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The Global Power of Being Local

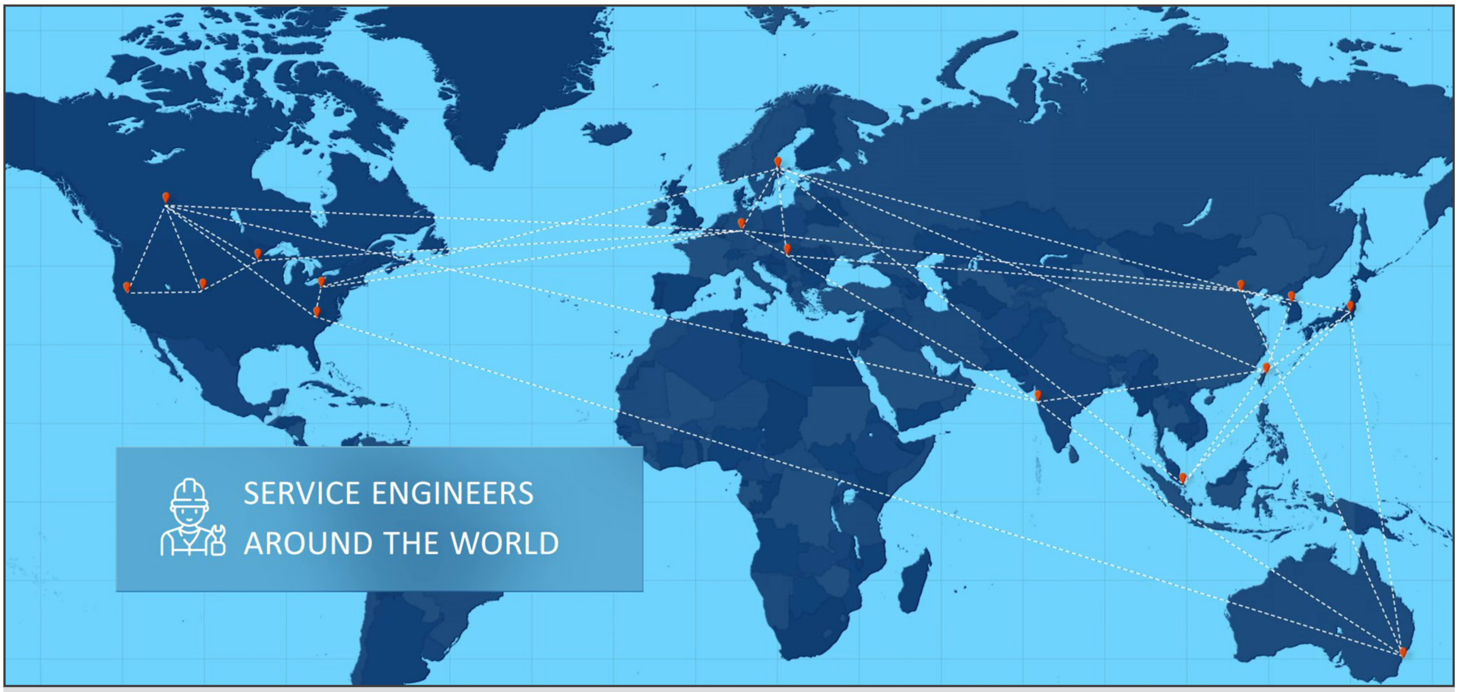
Scienta Omicron During 2020

During the very challenging year with a pandemic affecting all of us, customers, and suppliers as well as our families, adaptation to a new normal has been crucial.
Despite the challenges from the pandemic, Scienta Omicron stayed committed to the scientific community, increasing speed in 2020 by hiring more staff, ramping production, and investing in the sales and service organisation.

Since the acquisition of the Sigma Surface Science business and products in early 2020, great effort has been on the establishment of the new business unit and ramp up of volume production. Shipping out 17 SPM systems proves this success.
During the year Dr. Peter Amann, inventor of the Bar-XPS system joined our family as our new Product Manager for HAXPES and APPES products. Both being key techniques supporting the research in sustainable energy.

