



# NANO Robotics Solutions for Electron Microscopes

# In situ probing and handling

# **Applications**

Bring probe tips in contact with semiconductor chips, measure the electrical characteristics of integrated components, localize defects and isolate structures.



### Nanoprobing

- Failure analysis and reliability testing
- Integrated circuits security threats assessment
- Chip design and reverse engineering



### Semiconductor device characterization

- I-V curve measurements of single transistors/diodes
- Characterization of SRAM bit cells
- · Resistivity measurements of via chains





### EBIC acquisition

- Visualize active areas of junctions and locate defects
- · Map electrical activity of samples under bias
- · Validate doping profiles and areas

### Scientific references

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Liu, Y., G. Hiblot, M. Gonzalez, K. Vanstreels, D. Velenis, M. Badaroglu, G. Van der Plas, and I. De Wolf, "In-situ Investigation of the Impact of Externally Applied Vertical Stress on III-V Bipolar Transistor", 2018 IEEE International Electron Devices Meeting (IEDM): IEEE, 12/2018. Kjeldby, S. B., O. M. Evenstad, S. P. Cooil, and J. W. Wells, «Probing dimensionality using a simplified 4-probe method», Journal of Physics: Condensed Matter, vol. 29, pp. 394008, 10/2017.

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### **EBAC/RCI** acquisition

· Localization of any open, resistive or shorting defect to the exact layer and die location • Fabrication and long-term issue diagnostics Low resistance gradient mapping

### **Electrical measurements**

• MEMS and sensor actuations and qualifications • Optoelectronics device tests: MicroLED, solar cells • Materials characterization: nanowires, graphene, thin-films, nanoparticles

### Nanomanipulation

· Single particles isolation and positioning • TEM sample preparation Micro- and nano-assembly

# **Revolutionary mobile robot motion** technology

# Technology

Imina Technologies' miBot™ is the world's most compact robot with 4 degrees of freedom and nanometer positioning resolution. It is designed for electrical probing and manipulations inside scanning electron microscopes (SEMs).

Contrary to other manipulators, miBot<sup>™</sup> is a mobile robot. It is virtually untethered and free to move over the surface of its stage. Since it has no mounting screws, miBot<sup>™</sup> can be coarsely positioned by hand in arbitrary positions and naturally adapts to changing samples geometries and microscope configurations.

miBot™ features a unique integration of piezoelectric actuators with movement range up to centimeters, and scalable positioning resolution from micrometers to nanometers. The coarse positioning mode saves time when approaching the region of interest, while the fine positioning mode allows for precise contact landing of the probes.



The high stiffness of miBot™'s monolithic design makes them robust against vibrations and guarantees smooth motion. The unmatched stability of miBot ensures steady contacts over time on even the smallest samples.

miBots move along their natural axes; no rotational and translational motion are coupled. Thanks to such design, miBots are intuitive to control. The users learn to control them very fast, and there is much less risk to damage sensitive samples. Such straightforward control gives the operator confidence to carry out delicate positioning maneuvers and saves time.

- Easily adapted to different setups and samples.
- Optimized workflow ensures straightforward operation, safe and reliable measurements, and fast time-to-data.
- Compatible with low accelerating voltage and short working distances, as well as high-resolution imaging using magnetic lenses.
- Stable positioning and contact over long periods of time, even at 55° tilt angle.
- Coarse motion over centimeter range is complemented with nanometer-scale fine motion in the range up to  $15 \,\mu\text{m}$ .





# Integrated nanoprobing solutions for SEM and FIB

# **Solutions**

Independent cabling for excellent signal-to-noise ratio and low-current measurements

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Fast and safe landing of the probes

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Imina Technologies' NANO solution is designed for electrical characterization of microelectronic devices, in-situ semiconductor failure analysis, and manipulation of nano-objects in SEM and FIB chambers.

Landing probe tips, measurements and reporting are fully controlled from Precisio™ software suite. The operator is assisted during measurement setup and guided through comprehensive nanoprobing workflows.

NANO system solution can fit up to 8 miBot<sup>™</sup> nanoprobers. Various system configurations and optional modules help to adapt to application-specific requirements and chamber setups.

Platforms for the robots are **compatible with** almost any electron microscope. They can be mounted on the SEM sample positioning stage, or loaded via SEM load-lock. The platforms are compact and light so they fit even the crowded chambers.

miBots are compatible with high-resolution imaging. The operator can perform nanoprobing experiments with the most advanced state-of-the-art scanning electron microscopes and probe the samples that require high-resolution imaging conditions, even at accelerating voltages below 0.5 kV or using magnetic lenses.

