Electron Beam Technology

eLINE Plus

Discover Nanoengineering beyond Electron Beam Lithography

Ultra High Resolution Electron Beam Lithography,
Imaging and Nanoengineering

MULTI TECHNIQUE ELECTRON BEAM LITHOGRAPHY

RAITH
NANOFABRICATION

eLINE Plus – designed for the broadest bandwidth of applications by multiple *in-situ* nanofabrication techniques, beyond classic Electron Beam Lithography (EBL)

Undeniable preconditions for further pushing the limits with eLINE Plus in its 3rd generation:

- Smallest beam size in the world of a professional EBL system (< 1.6 nm)
- Sub-5 nm linewidth in EBL resist demonstrated
- Sub-7 nm lines using electron beam induced deposition (EBID) techniques demonstrated

The swiss army knife for nanofabrication

Fabricate, relocate, modify, measure!

The new eLINE Plus is designed as the most versatile multiple technique nanolithography system for a broad bandwidth of applications across all scientific disciplines and is – now in its third generation – indeed a consequent evolution of the best-selling EBL system in the world.

eLINE Plus's advanced lithography infrastructure enables both ultra-high resolution and large-area nanofabrication, and unites the worlds of Electron Beam Lithography, nanoengineering and ultra-high resolution imaging.

Professional and uncompromising EBL: Guaranteed superior system specs and the world's smallest beam size paired with a worldwide application support infrastructure make eLINE Plus the ideal solution for academic institutions striving to efficiently set new frontiers in nanofabrication.

Integration

EBL resist exposure is the focus, but not the limit of eLINE Plus nanofabrication system. Essentially, it features a comprehensive TFE-based nanolithography platform with integrated, highest-precision Laser Interferometer Controlled Stage technology. Additionally, this setup can uniquely be combined with multiple electron detector capabilities and to enable the use of nanoengineering options such as nanomanipulators or a gas injection system.

Upgradability & Customization

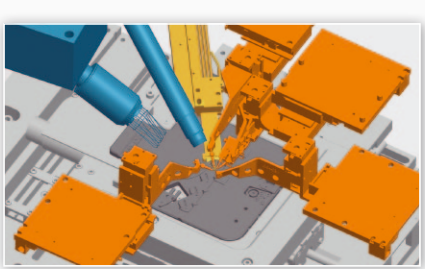
eLINE Plus has been designed as a configurable and open platform – yet without compromising on EBL performance. Thus, the system can be customized and field-upgraded at any later time in future. Only this approach allows for keeping pace with and adapting to most recent research trends – even long after the original system purchase. eLINE Plus can grow with your needs.

Versatility

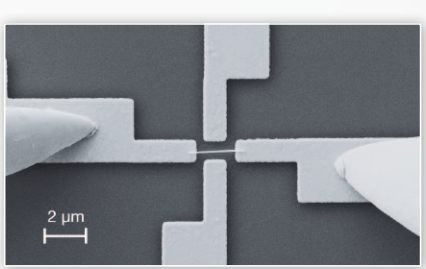
A major challenge in nanotechnology is connecting nanostructures to the outside world!

eLINE Plus is capable of covering the entire workflow for tasks including the following in a single tool and a single software *in-situ*: nanofabrication with EBL, relocation and alignment using the SEM as imaging functionality in conjunction with the high precision navigation capabilities of the Laser Interferometer Stage, modification by nanomanipulators or focused electron beam induced processes (FEBIP), using the gas injection system, and finally, measuring sample properties using nanoprobes.

Advanced EBL: Photonic crystal structure in membrane;
William Whelan-Curtin, University of St. Andrews, UK



CAD view inside the eLINE Plus vacuum chamber showing the compact geometry with integrated GIS, SE- and EDX-detector and 4 nanomanipulators. Anti-collision control software features prevent system damage.



Freely suspended tungsten deposit between gold contacts, used for electrical conductivity measurement with nanoprobers.

eLINE Plus's smart building blocks

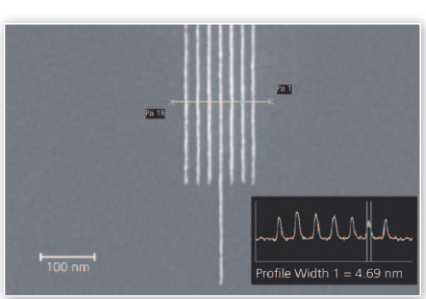
Stable, precise and innovative "Raith inside"

Unique column, stage and exposure mode technology inside

Given Raith's more than 30 years expertise in both nanolithography hardware and software development, a closer look at the system components and internal elements is obviously needed. Ask for a system demo and see how Raith does it!