In 2020, Scienta Omicron concluded close to thirty installations in seven countries. Given the wide spread of our product portfolio, ranging from various Deposition techniques to the most advanced Electron Spectroscopy and Scanning Probe Microscopy the demands for engineering skill and application know how is vast. Together with our core teams in Taunusstein and Uppsala a system for remote training has proven very successful, with new products such as the POLAR 5T being produced, delivered, and installed in the Scienta Omicron organisation.

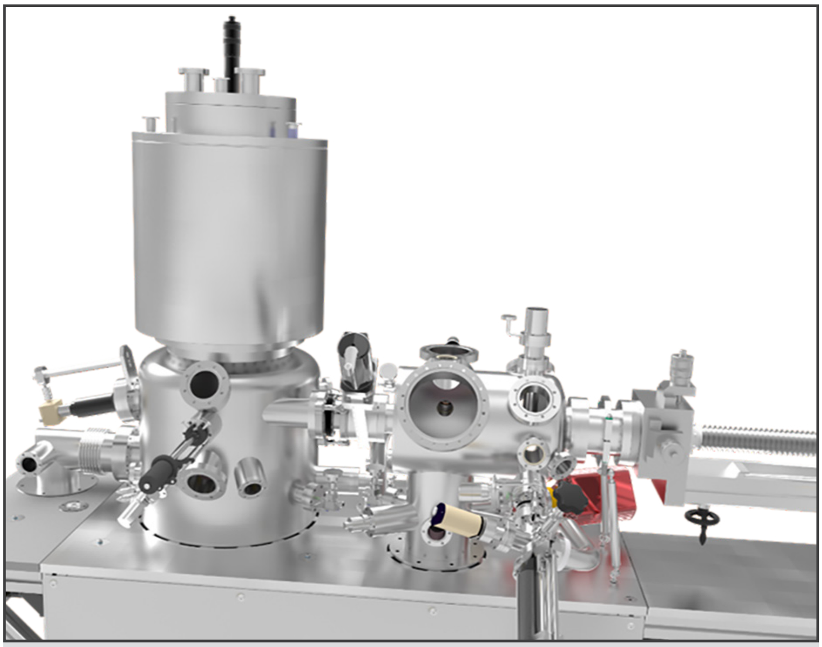
To overcome the international travel restrictions, we have continuously developed methods and offerings of remote training. Thereby we have managed to provide customer training as well as dedicated installation training of our local teams from our headquarters in Europe. A great example of the power of our Global access to Local presence is the achievements made in China throughout 2020. The combination of continuous remote training and support of the skilled local China Team prepared them for installation of entirely new products at the same time as we reduced the overall average installation time with more than 50 %.



Customers purchasing products from Scienta Omicron invest in Nobel Prize technologies while being supported by a truly global and local company.

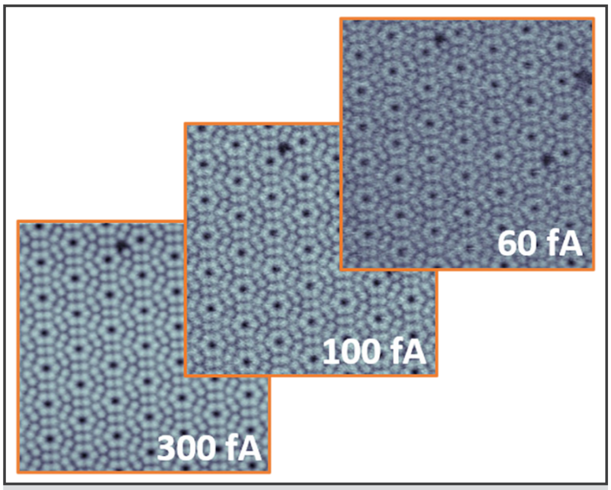
POLAR SPM LAB

Low Temperature SPM with Unsurpassed Hold Time



POLAR SPM Lab with Preparation Chamber and Liquid Nitrogen Cooled Manipulator

- STM, QPlus® AFM & Spectroscopy
- Guaranteed Helium Holding Time: >200 h
- Integrated TRIBUS Head
- Sample and Tip Temperature T <5 K
- Vertical Magnetic Field: B = ±5 T
- Independent Tip and Sample Exchange

