ElProScan

ELP 1 Systems

2019/2020

- Scanning Electrochemical Microscopy
- Scanning Ion Conductance Microscopy
- Scanning Electrochemical Cell Microscopy
- Scanning Kelvin Probe

HEKA

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For over 45 years HEKA has designed and manufactured sophisticated instrumentation and software for biomedical and industrial research applications. Through the years, HEKA has achieved an unparalleled reputation for precision and quality. Medical, pharmaceutical and industrial research facilities world-wide rely on HEKA ingenuity for their discoveries.
While there have been many changes in research, instrumentation, and software, our commitment to bring innovative technology to our customers remains constant. HEKA is a select group of engineers, biomedical researchers, and computer scientists who pride themselves on the quality of HEKA products. HEKA offers complete pre- and post-sales technical support, and takes care of each customer personally. In every way, HEKA provides solutions.

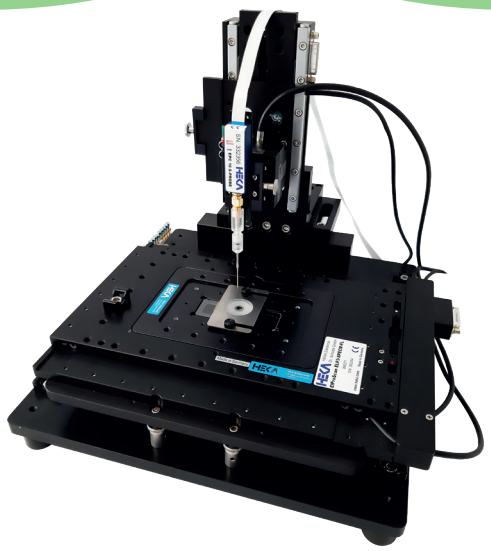
Smart Ephys

a **Harvard Bioscience, Inc.** brand

HEKA Elektronik GmbH is proud to be part of the new Smart Ephys umbrella. Together with our other Harvard Bioscience, Inc. brands Multi Channel Systems GmbH and Warner Instruments we offer complete solutions for both electrophysiology and electrochemistry with unprecedented synergy.
You will find the high-quality products and service that you know and trust from each of the individual companies, but you can get information on all products, complete set-ups (e.g. patch clamp rigs), and product consultation from one source.
Please check out the Smart Ephys website and contact your local sales representative with any questions.

The HEKA ElProScan is a unique electrochemical scanning probe microscope (e-SPM) system, which employs an ultramicroelectrode and/or nano-/micropipette as a scanning probe to perform *in situ* high-resolution microscopic imaging of local reactivity and topography of various types of samples and materials. ElProScans are offered in different models and various configurations to tackle a wide range of cutting edge and engineering applications.

- **Environmental Processes**
- **Micro-Sensors**
- **Nano-Electrochemistry**
- **Photoelectrochemical Processes**



- **Micro-patterning & Micro-fabrication**
- **Corrosion Processes & Protective Coatings**
- **Energy Conversion & Storage**

Multifunctional Research Tool for Various Materials:

- Metals, alloys & cermet
- Active catalysts & carbon substrate
- Semiconductors
- Conductive polymers
- Hybrid nanostructures
- Biological cells & membranes
- Aqueous electrolyte & ionic liquid

And more …

ElProScan Supports State-of-the-Art e-SPM Techniques:

- Scanning Electrochemical Microscopy (SECM)
- Scanning Ion Conductance Microscopy (SICM)
- Scanning Electrochemical Cell Microscopy (SECCM)
- Scanning Microcapillary Contact Method (SMCM)
- Scanning Kelvin Probe (SKP) with µ-EIS
- Simultaneous Surface Topography Mapping
- Shear Force regulated Surface Tracking
- Scanning Photoelectrochemical Microscopy (SPECM) with top illumination

For more information about applications and techniques, consult our product experts at sales@heka.com or visit our website elproscan.com.

Models

HEKA's ELP 1 systems are divided into four models with different scanning properties. Available models are featured with long scan range (ELP 1), or super-high scan resolution (ELP 1A), or combined long range and high resolution (ELP 1A-MXYZ-PC100), or specially integrated with a support frame (ELP 1 Arch).

