ/□.

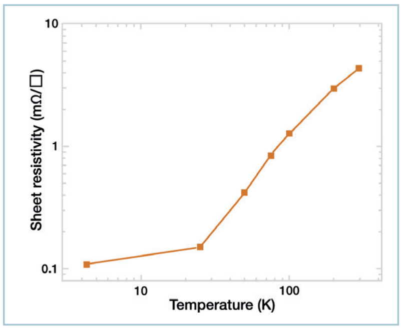


Fig. 2: Temperature-dependent sheet resistance of a silver-platinum layer (Heraeus C4729).

These results show that this material exhibits a similar drop in sheet resistance at decreasing temperatures as moderately pure silver. Below 30 K, there is less of a drop due to the lower phonon contribution to electron scattering. In this example, the sheet resistance at 4 K is close to 100 μΩ/□. (Fig. 2)

Following this example we see that the combination of a Lake Shore Probe Station and M81-SSM is suitable for carrying out precise four-point surface measurements at different temperatures. Such a measurement setup can also be extended to other areas of application in the field of semiconductor thin-film characterization or the development of new materials.

Please contact us if you have any questions about the Lake Shore Probe Stations or the M81-SSM.

[1] Semiconductor Material and Device Characterization, Third Edition, D. K. Schroder, John Wiley & Sons, 2015

[2] "Minimizing the Effect of Common-Mode Noise Interference in Low-Temperature Applications," Lake Shore Cryotronics Application Note, J. R. Lindemuth and E. A. Codecido, 2022

Please contact us
cryo@qd-europe.com

NV magnetometry for 2D materials

The use of nitrogen-vacancy (NV) spins in diamond for magnetic imaging is a powerful technique for measuring magnetic order at the sub-microscopic scale. This technique is increasingly used for the study of 2D materials as it offers high sensitivity combined with high spatial resolution. One challenge is to position the NV centers at a precisely defined distance in the nanometer range to the target material. This is the only way to detect the very small magnetic fields generated by magnetic monolayers of some 2D materials. Toeno van der Sar's group at TU Delft has published an interesting paper on this. [1] The group has developed a "dry transfer" technique to transfer a diamond micromembrane with NV centers directly onto a CrSBr sample. CrSBr is an antiferromagnetic 2D material. This technique achieves a close contact between diamond and sample, which is crucial for the detection of weak magnetic fields. The direct contact between the diamond membrane and the 2D magnet is one of the main advantages of this technique. The method minimizes the risk of contamination at the interface and can be used in an inert gas atmosphere, making it suitable for air-sensitive 2D magnetic materials. Due to the proximity of the NV sensors in the diamond to the sample, the magnetic stray fields of the CrSBr could be spatially resolved, which only occur when the thickness of the CrSBr changes by an odd number of layers. A monolayer magnetization of MCSB = 0.46(2) T was measured from the magnetic stray field of a single uncompensated ferromagnetic layer in CrSBr without the need to exfoliate monolayer crystals or apply large external magnetic fields.

The measurement was performed with a Montana Instruments cryostation. This optical cryostat with integrated objective provides the vibration stability and high NA required for measuring the PL spectrum of NV centers. The PL spectrum can be used to infer the magnetization.

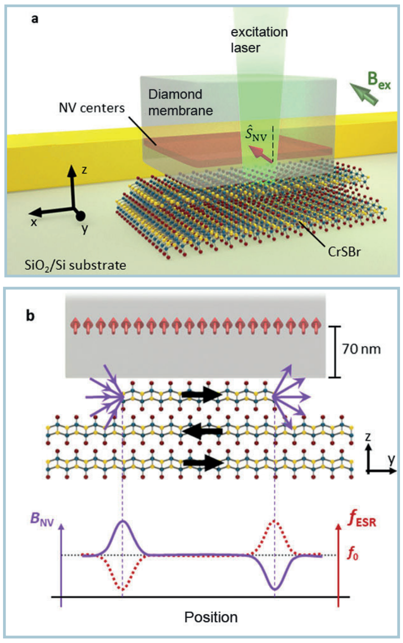


Fig.1 NV magnetometry of the interlayer antiferromagnet CrSBr. a) Schematic representation of the sample. B) Illustration of the modulation of the NV ESR frequency by the stray fields (purple arrows) generated by the uncompensated CrSBr magnetization at the CrSBr edges.