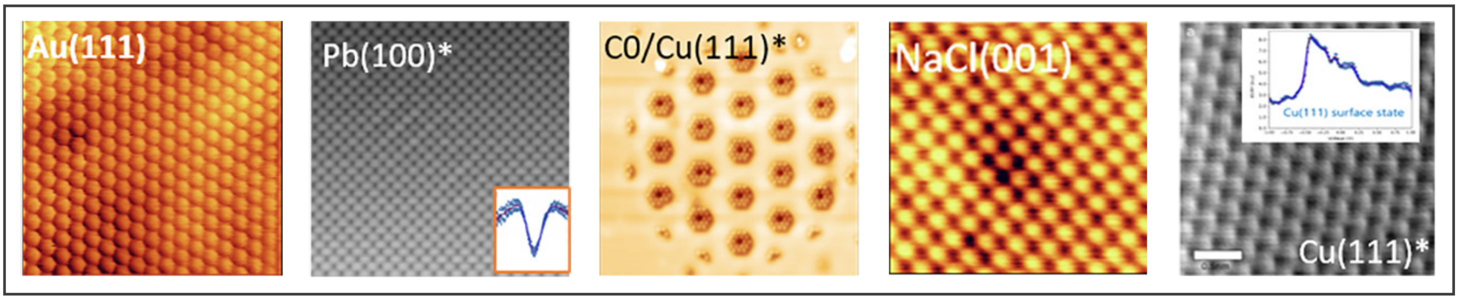


The accompanying series of images show an example of data measured on a Si(111)7x7 surface at a temperature of 4.6 K. The atomically resolved images have been acquired with very small tunnel current setpoints of 300 fA, 100 fA and 60 fA, illustrating the excellent signal quality achievable with the POLAR XT SPM.

The POLAR UHV SPM is a new Low-Temperature Scanning Probe Microscope (SPM) for the highest resolution STM, QPlus® AFM, and spectroscopy experiments at temperatures ranging from <5 K to 420 K and in magnetic fields of up to 5T. Viewports and closable entry doors in the radiation shields allow for independent tip and sample exchange, optical access, and in-situ evaporation.

The ultra-compact cryostat design delivers exceptional mechanical stiffness, creating superior STM stability. Cryostat hold time is optimised through a series of advanced thermal decoupling stages and thermal radiation shields, designed to provide an extremely low rate of liquid helium (LHe) consumption. With a rate below 1 l/day, the instrument achieves an unsurpassed hold time of >200 hours at <5 K with cryostat refilling.

Many of today's SPM applications require extremely low noise for detection of very small (<500 fA) tunneling currents (e.g. STS or molecular imaging). In the POLAR SPM, ex-situ signal amplifiers for both STM and QPlus® AFM, combined with dedicated wiring, result in maximum experimental flexibility and the highest achievable S/N ratio.



Installed at the Henry Royce Institute at Manchester University

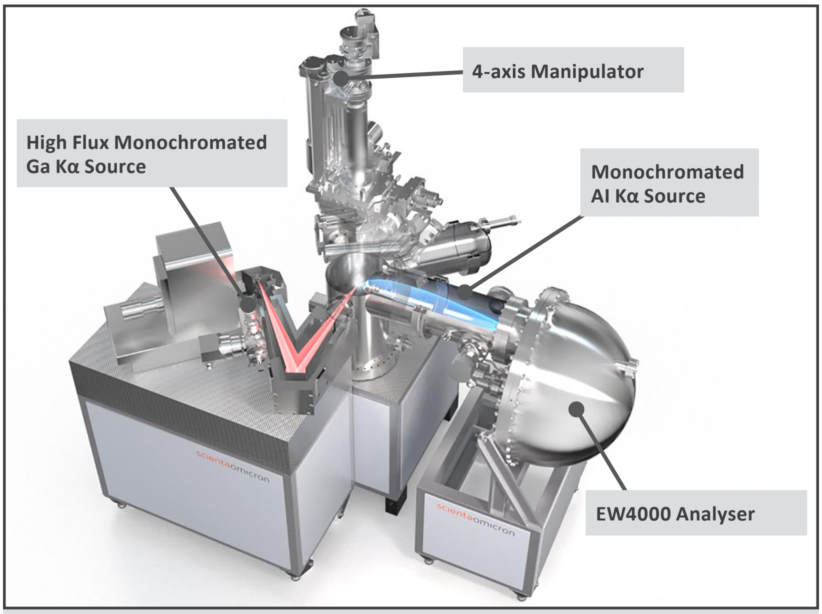
Modelling of Inelastic Photoelectron Background Reveals Information From Deep Below the Surface

X-ray Photoelectron Spectroscopy (XPS) is a well-established technique to probe the surface near area of materials in an element sensitive fashion, giving rise to rich information about material composition.
With the HAXPES Lab, Scienta Omicron is lifting this technology to the next level. The system combines a unique liquid Ga hard X-ray source with a wide acceptance angle spectrometer for efficient electron collection. The combination with charge neutralisation via cluster sources and soft X-ray sources makes this system at the leading edge of this technology.