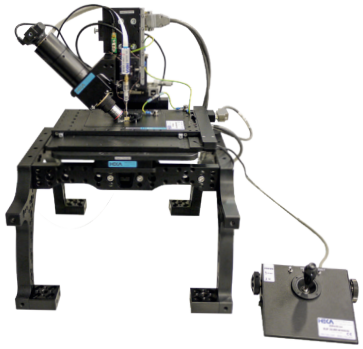
ELP 1

The ELP 1 system is a compact and versatile electrochemical scanning platform. It uses a highest quality closed-loop controlled multi-axis motorized positioning system. A linear encoder at each axis allows a real-time position control with closed-loop regulation to eliminate backlashes.
The XY-motor stage manipulates samples in XY-direction. The probe is mounted on the vertical Z-axis assembly with an integrated motor and piezo unit, which allows the scan probe to step at nanometer resolution through the centimeters travel range.

ELP 1 with 45° optics

ELP 1 Arch

The ELP 1 Arch system is an electrochemical scanning platform which is mounted on an arch stand raising the XY-stage by about 26 cm. This setup allows the integration of optics, illumination from the bottom or a setup with two aligned microelectrodes.
ELP 1 and ELP 1 Arch share the same specifications, with the difference of ELP 1 Arch being integrated with an arch support frame.



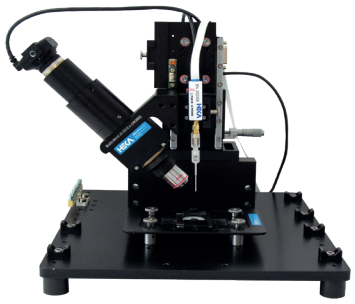
ELP 1 Arch with 45° optics

Specifications

Positioning System	X/Y/Z 3D positioning system	XY/Z 3-axis DC servo motor stage integrated with ultra-fine Z-axis Piezo motor. A joystick facilitates manual positioning.
	Resolution of X/Y/Z Axis	2.5 nm intrinsic resolution for XYZ-motor linear encoders XY/Z-scan resolution = 10 nm Z-scan using Z-piezo resolution = 1.5 nm
	X/Y/Z Axis Travel Range	Motor scan range: X = 100 mm, Y = 75 mm, Z = 50 mm Z-axis piezo range = 100 µm (closed-loop controlled)

ELP 1A

The ELP 1A system is a very compact electrochemical scanning platform for high resolution imaging and high scan speed.
It is equipped with a fixed XY-stage and a motorized closed-loop Z-axis with linear encoder. The option of manual coarse positioning in XY direction is integrated into the Z-Axis assembly. A XYZ piezo cube for scanning of the probe is mounted on the Z-axis motor.



The ELP 1 A with 45° optics

Specifications

Positioning System	X/Y/Z 3D positioning system	Z-axis DC servo motor integrated with ultra-fine XYZ-axis Piezo cube
	Resolution of X/Y/Z Axis	2.5 nm intrinsic resolution for Z-motor linear encoders Z-scan resolution = 10 nm XYZ-scan using piezo cube resolution = 1.5 nm
	X/Y/Z Axis Travel Range	Motor scan range: Z = 50 mm XYZ-axis piezo cube range = 100 µm (closed-loop controlled)

ELP 1A-MXYZ-PC100

The ELP 1A-MXYZ-PC100 system is a multifunctional electrochemical scanning platform. A XY motorized stage with a large travel range is combined with a XYZ piezo cube for high resolution imaging and high scan speed. The piezo cube is mounted on a motorized Z-axis. The system uses a highest quality closed-loop controlled multi-axis motorized positioning system. A linear encoder at each axis allows a real-time position control with closed-loop regulation to eliminate backlashes.