Platform and robots can be tilted up to 55°, so in-situ FIB circuit editing can be performed simultaneously with nanoprobing to provide faster and more accurate results.

NANO solution does not require a dedicated microscope or any permanent modification of the chamber. The installation and removal of the system only takes a few minutes.

The main components of a NANO solution can also operate under optical microscopes, and be integrated into probe stations, inspection tools, AFMs or nanoindentors, increasing the value of your investment.

Industry standard tungsten probe tips with tip radius down to 5 nm

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Sample holder with adjustable height for imaging at short working distances and low accelerating voltages



From 1 to 8 independent miBot<sup>™</sup> nanoprobers

> Choice of compact or wide platforms, with direct mounting on SEM positioning stage or insertion through an airlock system



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Options:

- Sample positioning XYZ
- sub-stage
- Heating/Cooling Thermal
- Stage
- Large sample adapter

# Advanced features for challenging applications

Designed to match the most demanding technical and operational requirements in semiconductor industry. Our nanoprobing solutions seamlessly fit into the standard FA workflows, help to streamline the experiments and significantly reduce the timeto-data.



**Features** 



### **Short working distances**

miBots can operate at working distances down to 2 mm between the sample surface and SEM pole piece. Thanks to their compact design, miBots can be used for the most challenging technology nodes that require imaging at low accelerating voltage <0.5kV.

### Magnetic immersion imaging

Critical components of the nanoprobing system are non-magnetic, enabling full compatibility with high resolution imaging of electron microscopes immersion-lens columns.



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### Tilted angle

The platform with miBots can be tilted up to the FIB operation angle (54°). The nanoprobers can maintain steady electrical contact with the device under test, enabling simultaneous FIB circuit editing and nanoprobing.



### One software to control, measure and report Our software application Precisio<sup>™</sup> provides intuitive and to process them.





### Fast installation and storage

to use.



### Flexible platform configurations

Modify the nanoprobing setup by adding or removing robots and by adjusting their position and orientation by hand or in situ. Naturally adapt to different sample size and geometry in no time.

step-by-step operator assistance to position the nanoprobes, as well as to run electrical test measurements

### Probe holders: quick tips replacement

The probe holders are compatible with industry-standard probe tips. We offer a wide range of tungsten probe tips, with tip radius from 1 µm down to 5 nm. The probe tips are easy to exchange or to be replaced with optical fiber holders.

Install and remove the nanoprobing platform from the SEM chamber in minutes, avoiding the need to dedicate an SEM to the probing system. Compact storage solution is available to minimize ex-situ contamination and maintain the system ready

# Nanoprobing platforms for all chamber and sample sizes





### Stage-mounted platform 4-Bot [SM100]

Compact design (diameter: 100 mm)

- Up to 4 independently driven miBot<sup>™</sup> nanoprobers
- Sample size up to approx. 1"

### Stage-mounted platform 8-Bot [SM125]

- Wide design (diameter: 125 mm)
- Up to 8 independently driven miBot™ nanoprobers
- Sample size up to approx. 2"

### Load-lock platform 4-Bot [LL10]

- Wide design (diameter: 100 mm)
- Up to 4 independently driven miBot™ nanoprobers
- Sample size up to approx. 1"
- Typical airlock door inner dimensions: 100 (w) x 45 (h) mm



### Load-lock platform 8-Bot [LL11]

- Wide design (diameter: 112 mm)
- Up to 8 independently driven miBot™ nanoprobers
- Sample size up to approx. 1.5"
- Typical airlock door inner dimensions: 150 (w) x 45 (h) mm

Custom configurations are offered for integrating our nanoprobers with unconventional vacuum chambers, heating / cooling sample stages, or third-party analytical equipment.



# **Platforms**



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### Need to probe outside the EM ?

We offer various solutions to: • Retrofit standard probe stations • Integrate with wafer inspection tools • Mount under optical microscopes and AFMs

Look for details in the MICRO product line brochure

# Upgrade your system and cover all your present and future needs

We offer optional components and modules to ensure your system satisfies all your requirements. Not sure if you need an optional module right now? No worries, onsite or factory upgrades of your equipment are always possible.

# **Options**



- cases.