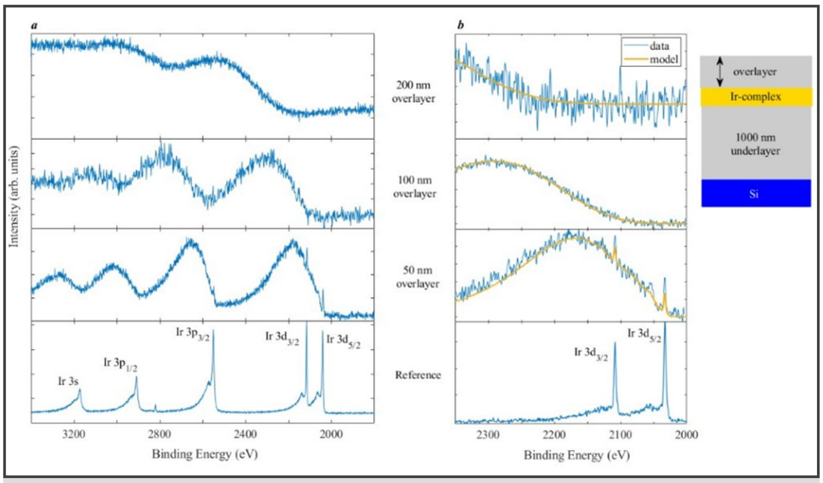
Dr. Ben Spencer is the Technical Lead for the HAXPES System at the Henry Royce Institute as well as the senior experimental officer at The University of Manchester. He says:

"We wanted to quantify atomic concentrations and gauge exactly how deep below the surface we can extract information from. We found it remarkable that we can extract information from up to 20 times the inelastic mean free path of the electron, which translates to hundreds of nanometres for these organic LED materials."

The extremely bright photon source provides hard X-rays at 9.25 keV, allowing the investigation of a material's properties down to about 35 nm from below the surface.
By sophisticated modelling of the inelastic photoelectron background, Dr Ben Spencer and co-workers from the Henry Royce institute at Manchester University could obtain information from up to 200 nm from below the surface. This was studied at an organic LED material buried deeply below some organic material.



The HAXPES lab combines a high resolution EW 4000 Analyzer with a unique, high flux, liquid Ga X-ray source. Using a Si based monochromator, instrument resolution of <0.5 eV can be achieved. The 4 axis manipulator allows working with LN2 cooling and PBN heating. Together with a monochromatic Al Ka source, this system becomes highly versatile for material research.



Results from the HAXPES Lab: Left: X-ray photoelectron spectra from the Ir 3d level at ca. 2 000 eV binding energy are presented for different overlayer thicknesses.
Right: Model results using the Quases software.

The work is presented in Applied Surface Science at:
https://doi.org/10.1016/j.apsusc.2020.148635

Researcher Spotlight

Scienta Omicron is proud of the work our customers are contributing to the field of surface science and nanotechnology. During 2021 we will be shining a spotlight on a wide selection of researchers and diving deeper into their careers, research, and publications.

Please join us in this series by following our social media accounts and we hope you enjoy learning more about these talented researchers and their future leading work.

Atomic Layer Semiconductors Poised to Change Our Lives

Dr Amalia Patanè at the University of Nottingham

Dr Amalia Patanè, University of Nottingham

Semiconductor physics is on the cusp of a revolution. Ultra-thin crystals may take the place of today's ever-present silicon semiconductors and may transform many applications. However, you have to be able to build them first. Professor Amalia Patanè is heading a project that aims to do just that.