ELP 1A-MXYZ-PC100 with 45° optics

Specifications

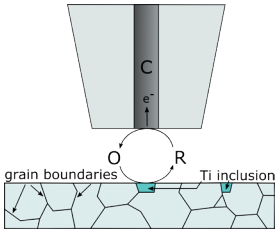
Positioning System	X/Y/Z 3D positioning system	XY/Z 3-axis DC servo motor stage integrated with ultra-fine XYZ-axis Piezo cube A joystick facilitates manual positioning
	Resolution of X/Y/Z Axis	2.5 nm intrinsic resolution for XYZ-motor linear encoders XY/Z-scan resolution = 10 nm XYZ-scan using piezo cube resolution = 1.5 nm (also available with 0.38nm)
	X/Y/Z Axis Travel Range	Motor scan range: X = 100 mm, Y = 75 mm, Z = 50 mm XYZ-axis piezo cube range = 100 µm (closed-loop controlled)

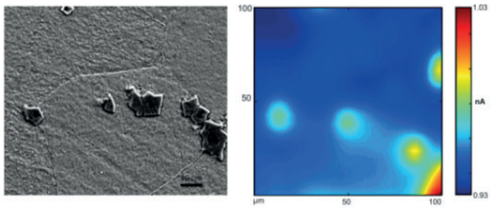
Featured application examples

In material sciences, the study of degradation and corrosion processes is of interest. SECM as well as micropipette techniques have been applied to investigate corrosion kinetics (generation-collection mode of SECM), local corrosion potentials (SECCM) and localized impedance measurements (SMCM). The combination with Shear Force sensing allows constant-distance scans.

Studying localized corrosion processes at alloys by SECM

The addition of Ti to ferritic stainless steel inhibits intergranular corrosion but takes part in the initiation of other localized corrosion processes. Spots of high reactivity in SECM images were attributed to Ti-rich inclusions. The localization of alloy elements will help understand localized corrosion resistance.



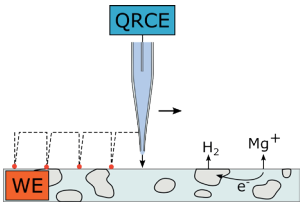


Scanning Electron Microscopy image (left) and SECM (right) image map of similar sites on the substrate. The local hotspots correspond to the conductive inclusions.

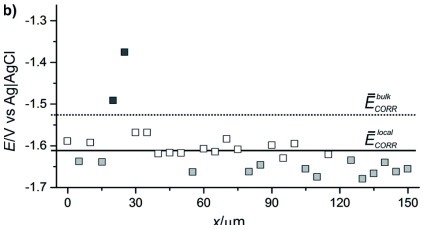
Gateman, S. M., Stephens, L. I., Perry, S. C., Lacasse, R., Schulz, R., & Mauzeroll, J. (2018) npj Materials Degradation, 2(1), 5.

Mapping in situ corrosion potentials and surface profile by SECCM

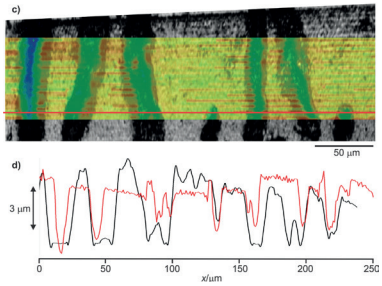
Corroded Mg alloys were investigated for topography variations and local corrosion rate.



Profile of local corrosion potentials



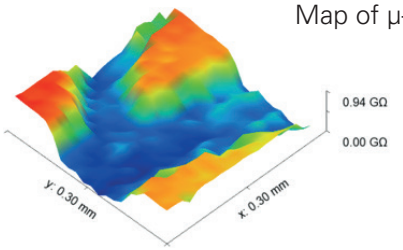
Height profile of corrosion surface



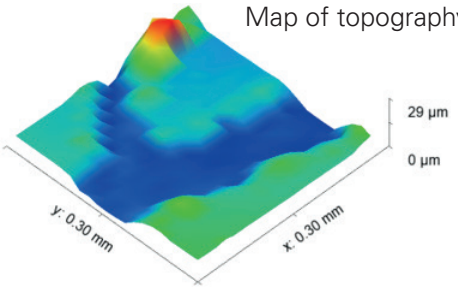
Dauphin-Ducharme et al. Faraday Discussion 2015, 180, 331-345 – Reproduced by permission of The Royal Society of Chemistry

Simultaneous spatially-resolved imaging of micro-impedance (µ-EIS) and surface topography via Shear Force sensing mode

Map of µ-EIS (5 kHz)