Ultra-high resolution using TFE technology

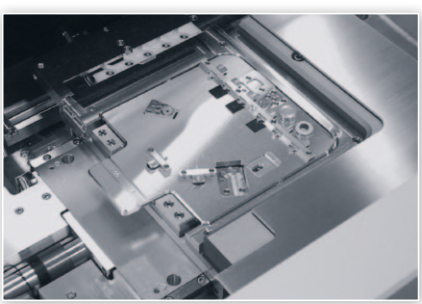
Using modified thermal field emission-based (Gemini) electron optical column technology, ultra-high resolution patterning and imaging are secured with excellent long-term stability. Besides the smallest beam size, the column design delivers lowest distortions, world-record beam current densities, and minimum beam current fluctuations for efficient, stable and high-precision nanopatterning.

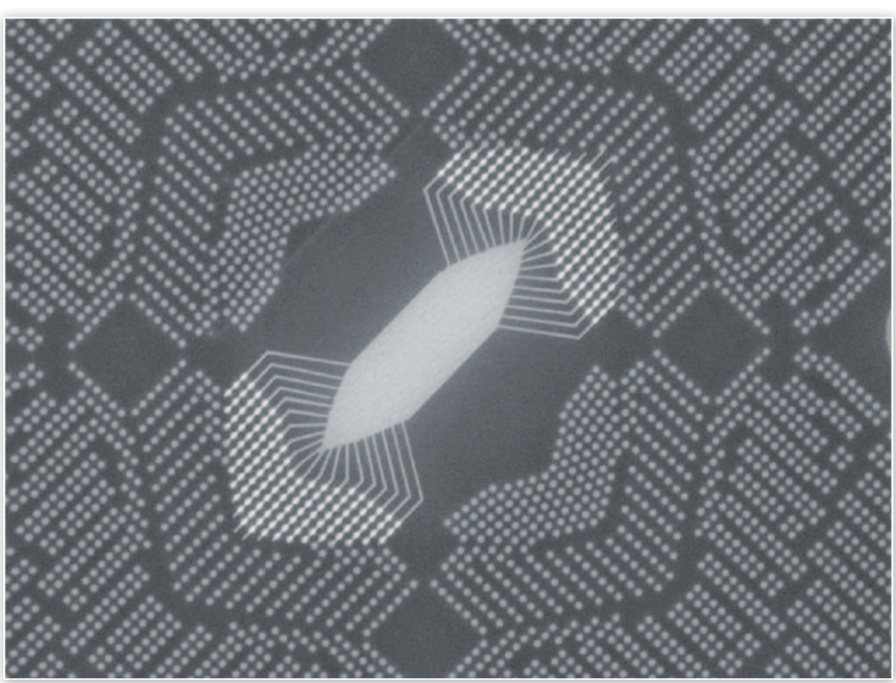


~5 nm lines in thin HSQ resist
J. Yang, D. Morecroft, M. Mondol, K. Berggren, MIT, and J. Klingfus, Raith USA

Accuracy and stability with a Laser Interferometer Controlled Stage

Distinct from other tools built around an analytical microscope infrastructure, eLINE Plus is equipped with Raith core technology existing for more than 25 years: an integrated Laser Interferometer Controlled Stage that yields placement accuracies in the nm regime. By this concept and technology, Raith delivers a fully integrated solution for automated large-area applications – whether nanolithography or image acquisition – with highest precision on samples from mm^2 up to 4 inch.