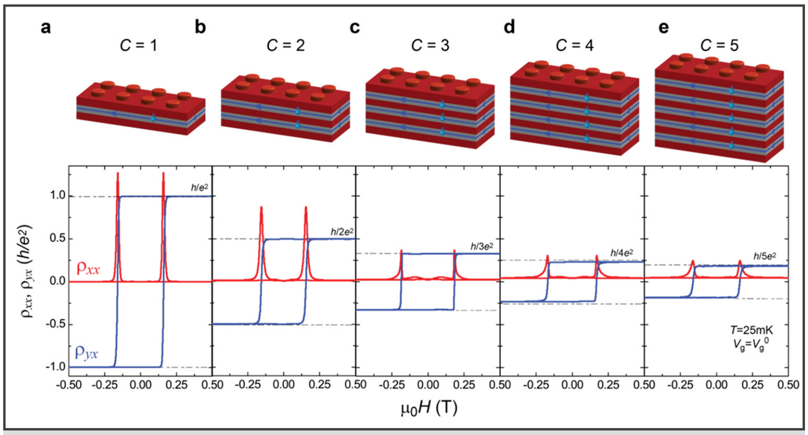
Amalia Patanè is Professor of Physics and Director of Research at the School of Physics and Astronomy at the University of Nottingham. For the last few years, she has been working on van der Waals crystals. These are extremely thin crystals, made up of atomically thin layers. These layers are not bound by ordinary covalent bonds, like in traditional semiconductors, but by much weaker van der Waals bonds.

Read the full article by Mr. Kim Bergström here>>.

Quantum Insulators May Bring Resistance-Free Current Transfer to Electronics

Dr. Cui-Zu Chang, Penn State University

So-called quantum anomalous Hall insulators are one of two ways of achieving resistance-free current transfer. Cui-Zu Chang at The Pennsylvania State University has made a breakthrough that has greatly increased the number of dissipation-free channels in quantum anomalous Hall insulators. These findings indicate that such quantum isolators are one step closer to revolutionizing electronics.



Dr. Cui-Zu Chang from Penn State has experimentally demonstrated a quantum phenomenon called the high Chern number quantum anomalous Hall (QAH) effect.

Cui-Zu Chang is currently an assistant professor of Physics at The Pennsylvania State University. His research focuses on a variant of magnetic topological insulators called quantum anomalous Hall insulators. A topological insulator is a special material in which the interior is an insulator, but the surfaces are metallic. This property allows electrons to travel along the metallic surfaces but not inside. Such quantum anomalous Hall insulators can transmit current with no resistance, like a superconductor.

Read the full article by Mr. Kim Bergström here>>.

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Molecular Beam Epitaxial (MBE) Growth of Topological Materials

Scienta Omicron’s MBE and In-Situ Surface Analysis Solutions Facilitate Future Development

Topological materials are a significant focus in today‘s condensed matter physics, as pointed out in the excellent perspective article recently compiled by Matthew Brahlek et al [1]. The novel physics arises from the special electronic band structure, based on band inversion. The novel states only determine the properties of the material when the Fermi level is positioned at a particular location in the band structure. For Topological Insulators (TIs) the Fermi level must be close to the 2D Dirac point, as shown schematically in Figure 1a ($E_{F,ideal}$). Likewise, in Dirac and Weyl semimetals the Fermi level should be close to the 3D Dirac or Weyl point. The positioning of the Fermi level requires a high level of control over the growth process.

Molecular Beam Epitaxy (MBE) is the ultimate method for well-controlled UHV growth with beams of atoms or molecules of dissimilar chemical species converging onto a substrate crystal (see Figure 2). At the substrate surface, the impinging atoms may diffuse, adsorb or desorb. For each material system, there is an optimum substrate temperature for growth, balancing surface diffusion and desorption. Optimisation of these growth conditions is moderated by understanding and minimising defects in the new material.

