CONVERT 2 GREEN

Catalogue of physicochemical and functional characterization facilities

Funded by the European Union

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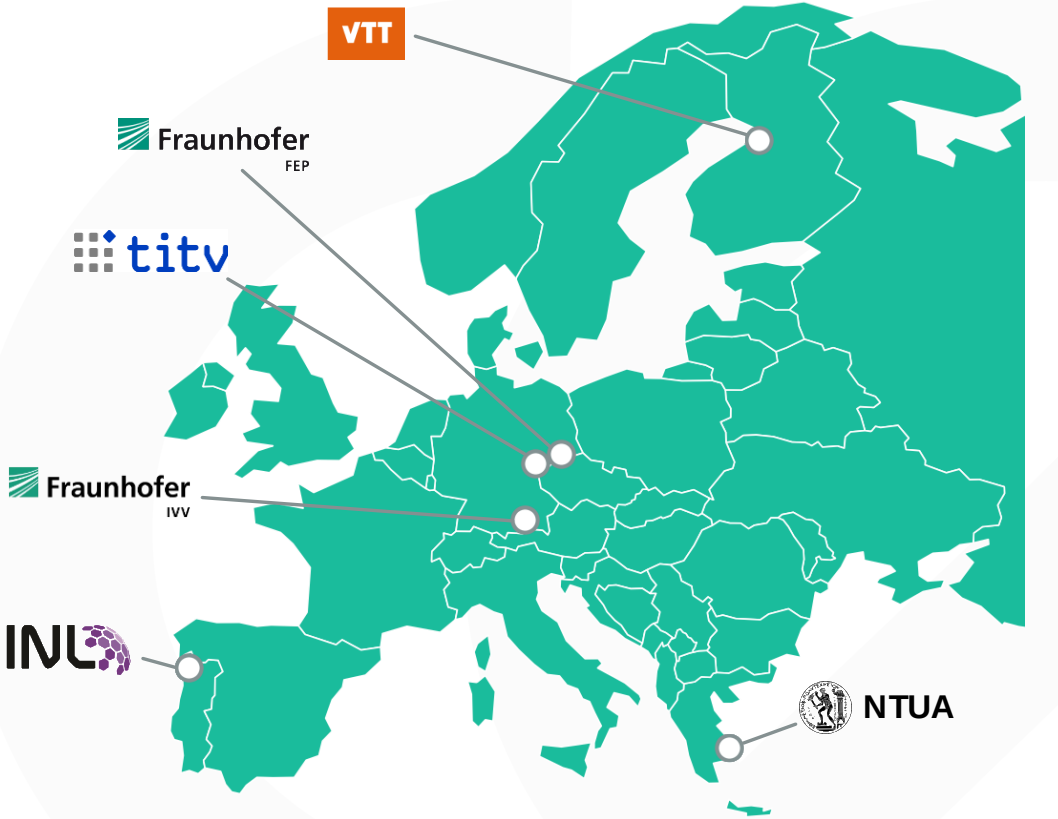
Overview of the catalogue