CMOS decoder circuit, aligned ebeam pattern with CMOS Metal 5 vias;
Kuk-Hwan Kim, EECS, University of Michigan, USA

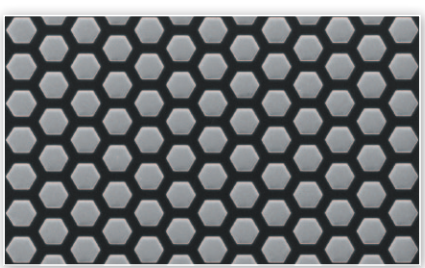
eLINE Plus's smart building blocks

Stable, precise and innovative "Raith inside"

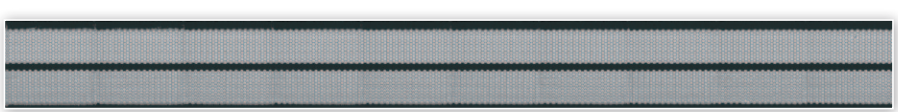
Innovative and unique writing strategies

Conventional step and repeat writing strategies involve stitching errors. These can be avoided by Raith's unique continuous and stitching error-free writing modes traxx and periodixx – using proprietary fixed beam moving stage (FBMS) and modulated beam moving stage (MBMS) technology respectively. Thus, device quality, especially in optical and optoelectronic applications such as large-area gratings, zone lenses, waveguides or photonic crystals can be significantly improved.

Detailed picture of FBMS lithography mode produced 450 nm wide waveguide structures in silicon master stamp.
R. Schmits, TNO Delft, The Netherlands

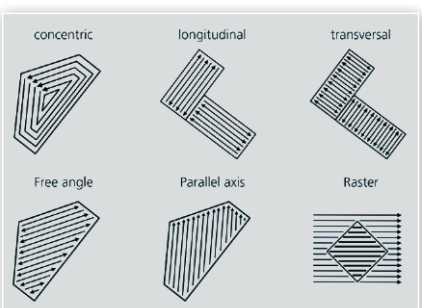


Honeycomb structure fabricated with MBMS technology



Part of several-mm-long photonic crystal seamlessly written using MBMS technology

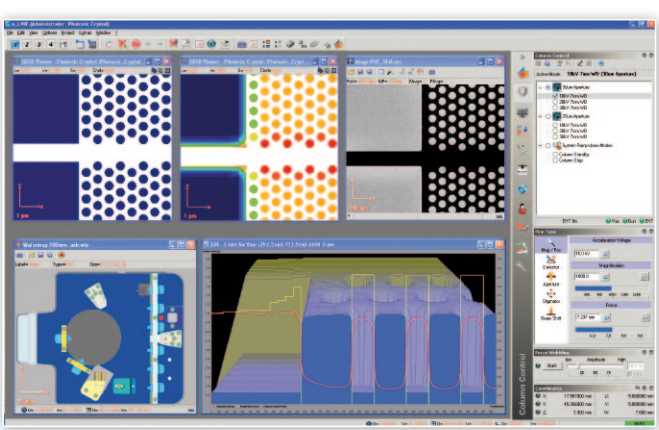
Writing of complex shapes, smallest nanostructures or FEBIP may require specific exposure strategies for optimum pattern placement accuracy. Raith FLEXposure directional scanning modes and attributes help to optimize pattern fidelity, especially when it comes down to nm-fabrication-tolerance.



FLEXposure attributing per pattern shape within GDSII, multiple choice of directional patterning – in total 5 main operating modes with 47 submodes*

Flexibility and ease of use of the Raith Nanosuite

With more than 100 man-years of development, Raith Nanosuite is the most advanced, comprehensive and mature software for nanolithography. A true multi-user management system with 3 different user levels (user, expert, administrator) allows for user-specific system parameter administration and system settings. Thus, there is no "interference" and users always find "their" system as they have left it.



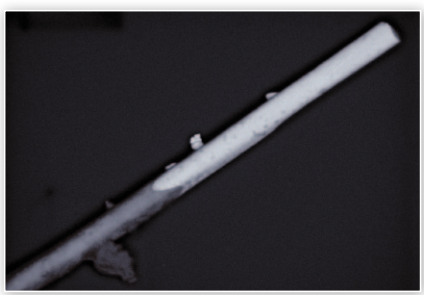
Screenshot of Raith NanoSuite software showing intuitive data flow and instrument control from design to result: GDSII design of photonic crystal waveguide, proximity-effect-corrected GDSII design thereof, SEM image of exposed and developed photonic crystal (from upper left to right), 3D resist profile simulation by energy distribution calculation thereof and universal sample holder wafermap.