[1] Ghiasi, T.S., Borst, M., Kurdi, S. et al. Nitrogen-vacancy magnetometry of CrSBr by diamond membrane transfer. npj 2D Mater Appl 7, 62 (2023)

Please contact us
cryo@qd-europe.com

Commitment to science and innovation – Product manager at Quantum Design Europe in conversation

Dr. Marc Kunzmann, Product Manager at Quantum Design Europe (QDE), emphasizes the importance of international cooperation. "The close exchange with our current and future customers is a highlight for me," he explains. Collaboration with research institutes and experts worldwide contributes significantly to the success of the projects. QDE's products, particularly in the fields of cryogenics and magnetometry, play a key role in research. "Our cryogenics and magnetometry products not only promote basic research, but also solve practical scientific challenges," Kunzmann continues. As a chemist, he is proud to live by the motto "From Scientist for Scientists" and to support the scientific community.

Please contact us
kunzmann@qd-europe.com

Selecting the right teslameter

When looking for the right Gauss or teslameter for your application, it needs to be considered that not every sensor, sample and teslameter are the same and that every solution has its own place in the market.

The challenge is to find out what properties you need and where the manufacturers hide them in their marketing material.

Teslameter F71

Our partner Lake Shore has published a white paper to help you choose the right teslameter. In this paper they highlight the most important parameters to help you select the right device.

They explain which hardware and software properties are most important. Crucial for selecting the hardware are accuracy, measuring range, choosing the right probe, temperature compensation and user-friendliness.

On the software side, it is important to have settings options such as the ability to switch between direct and alternating current and error correction. In addition, holding functions and data acquisition are necessary for many applications in order to be able to use the collected data for further evaluations.

Finally, Lake Shore provides a decision tree to help you select the appropriate measuring device.

We will be happy to help you with your selection and answer any further questions you may have.

The white paper can be downloaded here:: bit.ly/3NT68IH

Please contact us
materials@qd-europe.com

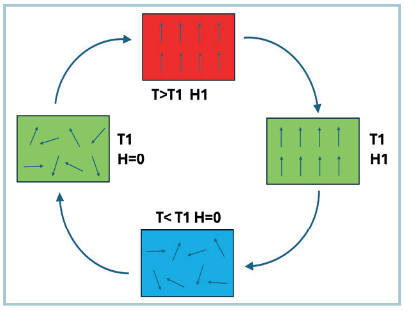
Magnetocaloric effect – Characterization with the PPMS and MPMS

The magnetocaloric effect describes the interaction between magnetic and thermal properties. Materials with this effect are of interest for both fundamental research and practical applications. For example, the first commercial refrigerators that use this effect are more energy efficient.

PPMS DynaCool system

On the basis of a recently published article in the journal Nature Communications [1], we will discuss the use of the QD systems PPMS and MPMS. The authors, under the project management of Professor G. R. Blake from Groningen, have studied the cobalt compound $Co_4(OH)_6(SO_4)_2[enH_2]$*. This compound exhibits a gigantic magnetocaloric effect at temperatures around 10 K and could therefore be used for magnetocaloric cooling at cryogenic temperatures. Measurements with the Quantum Design systems PPMS and MPMS provided key data for the characterization.

In the experiment, researchers measured the magnetic properties DC magnetization (MPMS SQUID magnetometer), the AC susceptibility (PPMS), and the heat capacity (PPMS). From the heat capacity measurement data, they were able to determine the change in entropy of the sample, an important quantity for classifying its magnetocaloric properties. A detailed description can be found in the "open access" publication. If you have any questions about the QD systems and their measurement capabilities, please do not hesitate to contact us.