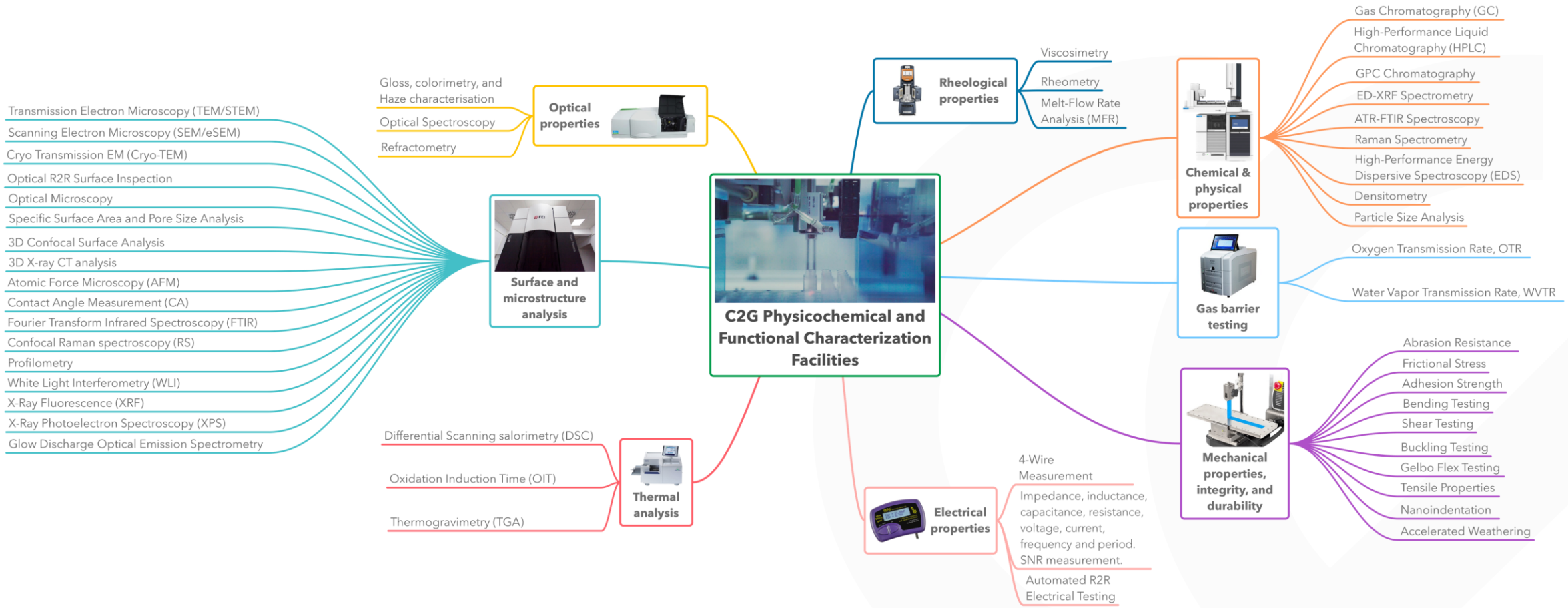
Catalogue of testing capabilities (p. 3)

- Chemical and physical properties (pp. 4–8)
- Electrical properties (pp. 9–10)
- Gas barrier testing (pp. 11–12)
- Rheological properties (pp. 13)
- Thermal analysis (p. 14)
- Optical properties (pp. 15–16)
- Surface and micro- /nano-structure analysis (pp. 18–26)
- Mechanical properties, integrity, and durability (pp. 27–31)

Physicochemical and Functional Characterisation Testing Facilities in Conver2Green



Physicochemical and Functional Testing Portfolio



Chemical and physical properties

Functionalities	Equipment	Technical specifications	Application examples
Gas chromatography (GC)	Shimadzu QP-2010 Thermo DSQ II Thermo ITQ1100 Finnigan MAT-95 XL MAT-95 S with GC/MS coupling and direct inlet probe	Low- and high-resolution mass spectrometers available. Gas Chromatography with ECD, FID and EPED detectors. LC-GC coupling possible for for mineral oil analysis. Depending on the scope of the analysis 5–100 g of material are required.	Analysis of contaminants in materials, including polymers, environmental matrices, and foods, detecting persistent organic pollutants (POPs), substances of very high concern (SVHCs), and other potential contaminants and hazardous substances.
High-Performance Liquid Chromatography (HPLC)	Shimadzu HP 1100 Series	Mass detectors with triple quad and ion trap technologies.	Analysis of contaminants, such as plasticisers or flame retardants, within polymers and recycled plastics. Identification of bioactive compounds (e.g., phenolics, carotenoids) in various sample matrices.

