

Catalogue of physicochemical and functional characterization services

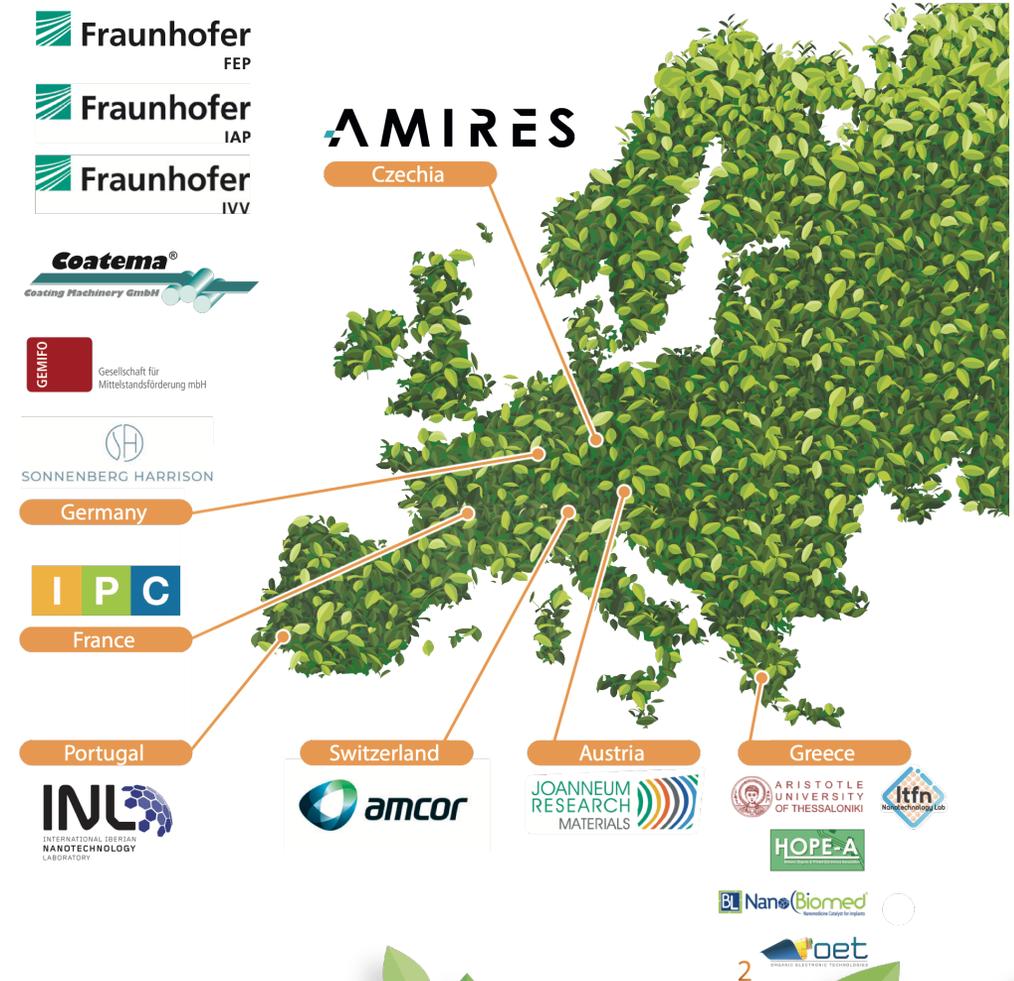


This project has received funding from the European Union's Horizon 2020 research and innovation programme under [grant agreement n°862156](#)

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Service Providers in FlexFunction2Sustain



Use Cases of the FlexFunction2Sustain project

FlexFunction2Sustain’s technical facilities and the performances of novel nano-functionalised surfaces will be demonstrated and validated by Europe’s leading companies within six industrial application scenarios. Application examples for the services related to the Use Cases are labelled with a code specific for each one (UC#)