Schematic of magnetic cooling

[1] J. J. B. Levinsky et al. "Giant magnetocaloric effect in a rare-earth-free layered coordination polymer at liquid hydrogen temperatures". Nature Communications (2024)15:8559

Please contact us
materials@qd-europe.com

New corporate film presents our headquarters in Pfungstadt

We are delighted that, together with Schreckenberg Film and coinciding with the move to our new headquarters in Pfungstadt, we were able to launch a brand-new corporate film. The film not only shows our state-of-the-art building, but also gives an insight into our daily work and our innovative products.

Over the course of two days, both our building exterior and interior were captured on film, partially by using drones. The interior shots put a special focus on our laboratories and demo rooms. A central role was played by our products and technical innovations, which were impressively staged. A variety of shots of modern workplaces and technological solutions enables us to show to the public what our site has to offer.

It was particularly exciting to experience the filming process and to see how our company can be presented in different ways. The professionals at Schreckenberg Film supported us with many creative ideas and made this an event to remember. Thanks you for this!

Please contact us
spectrum@qd-europe.com

QD summer party – a great event for togetherness

Our annual summer party took place on September 6. In perfect summer weather, employees and former colleagues gathered for a relaxed day full of conversation and good humor. While we enjoyed a barbecue and chatted over delicious food, there was also an opportunity to get to know new colleagues. There was a bouncy castle for the children, which provided plenty of fun. The new headquarters in Pfungstadt, with a magnificent view of the Odenwald, provided the perfect backdrop for a successful party.

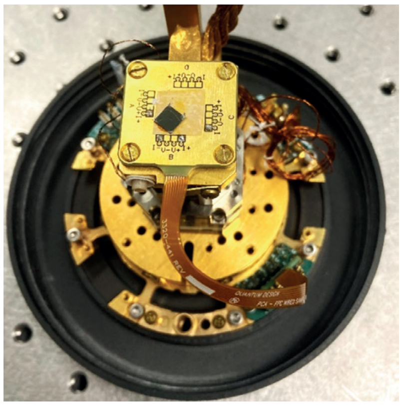
Please contact us
spectrum@qd-europe.com

Charge carrier-resolved photo Hall effect measurements in the OptiCool with the M91

In the cited application note [1] from Quantum Design (QD), the Lake Shore Fast Hall System M91 is used together with an OptiCool from QD. OptiCool is a closed-loop helium optical cryostat with a superconducting magnet designed for low vibration in the sample area. The M91 controls the temperature and magnetic field in the OptiCool. At the same time, the M91 performs resistance, Hall and mobility measurements in Van der Pauw geometry or Hall measurements in 6-cable geometry. In addition, the sample is optically excited. This enables charge carrier-resolved photo-Hall effect measurements.

The application note explains the required hardware and how to control the entire system with MeasureLINK. The software was developed by Lake Shore and controls both the M91 and the OptiCool.

The application note also explains how the samples are attached and wired. The illustration shows an InAs sample as an example. It is mounted on a wired sample holder. A common trick to electrically isolate the sample from the sample holder without significantly impairing the thermal connection is to place a cigarette paper between the sample and the holder.



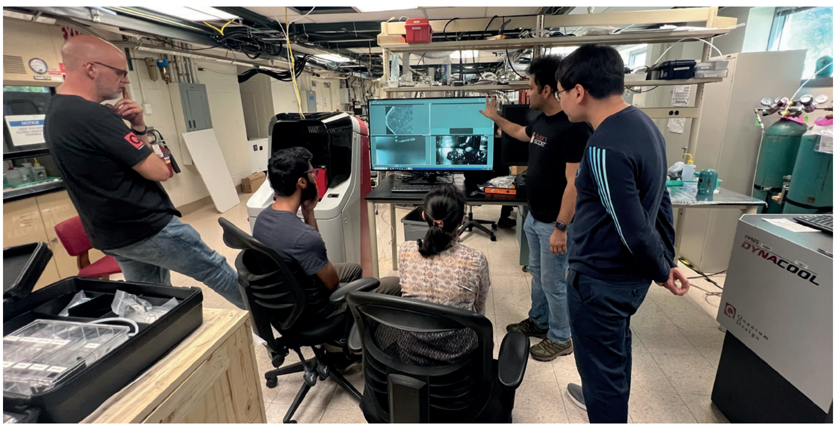
For more details of the sample measurement and its evaluation, you can check out the application note or contact us.