Chemical and physical properties

Functionalities	Equipment	Technical specifications	Application examples
Gel Permeation Chromatography	Gel permeation chromatography system (GPC & High-temperature GPC)	Depending on the method and the scope of the analysis 50 mg to 1 g of polymer are required. Standard and High-temperature GPC modes.	Determine the molecular weight distribution of polymers. Physicochemical quality evaluation of recycled polymers based on small sample quantities prior to time-consuming mechanical testing.
X-Ray Fluorescence (XRF)	SPECTRO XEPOS III BRUKER S8 TIGER	Up to 27 mm x 27 mm or circular samples diameter 40 mm. Element analyses from Na to U. For flat and solid samples (powder and liquid sample processing available on-demand). ED-XRF and WD-XRF modes available.	Quality control. Determination of trace elements in the surface of materials (e.g. toxic elements in plastics).

Chemical and physical properties

Functionalities	Equipment	Technical specifications	Application examples
Fourier-Transform Infrared Spectroscopy (FT-IR)	Bruker VERTEX 80v vacuum FT-IR spectrometer JASCO ATR PRO410-S Perkin Elmer FT-IR Spectrum 100 PerkinElmer Spectrum 2000 PerkinElmer Spotlight400 Bomem FTIR MB 155	PEAK resolution up to 0.06 cm^{-1}. Spectral Range: 7900 to 370 cm^{-1}. Modes: transmittance, reflectance, ATR (attenuated total Reflectance). Non-destructive sample processing.	Polymer fingerprinting and quality control of recycled plastics.

Bruker VERTEX 80v FT-IR system, available at INL

Chemical and physical properties

Functionalities	Equipment	Technical specifications	Application examples
Raman Spectrometry	BWTek BTR111	200 – 2800 cm^{-1} highly sensitive response range.	Molecular identification and stability assessment of polymers and biodegradable compounds. It can be used as a tool for detecting contaminants or additives that could impact the recyclability of polymers and for monitoring the decomposition of sustainable materials.
Advanced Energy Dispersive X-Ray Spectroscopy (EDS)	EDAX Octane Elect Plus	Silicon drift detector (SDD) of 30 mm^2 with a silicon nitride (Si3N4) window, offering enhanced light element performance.	Determine the elemental composition of materials.

Chemical and physical properties

Functionalities	Equipment	Technical specifications	Application examples
Densitometry	Quantachrome Instruments Stereopycnometer	< 0.2% Accuracy. Sample size range: 5 – 135 cm^3.	Quality control. Measures the true volume and density of solid materials.
Particle Size Analysis	Laser particle size analysers (HORIBA LA-960) Sieving systems	Sieving (particles > 500 µm). Laser light diffraction (particles < 500 µm). Particle size range: 10 nm – 5 mm.	Quality control and characterisation of nano- and micro-particulated materials.

HORIBA LA-960 Particle Size Analyser, available at NTUA

Electrical properties

Functionalities	Equipment	Technical specifications	Application examples
Electrical Parameters Characterisation	Peak Atlas LCR40 Fluke 8845A/8846A 6.5 Digit Precision Multimeters Haut-Model 1.0 Haut-Model Y-tube or 2.0	Measurements at 20 °C and 55–65% RH. Measurement of inductance, capacitance, resistance, voltage, current, frequency and period. Bode and Nyquist plotting. Measurement of Signal-to-Noise ratio (SNR). 100 µA to 10 A current range, with up to 100 pA resolution. Resistance range from 10 Ω to 1 GΩ with up to 10 µΩ resolution. 4-wire and 2 x 4 ohms 4-wire measurement techniques. Measurement of conductive surfaces with minimum dimensions of 0.5 x 0.5 cm. Possible to test according to DIN Spec 60029 and CEN & DIN 6812.	Characterizing the electrical properties of conductive inks, substrates, and textile-based electrodes for development of printed electronics and smart textiles.