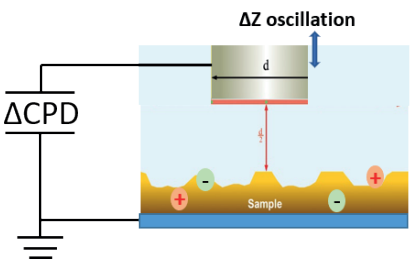


Map of topography

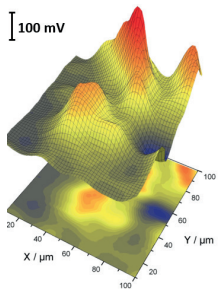


Scanning Kelvin Probe (SKP)

- A material's work function is an extremely sensitive indicator of surface conditions and is affected by adsorbed or evaporated films or species, surface reconstruction, surface charging, oxide layer imperfections, local and/or bulk corrosion processes.
- HEKA's SKP scans a vibrating capacitor probe to image work function at true micron scale.



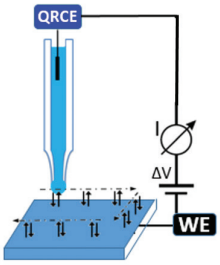
Flexible constant-height or constant-distance mode

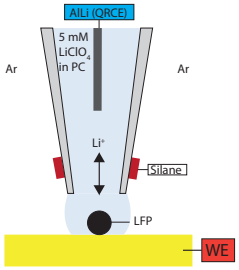


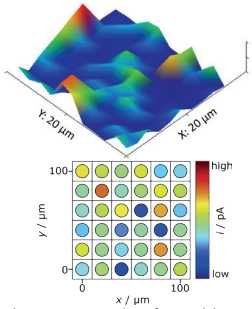
Map of work function from a corroding surface

Investigation of Li-ion batteries inside the glove box

© M. Braun Inertgas-Systeme GmbH







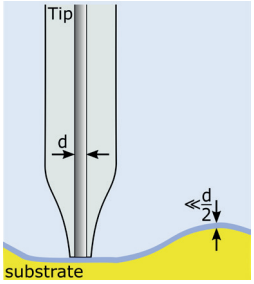
Map of topography

Map of peak current from micro-CV Matrix

Working electrode containing lithium scanned by ElProScan SECCM integrated in a glove box.

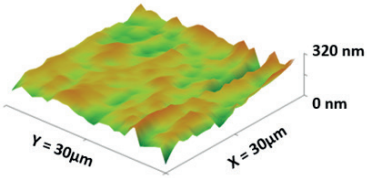
Similar experiments can be found in *Snowden et al. Journal of Power Sources, 325 (2016) 682-689*

Constant-distance scan in GC mode with simultaneous topography imaging

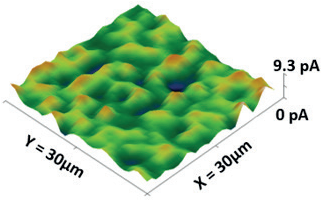


Scheme of constant-distance 2D Scan

Topography

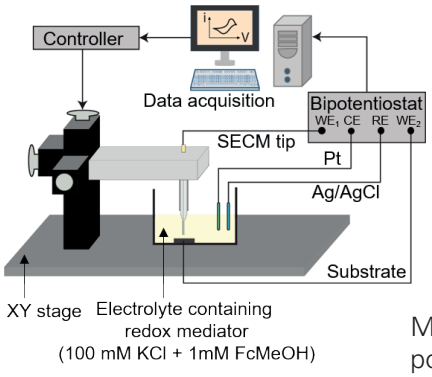


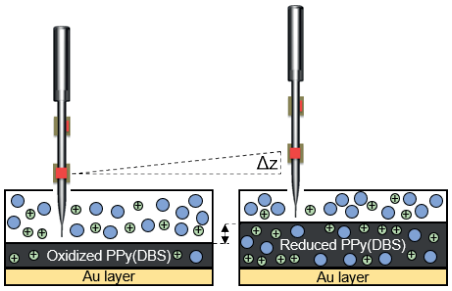
Reactivity

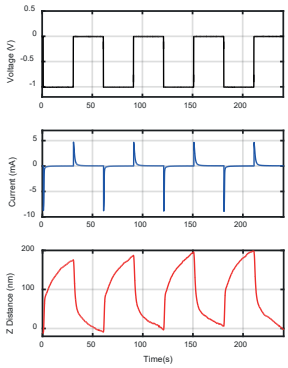


In situ topography (left) and electrochemical activity (right) maps of conductive polymer (PEDOT film)