Identifying and aligning to a sample

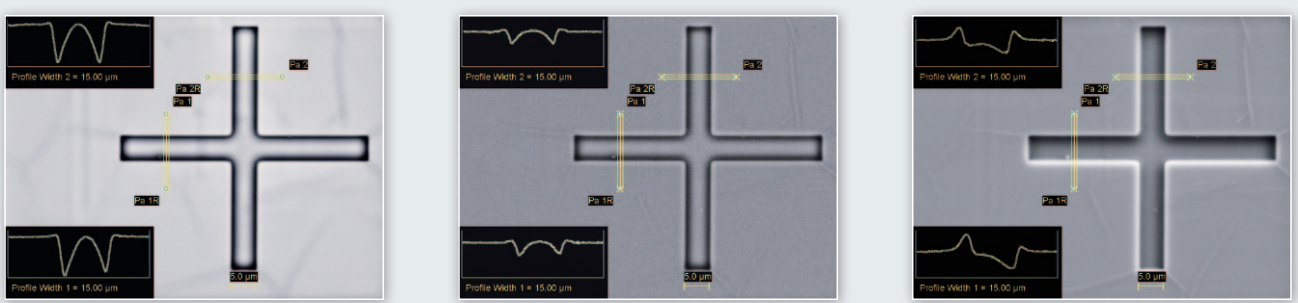
Detector capabilities for mark recognition, imaging and analytical sample information

Secondary electron (SE) detectors are essential for optimum beam calibration and for mark recognition with respect to ultra-high resolution direct write, sequential multi-layer exposures or “mix and match” applications with optical lithography. Beyond the standard, eLINE Plus offers additional patented, high-efficiency detectors for collection of:

- topographical information
- compositional information, material contrast
- surface information
- crystallographic information
- ultra-high resolution STEM imaging with dark field & bright field information and
- chemical / stoichiometric information or elemental mapping data



Compositional / material contrast showing an Au-capped Ni/NiO_2 nanowire, clearly resolved with inlens EsB detector



Deep-etched buried mark under 700 nm PMMA on InP, visualized by different detectors (AsB, inlens SE and ET-SE from left to right). Exploitation of best signal quality by selecting optimum electron detector (or mixed signal) for most reliable mark registration

This dramatically increases the flexibility for trying out diversified process steps and applications such as:

Reliable and flexible alignment mark registration

Virtually any shape, topography or material can be used as a mark. eLINE Plus users are not limited to specific mark geometries, materials or deep-etched marks.

Calibration and focussing

The user is not limited to specific samples or geometries to calibrate the instrument. Actually, *in-situ* deposited materials with nm dimensions could be used for most precise focusing and calibration.

Identification of specific nanostructures

Using the energy selective backscattered inlens (EsB) or angle selective backscattered (AsB) detectors, different materials can be identified as THE nanostructure of interest for subsequent characterization or manipulation.

Ultra high resolution imaging and analysis

Using the electron optical (Gemini) column in conjunction with various detectors, eLINE Plus can be operated in an “SEM-like” manner.

Nanoengineering options

Nanomanipulators – *in-situ* helping hands

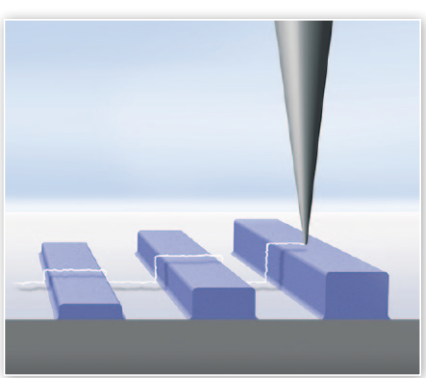
eLiNE Plus is the only professional EBL system designed to include multi-application techniques. Integrated nanomanipulators are operated and live-monitored by the user under visual SEM control – assisted by smart anti-collision software control mechanisms. These helping hands at the nanoscale can be used for:

- electrical nanoprobing
- nanomodification (e.g. cutting, bending, erasing…)
- nanoparticle sorting or assembly
- nanoprofilometry and dimensional measurements with NanoSense option for determination of material deposition (or etching) rates or for a 3D-topographical survey (linescan)