Please contact us
cryo@qd-europe.com

Another FusionScope was successfully installed at a customer

In mid-June, Quantum Design USA installed the first FusionScope in the United States at the University of Minnesota. Since then, Prof. Bharat Jalan's team has been using the system to examine thin films, focusing on the structural and electrical characterization of the samples. The FusionScope, which combines atomic force and scanning electron microscopy, offers a range of new for sample characterization at the micro- and nanoscale.

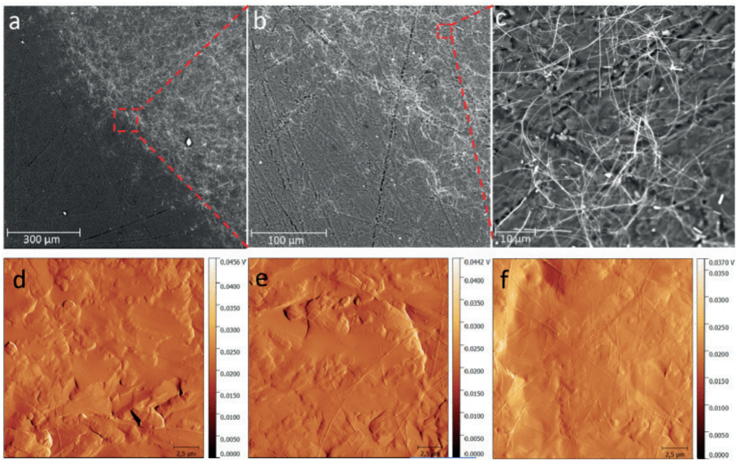
Through the precise analysis of surfaces and electronic properties, the FusionScope provides researchers with a new approach to optimizing material properties. Particularly in the development of nanomaterials and semiconductors, the gained knowledge might significantly improve the efficiency and performance of these materials. The high resolution and versatility of the system make it possible to visualize processes in the nanometer range that would not be accessible using conventional methods.



The installation of the FusionScope represents a major step forward for the University of Minnesota. The device strengthens the university's position as a leading research center in the field of materials science in the USA. Prof. Jalan and his team hope that their findings will not only advance the scientific community, but also provide the basis for new technological applications in electronics, communications and other high-tech industries.

Please contact us
em@qd-europe.com

New AFSEM publication: Development of a transparent touch sensor on reconstituted veneers



A recently published study by our client Wood K Plus Transparent Touch Sensors on Wood: Sustainable Development With Aesthetic Integrity presented the development of a transparent touch sensor on reconstituted veneers. This innovative technology could pave the way for the seamless integration of advanced electronics into wood surfaces while preserving their functionality.

Structure and function of the sensor

The touch sensor was applied to the veneer using a screen printing process with silver nanowire ink. A protective coating on the sensor prevents reactions to ambient humidity, which significantly increases the reliability and service life of the sensor.

Topography and distribution of the silver nanowires

Both scanning electron microscopy (SEM) and atomic force microscopy (AFM) were used to analyze the surface structure and the distribution of the silver nanowires on the coated veneer. The SEM images clearly showed the layer of silver nanowires and the transition from the veneer substrate to the printed sensor structures. Interestingly, this transition is not abrupt, but shows a gradual increase in nanowire density at the edges of the sensor line.

The applied layer of silver nanowires consists of a very loose network, as the amount of ink applied was deliberately kept low. This low network density was also confirmed by the AFM measurements.