Nanoscale height-tracking for conducting polymer membrane





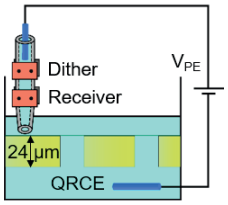


Measuring volumetric strains in conducting polymers between oxidized and reduced states

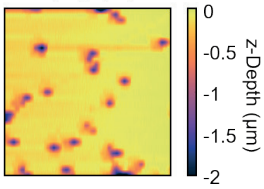
Methods outlined in Northcutt, R. G., Heinemann, C., & Sundaresan, V. B. (2016) Physical Chemistry Chemical Physics, 18(26), 17366-17372.

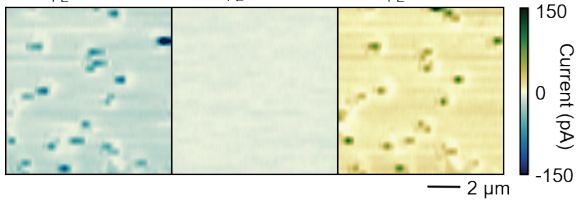
Topography-correlated transmembrane currents via surface-tracked ion conductance microscopy

Schematic



Topography

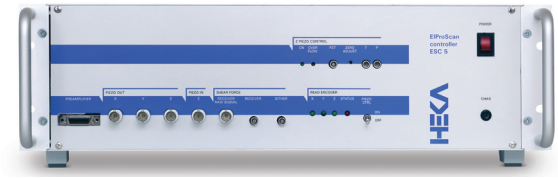




Simultaneously acquired substrate topography and transmembrane currents measured across porous polycarbonate track-etch membranes at different transmembrane potentials

Methods outlined in *Venkatesh, V., Heinemann, C., & Sundaresan, V. B. (2019). Micron, 120, 57-65.*

The New Generation of ElProScan Controller (ESC 5)



ESC 5 Controller for ElProScan

- The new ESC 5 Controller may be equipped with hardware lock-in electronics to empower the latest HEKA Shear Force Extension (SFU 3).
- Controller employs on-board computer system to process and integrate real-time positioning data with electrochemical signals online.
- The design allows the ESC 5 Controller to interface with and gain control of a wide range of external analog-driven piezoelectric stages, thus offering a cost-effective upgrade solution to users' existing non-HEKA scan stage.

Cutting-Edge Electrochemical Resolution for Nanoelectrochemistry

PG 618 USB USB Ultra Bipotentiostat/Galvanostat

- Low noise: 3.5 fA @ 15 Hz and 31 fA @ 1 kHz
- High resolution: 0.15 fA in 5pA range
- High bandwidth and fast sampling rate

- The world's 1st asymmetric dual-channel bipotentiostat with different current ranges for each channel, specially designed to support noise-free ultralow potential and current sensing experiments
- Built-in 16-bit 200 kHz AD/DA interface with 5 µs shortest sample interval
- User-configurable hardware filters tailored for fine tuning of electric signals
- Additional auxiliary I/O ports empower the control of external equipment

Specifications

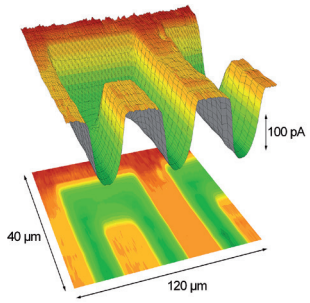
Biopotentiostat Workstation	Voltage Range / Resolution	±10 V (in single amplifier mode) / 610 nV (compliance ±12 V)
	Current Ranges	±20 nA to ±100 mA (Amp-1); ±5 pA to ±2 µA (Amp-2; total 18 ranges available)
	Max. Current Resolution	0.61 pA in 20 nA range (Amp-1); 0.15 fA in 5 pA range (Amp-2)
	Noise in Current	RMS value < 3.5 fA (at 15 Hz bandwidth in 5 pA range of Amp-2)
	DAC Interface	16-bit / 5 µs fastest pulse / 200 kHz sampling rate
	Optional Upgrade	External EIS measurement module (10 µHz – 2 MHz)

For more information about our different ELP models and customization, consult our product experts at sales@heka.com.