### Additional SEM integration kits



### Thermal stage

- Temperature range -30°C to 150°C
- Excellent thermal stability <0.05°C and precise temperature control
- Foldable radiator to fit into small SEM chambers
- · Vibrations-free heating and cooling by Peltier elements

### Sample positioning XYZ sub-stage

- Moves the sample independently from the probes in X, Y, Z directions.
- Reduces probes landing time and accelerate multiple device characterization.
- Travel range: 5 mm (X, Y), 330 µm (Z).
- Resolution: down to 2 nm (X, Y), 7 nm (Z).



### Large sample adapter

Acts as an upper "floor" for the nanoprobers and fits large/tall samples under it.

- Ideal to probe samples such as 2" wafers, packaged samples, cross-sections, etc.
- · Different elevations are available to match most sample heights



### Lab equipment kit

- contamination
- monitor





### Electrical Failure Analysis (EFA) module

- Designed for efficient and precise defect localization
- by EBIC, EBAC/RCI and EBIRCh.
- Live imaging for reduced time-to-data
- Automated routing for simplified workflow
- High-performance analysis of a wide range of failure

### Software Module "Nanoprobing Workflow"

- Step-by-step operator assistance and library of measurement recipes to reduce time-to-data.
- Quickly set up the system and land probe tips on the device under test
- Run predefined measurement recipes
- Manage the measurements database, compare curves, export results
- Install your nanoprobing system in minutes and operate in any of your microscopes by preinstalling the interface parts on the different chambers.

- Robust shelf to accommodate the system electronic controllers and optional parametric analyzer Desiccator to store the platform and avoid
- Toolbox for tools and accessories
- Pre-installed modern computer workstation and

# Robots control and data acquisition in a unified software suite

# Software

A streamlined computer-assisted workflow with step-by-step operator assistance to position nanoprobes, run device measurements, and isolate defects.

Precisio<sup>™</sup> software suite is an integral part of the NANO solution. All required controls and parameters are embedded into a streamlined workflow with the step-by-step operator assistance.

The operator is guided through the set-up of the nanoprobing system and test recipes, landing probe tips on a device under test, acquiring data and reporting the measurement results.

Probe movements are controlled from anywhere in the workflow with a light and ergonomic control pad.

An indicator panel shows the current hardware configuration and how it is linked in the selected electrical test recipe.

It also shows which miBot<sup>™</sup> nanoprober is selected, and what are its motion mode and speed.

Thanks to the visualization of the probes and of the measurement configuration, the operator does not need to rely on memory and can fully focus on the measurements.



Our software team is dedicated to making the user experience as smooth and enjoyable as possible.











the measurements.



### 1 - Test recipes

Create new or load existing measurement projects. Select the type of device under test (transistor, diode, resistor, etc.) from a library and remotely configure your semiconductor parameter analyzer (Keithley 4200A-SCS or Keysight B1500A) to match your characterization needs.

### 2 - Tips contact detection

Get a visual feedback with I-V traces to optimize each probe tip contact resistance with the substrate. Individually configure the contact tests to cycle according to the specifications of the device under test. Run automatic test sequences over all probes.

### 3 - Measurements

Run series of pre-configured tests. Automatically plot results in meaningful charts. Get direct access raw data of each curve. Write your notes next to

### 4 - Data management and reporting

Manage a database of all your measurements across time, per samples and test recipes. Perform side by side graphs comparisons and document your findings. Export results in usual office file formats for reporting and sharing with colleagues.

# **Specifications**

Main components of a NANO solution			
Nanoprobers	Up to 8 miBot <sup>™</sup> robots with independent high resolution piezo driving electronic controller.		
Platforms	1 standard stage mounted or load-lock platform for 4 or 8 miBot <sup>™</sup> , or a special integration. This includes all accessories for installation inside an EM chamber with model specific interface parts of the microscope sample stage and chamber port, and a shielded electric interface for low current, low noise <i>in situ</i> probing (coaxial I/O).		
Motion controller	1 unit to control up to 4 miBot <sup>™</sup> , or 2 units to control up to 8 miBot <sup>™</sup> . This includes a control pad and a license for Precisio <sup>™</sup> software Basic Edition (Microsoft® Windows 11, 10, 8 and 7).		
Options	Options include active sample holder, sample positioning XYZ sub-stage, EBIC and EBAC/RCI acquisition systems, additional SEM integration kits, lab equipment kits, computer, software modules Precisio <sup>™</sup> Probing, and Precisio <sup>™</sup> Data Management & Reporting.		
Probe tips	Range of Tungsten probes with tip radius from 5 nm to 1 um, 0.51 mm (0.020") shank diameter, and lengths of 15 mm or 20 mm. Other types available upon request.		