AFM amplitude images of the veneer substrate, the transition area between substrate and sensor and the structure of the silver nanowire network in the printed sensor line again showed a low network density. The topography images of the AFM measurements made it clear that the nanowires adapt well to the structure of the veneer substrate. Despite the low density of the deposited silver nanowire layer, the sensor response and performance were extremely satisfactory.

Special features of the AFSEM system

The AFSEM system was used for the AFM measurements and delivered outstanding results. The AFSEM, an AFM designed for integration into an SEM, combines the advantages of atomic force microscopy with those of scanning electron microscopy. This system allows precise analysis of the surface structure and distribution of materials on a nanometric scale, while simultaneously capturing high-resolution images of the overall structure. The use of the AFSEM system was instrumental in gaining detailed insights into the behavior of the silver nanowires on the veneer and confirming the efficiency of the sensor.

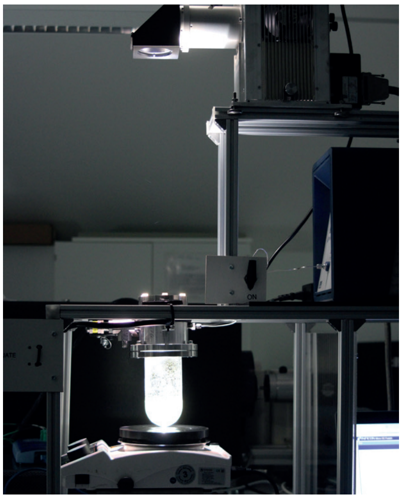
Please contact us
em@qd-europe.com

Shaping technology – Innovation and precision in product management

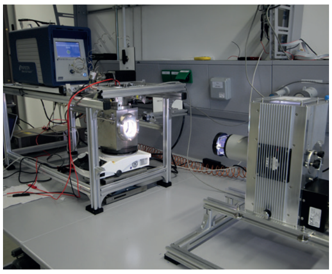
"As Product Manager, I attach great importance to working closely with development and cutting-edge research. Thanks to my extensive experience in quantum optics, I can precisely understand our customers' requirements and develop innovative solutions that meet the highest standards. I am driven by a passion for new technologies to constantly explore the limits of what is technically feasible. My goal is to create products that are not only forward-looking, but also offer sustainable added value for our customers and society."
— Matthias Müller, Product Manager at Quantum Design Europe

Please contact us
mueller@qd-europe.com

Solar-to-Hydrogen Efficiency (STH)



The development of a sustainable energy economy that is not based on limited fossil fuels but on renewable energies is an urgent task. Hydrogen is one of the leading alternatives for the storage and transportation of energy, provided that it can be stored safely and be produced efficiently using sustainable energy sources. The problems associated with electrical energy storage can be avoided as the energy is stored in the form of chemical bonds. Solar energy, the largest sustainable energy source, has the potential to provide enough power on the scale required for carbon dioxide-free hydrogen production. Direct solar water splitting using photocatalytic or photoelectrochemical processes is a promising alternative to the two-stage energy conversion of solar energy via electrical energy into chemical energy. This route has the long-term potential to become more economically attractive than the already established two-stage process. Today, there are neither materials nor reactors or cells that fulfill all the necessary requirements for an economical implementation of solar water splitting, as the complexity of photocatalytic or photoelectrochemical water splitting requires complicated component design and/or the use of rare and expensive materials.



An essential step in the development of photocatalytically or photoelectrochemically efficient water splitting systems is, similar to solar cells, the implementation of standardized, comparable performance measurements. There is one parameter in particular that has established itself internationally: Solar-to-Hydrogen Efficiency (STH), i.e. the quotient of the chemical energy that can be released by burning the hydrogen produced and the irradiated solar energy. If the STH is not available, the photocurrent density at a voltage of 1.23 V is used as a performance criterion, particularly in photoelectrochemical water splitting. Irradiation of the global standard spectrum AM1.5G is necessary for both. In the Functional Materials working group, the combination of a xenon lamp and AM1.5G filter was used to create the necessary radiation conditions to determine the STH or the photocurrent density with the aid of a gas chromatograph or a potentiostat. As the energy density of the light is also important in addition to the spectral distribution, this must be set by using a calibrated solar cell. This can also be easily accomplished with the set-up described. This means that nothing stands in the way of reproducible characterization of photoelectrodes and photocatalysts in accordance with international standards.