TI’s and their associated band structures are highly sensitive to defects. If defect density is too high, the material loses its exceptional properties, as it goes over to a trivial phase. A major source of defects for thin films are interfaces. A known defect mitigation strategy, borrowed from traditional semiconductor heterostructure growth, is to employ a “virtual substrate” [2]. In this process, a buffer layer that is epitaxially and chemically matched to the active material is grown between the substrate and TI. An example of the application of the virtual substrate method is shown for a tetradymite TI in Figure 1c. The reduction of interfacial defects by

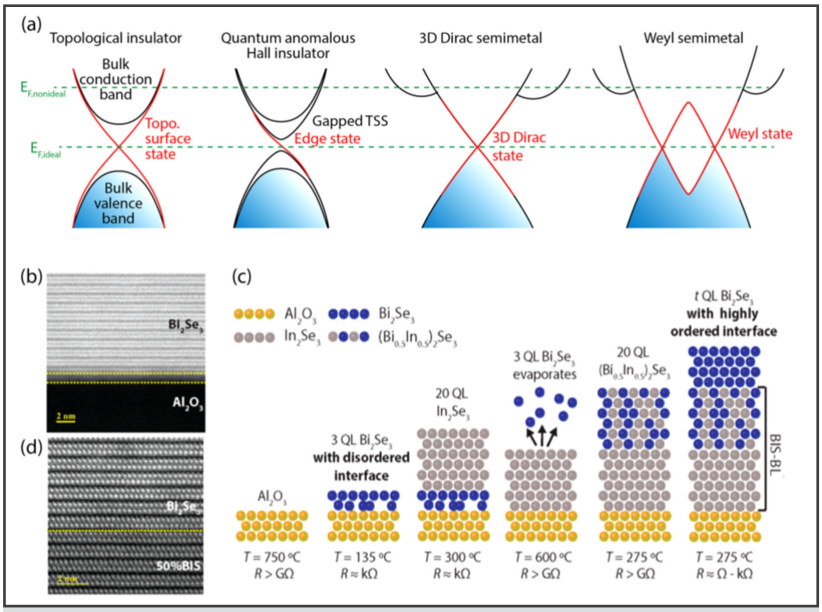

Figure 1. (a) Schematics of topological band structures for selected material classes. (b) TEM image of Bi_2Se_3 on Al_2O_3, showing increased defect density in the interface region. (c) Schematic of the virtual substrate method. (d) TEM image of the highly ordered interface between Bi_2Se_3 and the virtual substrate. Reprinted from Brahlek et al., J. Appl. Phys. 128, 210902 (2020), with the permission of AIP Publishing. Reprinted (adapted) with permission from Koirala et al., Nano Lett. 15, 8245 (2015). © 2015 American Chemical Society.

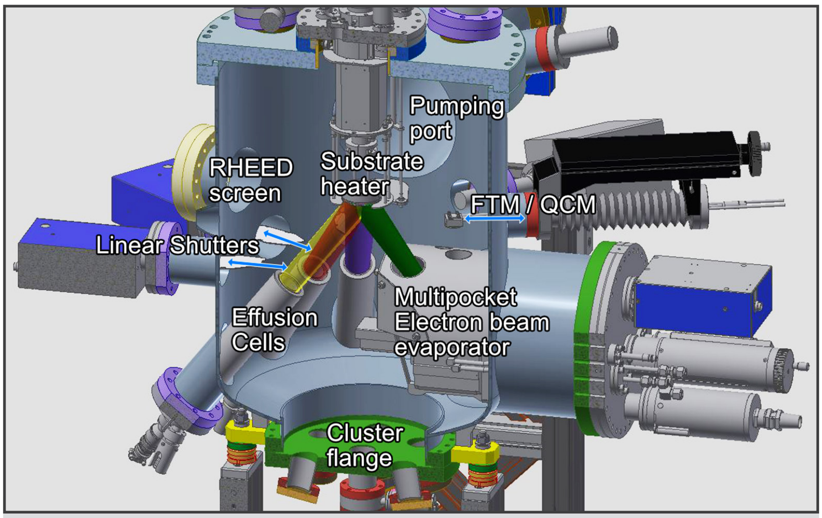

Figure 2. Schematic of the Scienta Omicron EVO-50 MBE chamber as delivered to the authors of the article [1]. The liquid nitrogen cryopanel is not displayed.

the addition of In_2Se_3 and $(Bi_{0.5}In_{0.5})_2Se_3$ buffer layers led to a reduction in charge carrier density and an increase in mobility for Bi_2Se_3 on Al_2O_3 substrate [2].
Refining the growth process requires a thorough understanding of the inherent properties of the desired synthesised sample, may it be intrinsic topological materials or heterostructures. Angle-Resolved Photoemission Spectroscopy (ARPES) has been proven to be a powerful tool for directly probing the surface band structure. Another technique that is commonly used for studying surface topography and information about the electronic structure on a specific spot is Scanning Tunnelling Microscopy (STM). As many topological materials degrade rapidly in air, the use of interconnected MBE-surface analysis systems is an indispensable approach for probing the inherent properties of the synthesised TIs. The in-situ combination of growth and analysis in a Materials Innovation Platform (MIP) is a time-efficient route to reveal signatures of non-trivial phases, e.g. 2D topological superconductivity. Scienta Omicron is proud to contribute with integrated MBE and surface analysis instruments to the investigation and development of topological materials.