Fluke 8845A Precision Electrical Multimeter, available at TITV

Electrical properties

Functionalities	Equipment	Technical specifications	Application examples
Automated R2R Functional Electrical Testing	TESLA Automated R2R Functional electrical tester	Stop-and-go operation mode. Testing area of 408 mm x 290 mm. 400 arbitrarily configurable test pins. Open and short circuit testing. LCR / current and voltage measurements.	Roll to roll electric characterisation and quality control of printed electronics.

Automated R2R electrical characterisation at VTT

Gas barrier testing

Functionalities	Equipment	Technical specifications	Application examples
Water Vapor Transmission Rate, WVTR	Elcometer 5100 Payne Permeability Cups Sempa HiBarSens 2.0 HAT Brugger WDDG MOCON Aquatran™	Samples Sizes: from 3 × 3 cm to 20 × 20 cm. Possible to test according to ASTM E96/E96M, ISO 15106-3, DIN 53 122-1, and on-demand protocols upon request. Sensitivity down to 10^{-6} g/m^2/d and up to 600 g/m^2/d. Possible to test under controlled RH and temperature: 23 °C / 50 % RH, 38 °C / 90 % RH, and on-demand conditions upon request.	Determine the water vapour transmission rate of barrier films for printed electronics and packaging, including those produced from biopolymers and recycled plastics.

Gas barrier testing

Functionalities	Equipment	Technical specifications	Application examples
Oxygen Transmission Rate, OTR	MOCON OX-TRAN MOCON OX-TRAN 2/20	Samples Sizes: from 3 × 3 cm to 20 × 20 cm. Possible to test according to ASTM D-3985, DIN 53380-3, and on-demand conditions. Sensitivity down to 5 x 10^{-3} $cm^3/m^2/d/bar$. Possible to test under controlled RH and temperature: 23 °C / 50 % RH, 38 °C / 90 % RH, and on-demand conditions upon request.	Determine the oxygen barrier properties of films for printed electronics and packaging, including those produced from biopolymers and recycled plastics.

Rheological properties

Functionalities	Equipment	Technical specifications	Application examples
Viscosimetry	Thermo-Haake ViscoTester VT7-R	For medium-viscous substances Measuring range: 20 to 40,000,000 mPa s	Flow properties analysis of polymer blends and fluid materials. Suitable for quality control and processing optimisation for applications such as manufacturing of eco-friendly films and plastic components.
Melt flow Analysis	Karg MeltFloW @on	Determination of melt flow rate (MFR) and melt flow volume rate (MVR). Temperature range up to 400 °C. Suitable for measuring according to ISO 1133-1 and ASTM D 1238.	

Karg MeltFloW @on Met Flow Analysis system, available at FHG-IVV

Thermal analysis

Functionalities	Equipment	Technical specifications	Application examples
Differential Scanning Calorimetry (DSC)	Perkin Elmer Pyris 6 Mettler Toledo DSC3+ TA Q2000	10 mg samples. Temperature range from 0 to 500 °C. Scan rate from 0.02 to 300 °C/min. Sensitivity up to 0.04 µW, ± 350 mW. dynamic range, and ± 0.02 °C. temperature precision.	Characterising thermal properties of materials, such as identifying melting, crystallisation, and glass transition temperatures, alongside assessing thermal stability and estimating durability and lifespan. These techniques serve, for instance, to determine whether recyclates retain equivalent properties to those of virgin materials.
Thermal Gravimetric Analysis (TGA)	Mettler Toledo Star-e TGA/DSC1 THEMYS ONE	Sample size up to 20 g. Temperature range from RT to 1600 °C. Measuring ranges: ± 1000 mg or ± 200 mg, electronic resolutions: 0.2 µg / 0.02 µg.	
Oxidation Induction Time (OIT)	Mettler Toledo DSC3+	Temperature range from 0 to 500 °C. Scan rate from 0.02 to 300 °C/min. Sensitivity up to 0.04 µW, ± 350 mW dynamic range, and ± 0.02 °C temperature precision.	