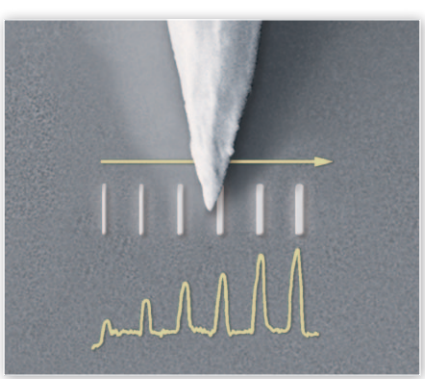
Direct-contact nanoprobing (4-point electrical measurement) of a Ni/NiO_2 nanowire with Au-caps

NanoSense – Adding 3D to conventional SEM surface imaging information

In order to be able to retrieve topographic surface information by nanoprofilometry, a new distance sensor has been developed. With its help, one of the manipulators can automatically and non-destructively approach a surface.

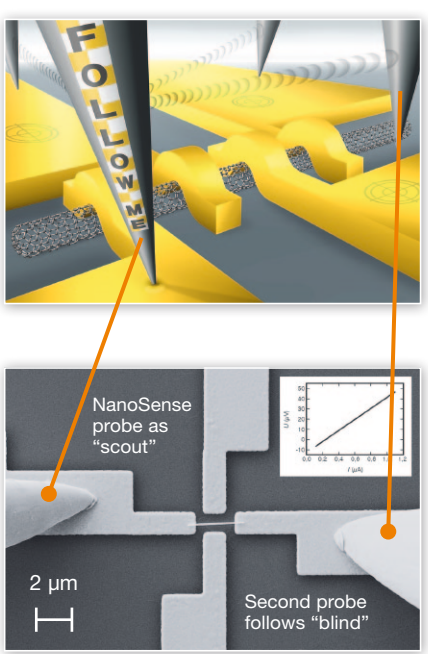


Operation principle of NanoSense distance sensor option



Nanoprofilometric linescan of deposits at various heights fabricated by EBID

This principle can be exploited to automatically “call and guide” further nanomanipulators straight next to the sample surface without time-consuming manual coarse approach (“scouting function”). Applying this, (up to 4-point) nanoprobing can be automated as a far more rapid solution.



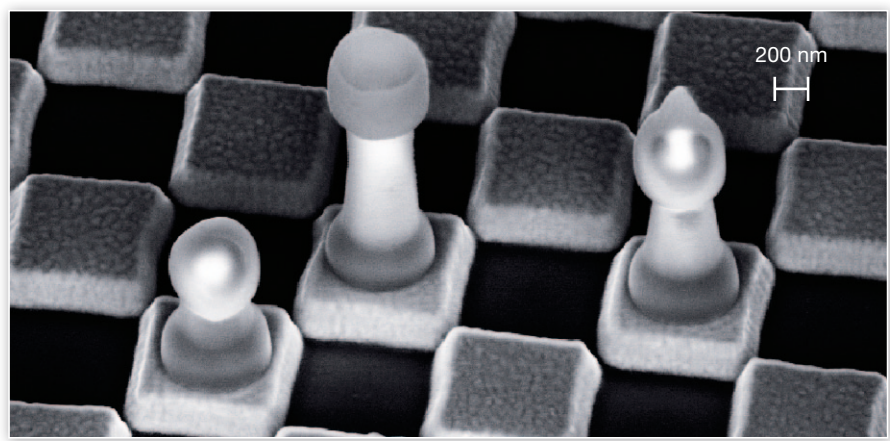
“Scouting function” for efficient nanoprobing

Nanoengineering options

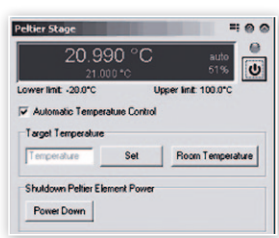
Gas injection system for surface modification – deposition, etching, nanosculpturing

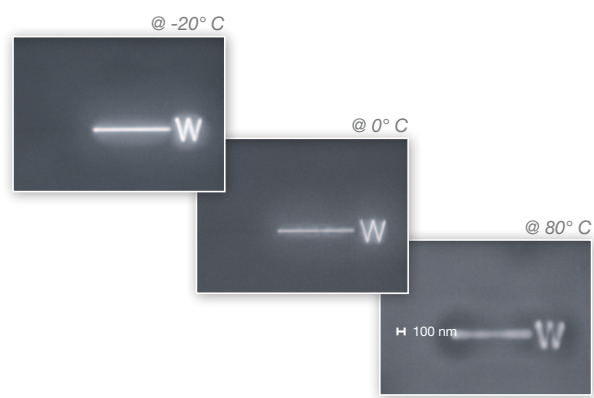
Focused electron beam induced processes (FEBIP) such as electron beam induced deposition (EBID) or etching (EBIE) can ideally complement EBL, if an existing nanostructure requires just a small *in-situ* modification or finetuning. State-of-the-art FEBIP applications involving multiple – if required, even simultaneous – gas processes are available for:

- AFM supertip fabrication
- field emission tip fabrication
- 3D nanosculpting
- nanopore fabrication
- hard mask/etch mask fabrication (surface protection/sealing)
- nano/micro tubes/pipettes
- "glueing" nanostructures to the surface
- R&D type circuit edit and mask repair
- *in-situ* contacting and wiring nanostructures for transport measurements



3D nanosculpting: "Nano-Chess" applying 3D-EBID

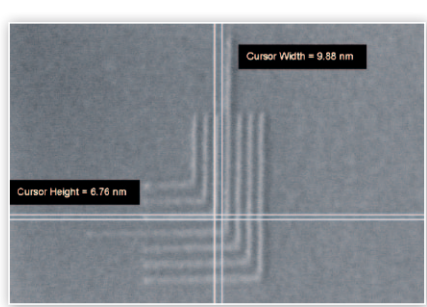




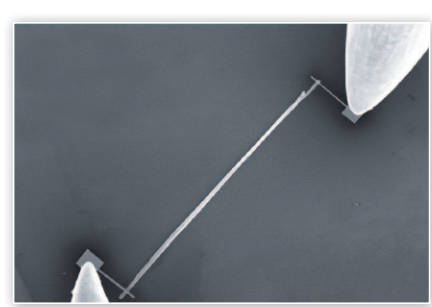
Tungsten deposit under identical deposition parameters but different temperatures

In order to advance FEBIP applications, precursor and process development is an important topic in applied research today. eLINE Plus has the following suitable supporting options:

- heating/cooling sample holder
- residual gas analyzer (RGA)
- LN_2 cooling trap ("Cryo-finger")
- plasma cleaner ("De-Contaminator")
- EDX



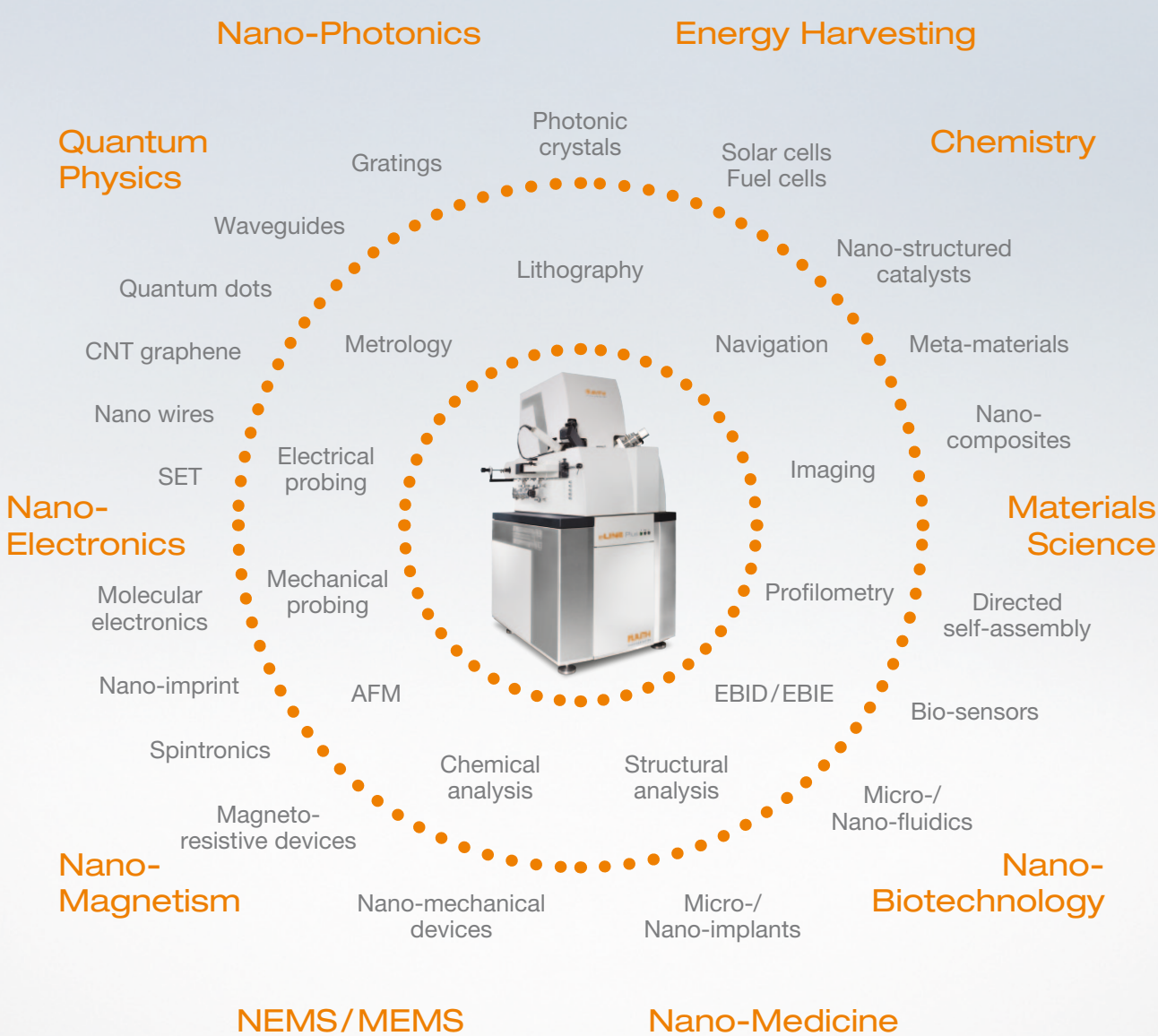
Sub-7 nm linewidth of EBID test nanostructures, imaged under 45°