[1] Brahlek et al., J. Appl. Phys. 128, 210902 (2020)
[2] Koirala et al., Nano Lett. 15, 8245 (2015)

Multiprobe Prep

A Versatile UHV Module for Sample Preparation and SPM

The Multiprobe prep is the latest addition to Scienta Omicron's range of modular UHV system platforms. It serves as both a preparation chamber for a wide range of analytical systems, and as an independent UHV system compatible with the addition of the award-winning Variable Temperature SPM (model VT SPM-XA) housed in its own bolt-on chamber.
The extended cylindrical chamber includes a scientific sample manipulator with a range of sample heating and cooling options. The design then includes ports for common sample preparation techniques including LEED, sample sputtering, three DN40CF evaporator ports, and a variety of spare ports (e.g., for sample cleaving, mass spectrometer, or custom components). The chamber enables connection to other systems and Scienta Omicron's UHV suitcase. Available design variations provide customers flexibility in choosing the pumping and manipulator configurations to match budget and technical requirements. The sample transfer concept ensures a simple connection to other UHV modules and safe, convenient sample handling with a wobble stick. Choice of sample load lock location can be based on expansion plans.
With its compact footprint and open design, it offers good access to all components. Its extremely ergonomic layout even allows for the bakeout enclosure to be assembled by a single person.

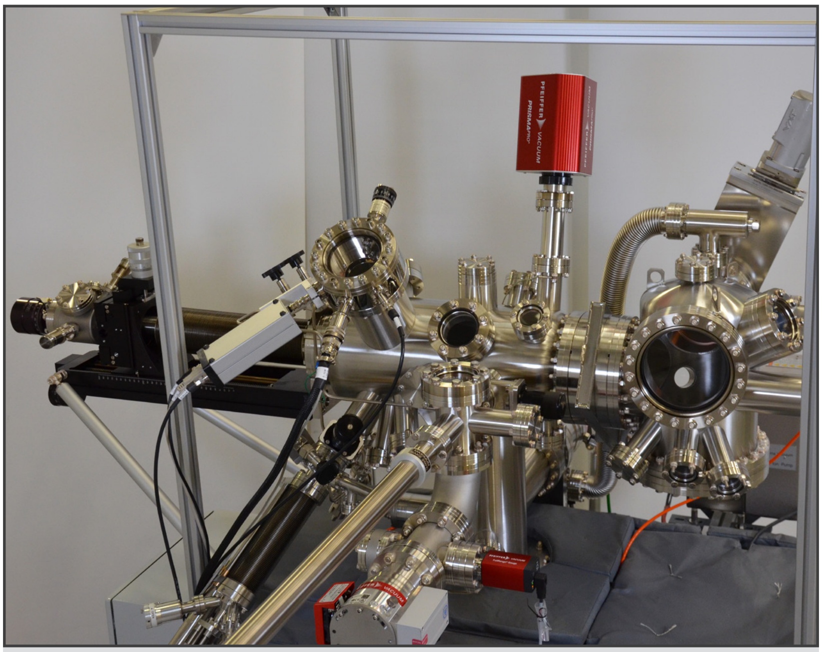

Figure 1. Multiprobe prep with separately pumped SPM bolt-on chamber. The system will be delivered to the Department of Chemistry and Chemical Biology at Harvard University in March 2021.

The rigid bench design ensures the system is capable of high-resolution scanning probe microscopy (SPM). An optional UHV gate valve in combination with a compact NEG/ion getter pump can be employed to ensure the best possible pressure and cleanliness in the SPM chamber. Even if initially used as a preparation chamber in a multi-module setup, the Multiprobe prep design offers researchers a simple upgrade path to add a VT SPM as a simple bolt-on component.