Nanoprober Robot N	NO+		
Degrees of freedom	4 independently driven (X,Y,R,Z) per prober		
Dimensions & weight	Body: 20.5 x 21.7 x 12.5 mm <sup>3</sup> Arm: 8.3 mm (without tool)   Weight: 12 g (without tool)		
Max. positioning resolution	Stepping (coarse):   60 nm (X, Y), 120 nm (Z)     Scanning (fine):   0.02 nm (X, Y), 0.1 nm (Z)		
Motion range*	Stepping (XY,R,Z): $20 \times 20 \text{ mm}^2, \pm 180^\circ, 41^\circ$ Scanning (X Y Z): $250 \times 440 \times 6'000 \text{ nm}$ (ca. 15'000 nm at the probe tip)Note : in stepping, actual X, Y, R range are only limited by the size and shape of the stage where the robot moves, and the length of the driving cable.		
Speed	X and Y: up to 1.5 mm.s <sup>-1</sup> Z: up to 150 mrad.s <sup>-1</sup>		
Forces & torques	X and Y: push: 0.3 N Z: lift: 0.7 mNm (5 g) hold: 0.2 N hold: 0.9 mNm (6 g)		
Tilt angle	Holding position up to 55°		
Drift	< 1 nm/min		
Tool holders	Range of holders for probes and optical fibers		

\*Measured at tool-holder tip (label "THT" on schema) and measured at 300 K with motion controller MC410/20.

### Platforms

Model	SM100	SM125	LL10	LL11
Туре	Stage-Mounted		Load-Lock	
Number of probes	4	8	4	8
Height (without interface part)	16.5 mm	17.5 mm	12.8 mm	16.5 mm
Width (without cables)	100 mm	125 mm	100 mm	112 mm
Weight (without cables)	180 g	220 g	200 g	233 g
Sample size	Up to ~25 mm (1")	Up to ~50 mm (2")	Up to ~25 mm (1")	Up to ~38 mm (1.5")
<b>Sample holder</b> Compatible with various SEM stubs with pin size Ø 3.2 mm and length 6 mm.				

### **Electrical probing**

Voltage range	± 100V	
Max. current	100 mA	
Leakage current	< 100 fA/V	
Resistance	Approx. 3.5 Ω	from probe tip to

Low noise probing accessories and suitable measurement environments are required to achieve the best measurement performance of the system.

### **Operating conditions**

Lowest pressure	10 <sup>-8</sup> mbar
Temperature range	273 K to 353 K
Humidity	< 95% (non-condensing)

### Site requirements

Equipment and facilities requirements may vary depending of the system and its options. Contact us for a complete evaluation of the requirements.



### flange connectors

## **Customer support**

Imina Technologies provides tailored services for product installation, maintenance and staff training worldwide. We pride ourselves on our recognized excellent customer support that ensures the best user experience throughout our product life cycle.

### **Nanoprobing services**

Outsource your nanoprobing tasks to our experienced applications team. Take advantage of our state-ofthe-art nanoprobing lab and let us characterize your most challenging samples to save yourself a lot of time and effort.

### Warranty plans

By default, our products are covered by a 2 years warranty against defects and workmanship. Warranty extension plans are available upon request.

### Installation and training services

Installation and commissioning at your facilities is performed by a skilled engineer. Advanced training sessions for single or multiple users are provided by one of our application specialists.

### SWAP programs

To avoid extended downtime during a repair or maintenance service on a component, enroll into a SWAP program for all, or part, of your system to get a functioning replacement delivered to your facilities within 3 business days.

### Site acceptance tests

Site acceptance tests on specific samples can be requested at installation and commissioning of a new system. This service is always preceded by a feasibility study at our demo lab.

### Demo lab

Our application team can perform live demonstrations and feasibility studies at our fully equipped demo lab for nanoprobing and semiconductor failure analysis. Contact us to arrange a visit. Cannot travel to Switzerland? Ask for a personal live web demonstration or register to one of our frequent webinars.





Imina Technologies SA Route de Montheron 8b 1053 Cugy (VD) Switzerland

www.imina.ch