Nanoprobing via EBID Contact pads for nanowire conductivity measurement

The Raith eLINE Plus “application universe”

Enabling broadest application bandwidth for interdisciplinary research across all scientific disciplines



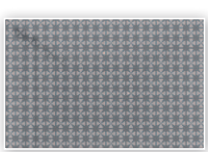
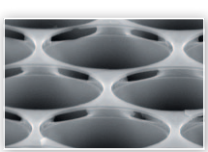
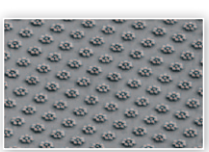
eLINE Plus

Discover Nanoengineering beyond Electron Beam Lithography

- Smallest beam size in the world of a professional EBL system
- Ultra-high resolution patterning (sub-5 nm linewidth in EBL resist, sub-7 nm lines using electron beam induced deposition (EBID) techniques achievable)
- Unique continuous stitch-error free writing modes, traxx and periodixx
- Uncompromising EBL infrastructure with complementary *in-situ* nanoengineering options for broadest bandwidth of applications
- Smart nanomanipulators for *in-situ* nanoprobing and nanoprofilometry
- Professional gas injection system for focused electron beam induced processes (FEBIP) such as deposition, etching or 3D nanosculpturing
- Upgradability at any time and open platform concept for customization
- Comprehensive Raith Nanosuite software with true multi-user management

Product specifications

Beam energy	20 eV – 30 keV
Beam current	5 pA – 20 nA
Writing speed	0.125 Hz – 20 MHz pixel frequency
Stage travel range/sample size	100 mm/≤ 4 inch wafer
Beam size	≤ 1.6 nm @ 20 keV
Beam current density	≥ 7500 A/cm^2
Beam current drift	≤ 0,5%/8 hours
Minimum grating periodicity	≤ 40 nm
Minimum linewidth	≤ 8 nm
Stitching accuracy	≤ 40 nm (mean+3σ)
Overlay accuracy	≤ 40 nm (mean+3σ)

Support and service concept

Specifications and system performance are certainly driving decisions; however, there is more to be taken into consideration to ensure an efficient start and subsequent solid support over the instrument lifetime:

All site surveys with environmental measurements, support with resulting clean-room setup, both factory and on-site acceptances, on-site basic and advanced trainings are included. Moreover, free-of-charge application support infrastructure is available in all global time zones. Service concepts that are affordable for university environments complement these benefits.

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