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The ARTOF-2 Time-Of-Flight Analyser

Full Acceptance Cone Measurement for Time Resolved Photoinduced Phase Transitions in $LaTe_3$

A. Zong and N. Gedik et al. investigated photoinduced phase transitions in $LaTe_3$ with their time resolved (tr) ARPES setup using an ARTOF analyser [1]. With the pump-probe scheme and a controlled time delay between photon pulses, tr-ARPES allows the generation of non-equilibrium states and track the dynamics in momentum- and energy-resolved fashion.

Prof. Nuh Gedik, Massachusetts Institute of Technology:

"The ARTOF is a very nice analyzer especially for performing time resolved studies. Operation is more involved than hemispherical analyzers and extra care must be taken to avoid MCP ageing. But having the capability to measure the entire dispersion of the 2D angular acceptance cone without having to rotate the sample or use sequential deflection is very useful."

ARTOF analysers are slit-free by design and acquire the full angular range of the 2D acceptance cone without the need for sequential movement of the sample or deflection of the angular pattern as used in hemispherical analysers. Therefore, with an ARTOF analyser no prior knowledge is needed to determine which part of reciprocal space has interesting dynamics to be explored with tr-ARPES. Instead, the full angular range of the acceptance cone is available as time resolved data, as shown for the 2D Fermi surface of $LaTe_3$ for a ±10 meV cut around E_F in Figure 1a. During the analysis phase arbitrary momentum cuts can be extracted from the data, to study the evolution of the band structure (Figure 2).

Figure 1.

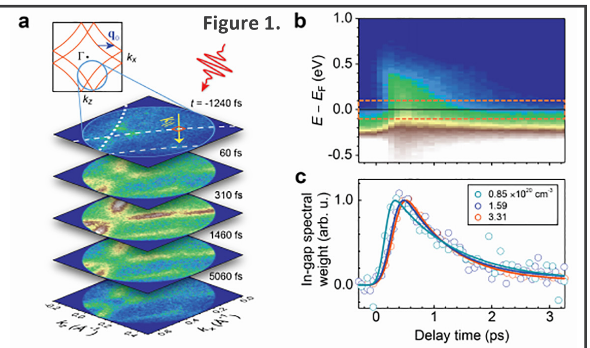

Figure 2.

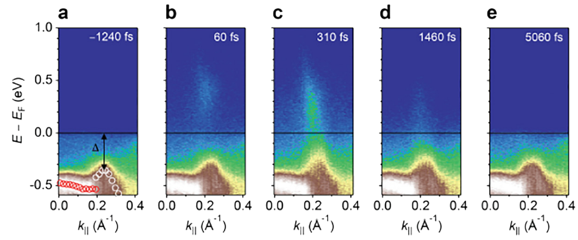

Figure 1. tr-ARPES measurements of the $LaTe_3$ sample. (a) Evolution of the Fermi surface for the full acceptance cone through the photoexcitation process. (b) Time evolution of the momentum integrated region (orange box in (a) for t=-1240 fs) with excited states above the Fermi level. (c) evolution of the spectral weight for ±0.1 eV marked in (b).

Figure 2. Evolution of the band structure for the $k_{\parallel}$ cut marked yellow in Figure 1(a). As the tr-ARPES data is acquired for the full acceptance cone, arbitrary momentum cuts can be extracted during the analysis phase.

References:
[1] A. Zong et al., Nature Physics 15(2019) 27–31

ARTOF Analysers:

Hemispherical and ARTOF analysers both provide angular resolution, but ARTOF analysers replace the energy dispersive hemisphere with a time-of-flight measurement. The ARTOF-2 features the 2nd generation lens optimised for Angular Resolved Time-Of-Flight measurements, providing large energy dispersions for large angular and energy windows. The slit-free lens of the ARTOF-2 measures the entire acceptance cone without sequential sample movement or deflection of the angular pattern. Accordingly, the transmission is extraordinarily high and especially useful for radiation sensitive samples, full cone tr-ARPES measurements, and applications with limited signal strength. The ARTOF-2 is also available as part of the ARTOF Lab, which is easily connected to other modules (Figure 3).

Figure 3. 2020 installation of an ARTOF Lab equipped with the ARTOF-2 analyser and a 5 axis closed cycle manipulator. An UHV transfer connects the ARTOF Lab with the Lab10 module for thin film deposition seen in the background.