Optical Properties

Functionalities	Equipment	Technical specifications	Application examples
Optical Spectroscopy	PerkinElmer Lambda900 PerkinElmer Lambda950 Carl Zeiss PMQII Ocean Optics USB-2000	Support for flat and solid samples, sizes: 120 mm x 120 mm, 150 mm x 150 mm for flexible samples. Possible to test according to DIN 10 050 Part 9 and on-demand conditions. Wavelength range: 220 nm – 2500 nm. Measurements in transmission, reflection, and diffusion modes. Available fixed-angle reflectance at 8°. Special setups: Polarization mode and angle-dependent measurements inside integrated sphere. Accessory for absolute (specular) reflectance measurements using the VN-principle and support for optical density of band-stop filters up to OD6.	Optical characterisation and quality control in optical-grade surfaces. Determination of UV-VIS barrier for light-sensitive products.
Gloss and Haze Characterisation	Erichsen Picogloss master 500 BYK Haze-gard plus	Gloss range 0 to 199.9 GU, 60°. Haze range from 0.1 to 30%. Testing according to DIN EN ISO 2813, ASTM D1003, and on-demand protocols.	Quality control in optical-grade materials and surface-treated products.

Optical Properties

Functionalities	Equipment	Technical specifications	Application examples
Refractometry	ATAGO Abbe Refractometer NAR-1T	Refractive Index Scale and the Brix measurements. Suitable for liquid and solid samples. Operates with D-line (589 nm) light source.	Formulation optimisation of polymer blends to achieve optimal light transmission properties.

Surface and micro/nano-structure analysis

Functionalities	Equipment	Technical specifications	Application examples
High-Capacity 3D X-Ray Computer Tomography	Bruker Skyscan 1273	40-130 kV, 39 W X-ray source. Object size up to 250 mm x 250 mm.	High Resolution imaging of the internal structure of solid materials, enabling the visualisation of microscopic features without damaging the sample.

Bruker Skyscan 1273
X-Ray CT system,
available at VTT

Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
Optical Profilometry	Cybertechnologies Vantage 50	0.01 µm resolution, measurement range up to 8 mm. 3D Line-scan capabilities with 1.1 mm width and 2 µm lateral resolution. 2D profiles and 3D topographical mapping.	Characterisation of surface topologies.
Contact Profilometry	Veeco Dektak 150	2D surface profile measurements. 55 mm Scan Length Range. Vertical range: 524 µm, with a max. resolution of 1 Å at 6.55µm range.	

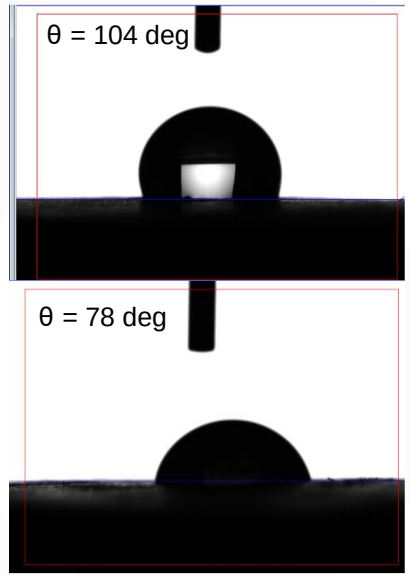
Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
Atomic Force Microscopy (AFM)	Park Systems NX20 Witec alpha500 RA	Measurement modes: non-contact mode (topography), Conductive AFM, Piezo Force Microscopy (PFM), and Nanoindentation. Up to 150 µm × 150 µm scan area. Scan height up to 200 nm.	Characterisation of surface topology and the examination of nano-scale physical properties. Understanding how nano-scale surface properties influence material performance, including adhesion, friction, and wear resistance.
Confocal Raman spectroscopy (RS)	Witec alpha300 R Witec alpha500 RA Nomadic Raman Microscope	Full Raman spectrum acquisition at every image pixel. 3D confocal Raman imaging. VIS-NIR excitations.	Chemical composition mapping and 3D structural analysis of composites (including polymorph distributions, crystallinity and orientation).

Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
Contact Angle Measurement (CA)	Krüss DSA100 Kruss DSA 100E	Up to A4 sample size. Range: 0-180°, resolution: up to 0.1°, accuracy: 1°. Advancing, receding, static, dynamic, tilting modes. Curve fitting to multiple models (Young Laplace equation, cycle, polynomial and Bashforth-Adams).	Characterisation of surface energy and hydrophilicity/hydrophobicity balance of materials. Effectiveness of surface treatments (e.g., corona or plasma).
White Light Interferometry (WLI)	Smart WLI Bruker ContourX-500	For flat samples with reflection > 3% Up to 100 mm × 100 mm size. Up to sub-nanometre height resolution.	Surface micro-nanostructure characterisation; surface roughness; defect characterisation; coating thickness determination.

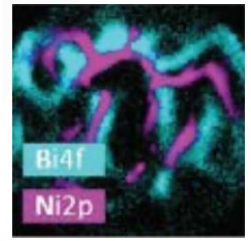
Surface hydrophobicity measurements. Acquired on a Kruss DSA 100E at INL



Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
X-Ray Photoelectron Spectroscopy (XPS)	Thermo Scientific Escalab 250 Xi	Measurements in samples up to 3 × 3 cm, Depth resolution up to 1-10 nm via depth profiling, and lateral resolution down to ~1 µm. Electron Analyser (0 – ±5000 eV). X-ray Sources (Monochromatic Al Kα and twin anode Mg Kα / Al Kα). Heating and Cooling of Specimen. UV Source. Flood Sources (Charge compensation and REELS). Monoatomic and Gas Cluster Ion Source for depth profiling “soft” (cluster mode) and solid (monoatomic mode) materials.	Quantitative elemental composition of materials and bonding state analysis. Composition mapping and detection of contaminants in thin films, surfaces, and coatings.

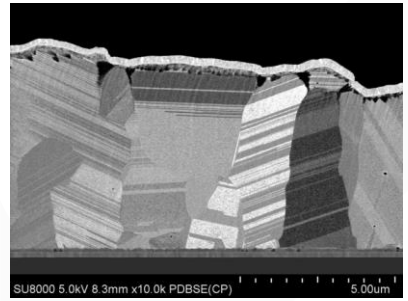
XPS mapping: Bi on Ni foam (Courtesy of O. Bondarchuk, INL) and Thermo Scientific Escalab 250 Xi, available at INL



Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
Glow Discharge Optical Emission Spectrometry	HORIBA Jobin Yvon GD-Profiler2	For substrates with flat surface (polymer films, silicon wafers, metals, glass). Chemical depth profiles from 10 nm to 100 µm with high depth resolution in a concentration range from 10 ppm to 100 %.	Qualitative and quantitative composition depth profiles of thin and thick films.
Scanning Electron Microscopy (SEM)	FEI Quanta 650 FEG Environmental SEM Hitachi SU-8000 JEOL JSM-7200FLV Neoscope JCM-5000 Jeol 6380 LV	Voltage: 1 – 30 kV. SEM Imaging (Resolution 1 nm). Low vacuum and Environmental SEM imaging for sensitive materials and non-coated samples. Cooling/Heating stage (in-situ): –20 ºC – 1500 ºC. SE/BSE detectors (Topographical/Structural analysis). EDXS (Chemical analysis).	Ultra-high resolution surface imaging for morphological/topographical characterization, failure analysis and or contamination detection

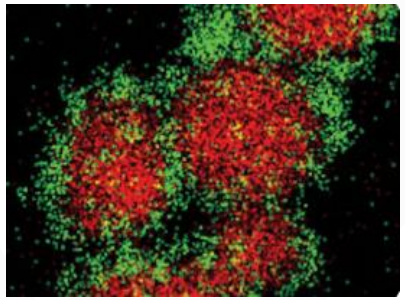
Ion polished cross section of a CdTe solar cell, performed at FHG-FEP



Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
Transmission Electron Microscopy (TEM)	Probe-Corrected FEI Titan G2 80-200 kV ChemiSTEM Double-Corrected FEI Titan G3 Cubed Themis 60-300 kV JEOL JEM 2100 LaB_6 80-200 kV	Corrected TEM and STEM Imaging (Resolution 63 pm). Diffraction (Crystallographic analysis). EDX – Super X (Chemical analysis). Dual EELS (Energy resolution 190 meV). Electron Holography. Lorentz microscopy. In-situ sample holder (heating/biasing). Differential Phase contrast (DPC) imaging. TEM/STEM Tomography (3D Reconstruction).	Internal structure of thin films including chemical and crystallographic information . Size, morphology, and distribution of nanomaterials within films and resin coatings. Determination of metallised layer thickness in coated films.

STEM-EDX mapping of Fe3O4@Au nanoparticles (courtesy of E. Carbo-Argibay). Acquired on a Double-Corrected FEI Titan G3 Cubed Themis at INL



Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
Cryo-Transmission Electron Microscope (Cryo-TEM)	Thermo Scientific™ Glacios™ Cryo-TEM	High-brightness X-FEG electron gun. 200 kV accelerating voltage. Cryo-Autoloader for up to 12 AutoGrids. ±70° alpha tilt. Falcon 4i high resolution camera. CETA-D 16M CMOS camera. Low Dose software (suited for minimised electron dose during cryo-TEM operation in single particle acquisition, tomography and micro-ED experiments).	Single-particle analysis: protein complexes. Micro-electron diffraction: nanocrystals of chemical compounds, proteins. Tomography: bacteria, thin cells, sections.

Glacios Cryo-TEM facility at INL

Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
Optical (R2R) Surface Inspection	ISRA-VISION Camera Optical Inspection	Inline optical inspection for rolls of flexible substrates. Defect size detection limit > 40 µm at 1 m/min over a width of 300 mm.	Quality control of film surfaces in roll-to-roll processes.
Optical Microscopy	Nikon LV150 Leitz Diaplan OGP Smartscope Zeiss SteREO Discovery V8	High-resolution lenses. Fluorescence microscopy mode. Coupling with DSC for polymer identification. Thin layer microtome for cross-section imaging.	Advance surface characterisation and quality control of materials, films and coatings.

Surface and micro/nano-structure properties

Functionalities	Equipment	Technical specifications	Application examples
Specific Surface Area and Pore Size Analysis	Quantachrome BET Nova 1200	Specific surface area and pore size distribution of materials by gas adsorption using the BET theory.	Surface area and porosity of materials at the nano and micro scales. For instance, in the development and optimization of catalysts.

Mechanical properties, integrity, and durability

Functionalities	Equipment	Technical specifications	Application examples
Abrasion Resistance	Custom-made devices	Testing up to 100 mm × 100 mm; spot for sand trickling with diameter of ≤ 10 mm. Pencil hardness test: 6B to 6H; Abrading wheels CS10F; 500 gf; 1000 revolutions; measurement of haze. Possible to test according ASTM D3363, DIN ISO 3537:2018-02, ISO 9352-2018, and on-demand protocols.	Assessing the wear resistance of materials and coatings.
Frictional Stress	Tensomat	For threads and thread guide elements. Min length of 40 cm and max diameter of 0.1 cm Measurements at 20 °C and 55–65% RH	Evaluation of a material's capacity to resist wear from friction and mechanical action when contacting another material.