Source: User report on the solar simulator from Quantum Design Europe University of Salzburg, Department of Chemistry and Physics of Materials, Functional Materials working group

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lightsources@qd-europe.com

Optical filters – standard and customized AR coating options

Andover Corporation specializes in advanced anti-reflective (AR) coatings that improve the performance of optical systems in various industries. Our AR coatings reduce reflections and increase light transmission to ensure optimal clarity and efficiency.

- Single-layer magnesium fluoride: For essential anti-reflective properties.
- V-coating: Optimized two-layer coating for specific wavelengths.
- W-coating: Multi-layer coating for a wider wavelength range.
- Highly efficient AR coatings: For applications in the UV, visible and near infrared.
- Broadband (BBAR) coatings: Coatings with extended range from UV to 15µm

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Quantum Diamond Microscope II – Imaging of electrical currents

The large-area magnetic imaging technique of the QDM (see page 1) opens up new applications, one of which we would like to present here.

Every current generates a magnetic field and vice versa. It therefore makes sense to use QDM for imaging currents in electrical components. The distribution of current densities in active integrated circuits (ICs) contains information about the structure and function of the circuit. The magnetic fields penetrate common materials used in the semiconductor industry and thus offer an effective way of analyzing the operating behavior of an IC. The magnetic fields vary depending on the operating state. Magnetic imaging can provide information about the structure and behavior of the circuit, which can be used for testing and troubleshooting. QDM can be used to map the magnetic fields of ICs under operating conditions. Edlyn V. Levine (Havard University), together with Amir Yacoby, Marko Loncar and other colleagues, has shown how information about the function and state of the IC can be derived from the field distribution [1]. Figure 1 shows the field distribution in the X, Y and Z directions for two different areas of a field programmable gate array (FPGA). Each area contains a cluster of 200 ring oscillators (ROs). The currents flowing through the vertical traces on the right-hand side of the image are clearly visible. In Figure 2, the measured magnetic field is plotted over an image of the circuit. The group has used machine learning techniques to classify operating states of both decapsulated and intact FPGAs based on the correlation of magnetic field patterns. This makes it possible to recognize the activity of individual areas and whether the operation corresponds to the norm.

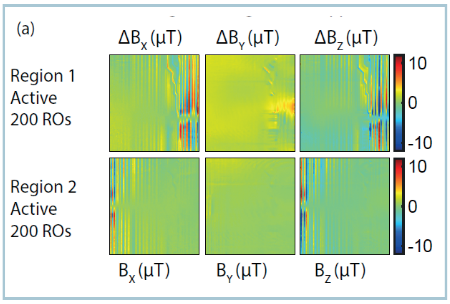


Fig. 1

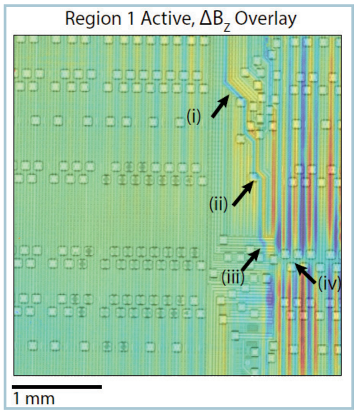


Fig. 2

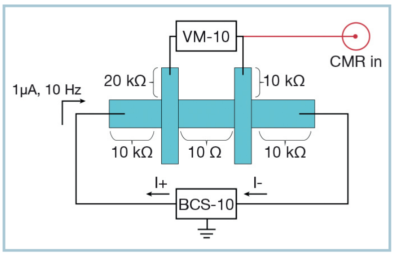
[1] Matthew J. Turner, Nicholas Langellier, Rachel Bainbridge, Dan Walters, Srujan Meesala, Thomas M. Babinec, Pauli Kehayias, Amir Yacoby, Evelyn Hu,Marko Loncar, Ronald L. Walsworth,and Edlyn V. Levine, Magnetic Field Fingerprinting of Integrated-Circuit Activity with a Quantum Diamond Microscope, Phys. Rev. Applied 14, 014097 - Published July 31, 2020