POTMASTER is a multi-purpose stimulation and data acquisition software with programmable experimental control and automation.

It supports the world's most comprehensive and up-to-date electrochemical scanning probe techniques, and additionally, the following unique features are available to empower advanced customization and automation of one's own experiments.

POTMASTER supports any HEKA Data Acquisition Interface and is compatible with all of our potentiostats.



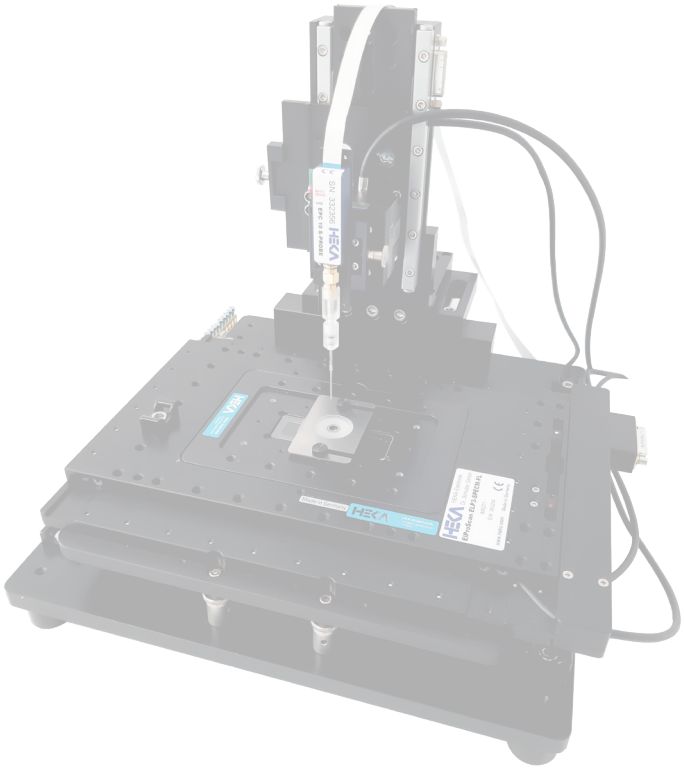
POTMASTER Software	SECM Scan Mode	1. Automatic and manual Probe Approach Curves (1nm/s up to 50 µm/s on Z-piezo) 2. Constant-Height 2D/3D Scan at constant velocity (10 nm/s slowest, with slope compensation and user-defined scan axes) 3. Constant-Distance 2D/3D Scan (available modes: Shear Force Hopping / Surface-Tracking / DC Hopping / Z-modulated Hopping for SECM/SICM/SECCM/SMCM) 4. Template Scan (user-defined micro-etching / micro-deposition / micro-3D printing; XY scan cycles available in zigzag or alternative directions) 5. 2D/3D Protocol-Controlled Matrix Scan (each scan point allows running any combination of experiment waveforms and sequence).
	SECM Working Mode	1. Feedback Mode 2. Generation-Collection Mode 3. Redox-Competition Mode 4. Surface Interrogation / Titration Mode 5. Mediator-Free direct Mode 6. Non-Hopping Continuous Surface Tracking Mode 7. Depth Scan (X vs. Z scans) Mode 8. AC-SECM Mode
	Supported Electrochemical Techniques	• Classical Voltammetry: Open Circuit Potential; Cyclic Voltammetry, FSCV, Linear Sweep Voltammetry; Staircase (Linear and Cyclic) Voltammetry, Chronoamperometry, Chronocoulometry, Chronopotentiometry, Normal Pulse Voltammetry, Differential Pulse Voltammetry, Square Wave Voltammetry; Multi-Current Steps; Potentiometric Stripping; RDE/RRDE techniques and many others • Devices and Materials Characterizations (e.g. batteries, sensors and biochips, etc.): Charge/Discharge (static and cyclic), Constant Power Tests, Multi-Vertex Scan, Noise Power Spectrum, and on-demand Potentiostatic and Galvanostatic controls with Auto-Stop Criteria (i.e. user-configurable threshold limits on potential, current, charge and power capacity in auto-stopping experiments) • Corrosion Techniques: Potentiostatic Polarization, Galvanostatic Polarization, Linear Polarization Resistance, Potentiodynamic Polarization, Tafel plot, Electrochemical Impedance Spectroscopy, etc. • Spectroelectrochemistry: supported via built-in DA/AD interface with trigger control and software batch-communication for precise synchronization with external instruments
	DA/AD Signal Acquisitions	Supporting simultaneous multi-channel analog and digital signal-communications with DA or TTL triggers; built-in fast-speed and low-noise DAC; supporting up to 32 user-defined data traces to be recorded and computed.