Mechanical properties, integrity, and durability

Functionalities	Equipment	Technical specifications	Application examples
Tensile Properties	Universal tensile testing machine with video recording (Zwick Z005) Self-made equipment with Zeiss microscope and AXIO-Vision camera set up and heating module	Typical sample size of 150 mm × 40 mm. Determination of elastic modulus, breaking force, elongation at break. Determination of elastic modulus up to 150 °C. Testing according DIN EN ISO 1924, DIN EN ISO 527, and on-demand protocols.	Evaluation of the mechanical properties of materials, such as textiles or films produced from biopolymers or recycled plastic materials, including assessment of cracks formation under tensile stress.
Gelbo Flex Testing	BRUGGER / KFT	For all types of flexible materials. DIN A4 sample size. Suitable for testing according to the ASTM F392-74 standard.	Simulating a creasing strain to films to determine their flexible durability.
Adhesion Strength	Peel tester Sebastian V Zwick Z005	Sample size up to 1 A4 sheet. Testing according IPC-TM-650, DIN 55543-5, and the standard EAA peel test of the Fraunhofer IVV/EMA (European Metallizers Association). Max force 3.5 N/15 mm.	Measurement of peel or adhesion strength between layers of materials, including adhesives, tapes, laminates, and coatings.

BRUGGER KFT
Gelbo Flex Testing,
available at FHG-IVV

Mechanical properties, integrity, and durability

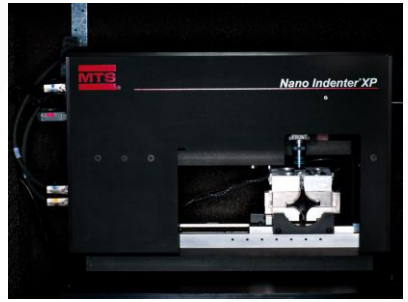
Functionalities	Equipment	Technical specifications	Application examples
Bending Testing	Self-made bending / rolling tester Flexomat	For flexible substrates (e.g., films, textiles). Bending and rolling testing with inline electrical measurements for samples up to 400 mm × 200 mm. Cyclic bending, torsion, friction, stretch stress for samples up to 350 x 350 mm. 20 °C and 55–65% RH.	Bending Strain and Bending Fatigue of flexible materials incorporating electrodes.
Shear testing	Shear tester	For flexible substrates (e.g., films, textiles). Sample size up to 50 x 50 mm. 20 °C and 55–65% RH.	Assess ability of materials to resist shear forces, handling simultaneous linear and rotational stress without significant deformation.
Buckling testing	Buckling tester	For flexible substrates (e.g., films, textiles). Sample size up to 350 x 200 mm. 20 °C and 55–65% RH.	Evaluate compression resistance and structural integrity of materials, ensuring they withstand loads without critical deformation or failure.

Bending / rolling testing at FHG-FEP

Mechanical properties, integrity, and durability

Functionalities	Equipment	Technical specifications	Application examples
Nanoindentation	MTS Nano Indenter XP	Suitable for polymers, glass, metals, semiconductors, or ceramics. Sample size up to 20 mm × 20 mm. Constant strain rate; continuous stiffness measurement allows determination of hardness and Young's modulus as a function of indentation depth; Oliver Pharr method is used for evaluation.	Characterisation of thin films and coatings. For instance, in scratch testing of coatings to evaluate the adhesion to substrate.

Nanoindentation
on an MTS Nano Indenter XP
at FHG-FEP



Mechanical properties, integrity, and durability

Functionalities	Equipment	Technical specifications	Application examples
Accelerated Weathering	Espec ML-811 Heating Chamber Espec LHU-113 Weather Chamber QUV Accelerated Weathering Tester	Allow alternating cycles of UV light and moisture at controlled, elevated temperatures. Fluorescent UV lamps in the UVA, UVB, and UVC portions of the spectrum for simulating the effect of natural sunlight and artificial irradiance. Suitable for testing according to ASTM G154, ASTM D4587, ASTM D5894, EN 927-6, ISO 4892-3, ISO 11507, ISO 16474-3, ISO 12944-6, SAE J2020, J15 K 5600-7-8, AATCC TM186.	Simulate outdoor weathering of materials.

QUV Accelerated Weathering Tester,
available at INL