Please contact us
materials@qd-europe.com

New application reports on the subject of "Electrical measurements"

New reports and application aids are available for all users who are interested in electrical measurements, lock-in, etc. Three reports on the following topics are currently available:

- Application Brief "Common-Mode Artifacts in 2D materials with Significant Contact Resistance"
- Application Brief "Compensated Resistance Measurements Using a Lock-In: How to handle Phase Shifts in a Measurement".
- White Paper "A Practical Approach to Understanding External Noise"



M81-SSM structure

The illustration comes from the paper "Common-Mode Artifacts". It shows a sketched test arrangement for the electrical characterization of a 2D material with a resistance of 10 ohms. The assumed contact resistances are 10 and 20 kOhm. A conventional test setup with a lock-in amplifier generally leads to an error of over 90% due to the common mode effect.

The M81-SSM measurement system from Lake Shore Cryotronics, performs measurements of th same sample almost error-free. This is achieved by using a balanced current source (BCS-10) and a voltmeter (VM-10) with a very high input resistance. A detailed discussion of the measurement example can be found in the application report mentioned above. We will be happy to send you this and the other two reports by e-mail.

If you have any questions about electrical measurements in AC, DC or with lock-in (also multi-channel), please do not hesitate to contact us.

Please contact us
materials@qd-europe.com

European Headquarters
Quantum Design GmbH
Breitwieserweg 9, 64319 Pfungstadt, Germany
Phone +49 6157 80710-0, Fax +49 6157 80710-920
E-mail spectrum@qd-europe.com

www.qd-europe.com

Quantum Design **BeNeLux**
Meerstraat 177
B-1850 Grimbergen, Belgium
Phone +32 2 3084324
Mobile +32 495797175
E-mail struyve@qd-europe.com

Quantum Design **Czech Rep.** and **Slovak. Rep.**
Krivoklatska 37, 199 00 Praha 9, Czech. Rep.
Phone +420 607 014 278, Fax +420 24 1046850
E-mail czechia@qd-europe.com

Quantum Design **France** SARL
Bâtiment Mac Kinley, 1, avenue de l'Atlantique,
91940 Les Ulis, France
Phone +33 1 69194949, Fax +33 1 69194930
E-mail france@qd-europe.com

Quantum Design Iberia
(for **Portugal** and **Spain**)
Roca i Roca, 45, 08226 Terrassa (Barcelona), Spain
Phone and Fax +34 937349168
E-mail boira@qd-europe.com

Quantum Design s.r.l., **Italia**
Via Francesco Sapori, 27
00143 Roma, Italy
Phone +39 06 5004204, Fax +39 06 5010389
E-mail italy@qd-europe.com

Quantum Design **Magyarország**
Primet Méréstechnikai Kft
Eszak u. 24, HU-1038 Budapest
Phone and Fax +36 1 2402711,
E-mail steinbach@qd-europe.com

Quantum Design Nordic
(for **Denmark, Finland, Norway** and **Sweden**)
Roddarestigen 3, 182 35 Danderyd, Sweden
Phone +46 8 41071791
E-mail eriksson@qd-europe.com

Quantum Design Przedstawicielstwo **Polska**
Mikołów: tel.:+48 32 24457
Fax: +48 32 4281169, kom.: +48 50 255112014
pdluzewski@qd-europe.com lub
Chorzów: tel.: +48 32 2482048
Fax: +48 32 70 21 160, kom.: +48 51 5166893
E-mail kowalczyk@qd-europe.com