Upgrades and Extensions

The upgrades and extensions for ElProScan can be combined with all ELP 1 models.

Components and Items	Description and Technical Specifications		
Shear Force Extension	Shear Force Sensing is a current-less method to control the distance between a vibrating probe and sample surface. It uses a dither/receiver assembly of piezo crystals to detect the shear forces at the sample surface via a change in amplitude and phase shift of the vibration of the piezo crystals. Available modes are constant-distance scans, surface tracking and slope analysis for the determination of stiffness.		
	Detectable topography changes	Up to 50 µm	
	Height resolution	1.5 nm	
Photo-Excitation System	Different options for synchronized photo-excitation during an experiment are available. Xenon-Arc Lamps use either a shuttered filter wheel with 10 filter positions or a galvanometric scanner with 4 filter positions. The LED-based Lamp comes with 16 LED lamps of different wavelengths. A range of equipment to couple the light are available.		
	Light source	# wavelengths	Switching time
	Xenon-Arc Lamp	10	50 - 500 ms
	Xenon-Arc Lamp	4	1.5 – 3 ms
	LED-based Lamp	16	< 1 ms
	Light Guide to Fiber Coupler Kit	For connection of a light guide to a SMA type optical fiber.	
	Opto-Pipette Holder Kit	A special pipette holder with a straight optical port (SMA type) for coupling light combined with SICM/SECCM experiments.	
	Glass Rod Holder	A special holder with a straight optical port (SMA type) for coupling light.	
45° optics	Top 45° camera system equipped with a 4x objective for recording and viewing the microprobe and sample surface in prepositioning. The camera is attached to and travels with the z-axis always keeping the tip of the microprobe in focus.		
Scanning Kelvin Probe	HEKA's SKP method scans a vibrating capacitor probe to image the work function of a surface in air at the micron scale. This method allows simultaneous topography imaging and CPD measurements within one scan. Supported probes are stainless steel, platinum/iridium and tungsten.		
	Probe diameter	10 – 100 µm	
	Surmountable topography changes	50 µm (step size 1.5 nm)	
	Backing Potential	0 – 10 V	

Components and Items	Description and Technical Specifications	
External EIS Module	The external EIS module supports electrochemical impedance measurements for both macro-sized and micron-scale substrates. EIS mapping in 2D line scan, 3D Matrix scan (protocol-controlled) can be performed. A frequency spectrum scan at fixed local positions is available with results displayed in Bode and Nyquist plots. Micro-EIS Matrix Mapping, with micron and sub-micron spatial resolution, are implemented in SECCM mode, which is capable of imaging surface's local impedance and topography height simultaneously.	
	EIS Frequency Range	10 μHz – 2 MHz (optional up to 4 MHz)
	Frequency Accuracy and Resolution	<0.0025%, 10000 steps/decade
	Controlled Current	Up to ± 2.0A
	Controlled Voltage	Up to ± 12 V (± 14 V compliance)
	AC amplitude	0 to 1 V
	Operating Mode	POT / GAL / OCP / ZRA (with Floating and Grounded modes)
Extendable Peripherals	Supporting online synchronization of a wide range of analytical equipment, such as: RDE/RRDE systems, FTIR spectrometers, UV-Vis Light Source and spectrometers, Photomultiplier tube (PMT), Filter Exchangers, temperature controllers, perfusion system, and research grade CMOS/EMCCD super-resolution cameras.	



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