Quantum Design SRL
(for **Romania** and **Bulgaria**)
Str Ion Nistor Nr 4, et 1, M2E
030041 Bucharest, Ro.
Phone +40 75 50 39 900, Fax +40 31 7107156
E-mail buiu@qd-europe.com

Quantum Design AG **Suisse**
Route du Roule 41, 1723 Marly, Switzerland
Phone +41 21 8699033, Fax +41 21 8699308
E-mail reinicke@qd-europe.com

Quantum Design **Turkey**
Phone: +90 544 741 99 97
E-mail turkiye@qd-europe.com

Quantum Design Ltd. **UK** and **Ireland**
1 Mole Business Park, KT22 7BA Leatherhead,
Surrey, United Kingdom
Phone +44 13 72378822, Fax +44 13 72375353
E-mail info@qd-uki.co.uk

Quantum Design **Russia**
(for Russia and Central Eurasia)
Phone +7 495 938-1866 , Fax +7 495 938-1907
E-mail academ@qd-europe.com

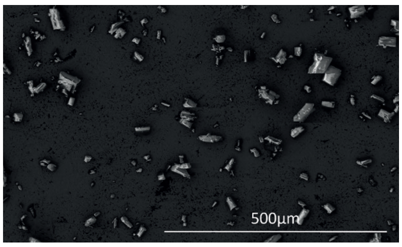
Analysis of vitamin C tablets using combined SEM and AFM techniques

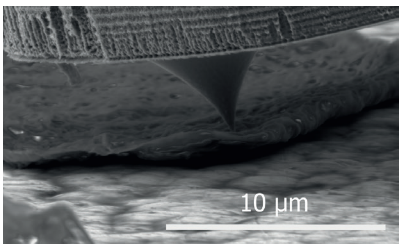
In pharmaceutical research, understanding the surface properties of vitamin C tablets is crucial for optimizing their administration.

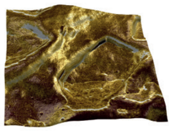
These properties are usually investigated using scanning electron microscopy (SEM) and atomic force microscopy (AFM). SEM provides detailed information about surface morphology, while AFM measures surface roughness at the nanoscale. However, the combination of these techniques presents a challenge, especially when it comes to particles in the nanometer range.

Conventional AFM has difficulty positioning its tip on such small particles due to the limitations of optical microscopy and the roughness of the tablet surface, leading to potential contamination and inaccurate data. Also, while SEM alone can visualize surface morphology, it cannot provide the detailed surface roughness data that AFM offers.

With the FusionScope, researchers can easily identify specific particles with the SEM and then guide the AFM tip to the exact location where they want to make detailed surface roughness measurements. The combined analytical approach and universal coordinate







system eliminates the need for sample transfer between instruments, reducing the risk of contamination and improving the efficiency of the analysis.

In this application example, the FusionScope was used to analyze vitamin C particles of different sizes and morphologies. The SEM examination provided an overview of the particles, while the AFM examination enabled precise measurements of the surface roughness. The measurements revealed significant roughness differences between the individual particles, with values ranging from 150 to 600 nanometers. FusionScope also enabled the identification of potential surface impurities through the combination of phase imaging and force-distance curves, providing insights into the material composition of the particles.

Advantages and results

Using FusionScope simplifies the process of nanoscale analysis by integrating multiple techniques into a single, easy-to-use platform. It reduces the time required for data acquisition and minimizes the risk of contamination or damage to the AFM tip. It also provides comprehensive, correlative analysis of particle properties, which is critical for optimizing the design and functionality of pharmaceutical tablets such as vitamin C.

By improving the accuracy and efficiency of particle analysis, FusionScope represents a significant advance in the field of pharmaceutical research and provides scientists in research institutes and industry alike with a powerful tool.

Please contact us
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Editor: Joachim Weiss, PhD

Please note that not all products are available in every country.