Industrial Validation in 6 Use Cases

UC1



Biobased
Optical Films
for Labelling of
Consumer Goods
and Surface
Design

UC2



Marine
degradable
shampoo sachets

UC3



Selective and
switchable
water filter
membranes

UC4



Multifunctional
scratch resistant
surfaces in
automotive

UC5



Recyclable
mono-polymer
drink pouches

UC6



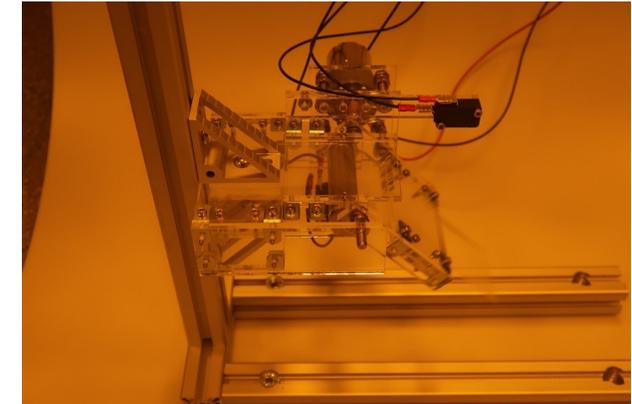
Sustainable
paper-based
food packaging

A full description of the six Use Cases can be found in the FlexFunction2Sustain Project Handbook, available at <https://flexfunction2sustain.eu>

Services from Upgraded Facilities: methodologies beyond the state of the art

Mechanical testing with inline WVTR characterization

- Coupling of optical calcium test for WVTR with mechanical bending test in device geometry
- Sensitivity down to 10^{-6} g/m²/d



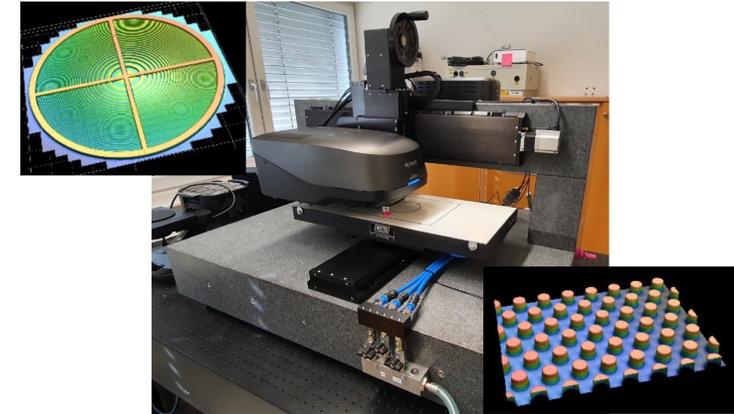
Combined gas barrier and mechanical testing

| Functionalities | Equipment | Technical specifications | Application examples |
|---|---------------|--|---|
| Flexural Testing with inline Water Vapor Transmission Rate via Optical Calcium test for ultra high barrier flexible materials | Own-developed | <p>Sample sizes: 50 mm × 150 mm</p> <p>Sensitivity down to 10^{-6} g/m²/d</p> <p>Testing according to on-demand protocols upon request</p> | <p>Mechanical testing with inline water vapour permeation measurement of flexible displays (UC4)</p> <p>Mechanical testing of active OLED devices (UC4)</p> |

Services from Upgraded Facilities: methodologies beyond the state of the art

Large area 3D Confocal Laser Scanning Microscopy

- Surface profiling, defect density characterisation
- Sample processing up to 300 x 600 mm²



Surface and microstructure analysis

| Functionalities | Equipment | Technical specifications | Application examples |
|--|---|---|--|
| Large-Area Laser Scanning 3D Confocal Microscopy | Keyence VK-X1050 + Custom-made platform for large area measurements | Up to 300 × 600 mm scanning area X,Y-resolution: 200 nm Z-resolution: 10 nm | Depth profiling and defect density characterisation in masters for nano/micro patterning and quality control of nano-imprinted films (UC1) |

Catalogue of physicochemical and functional characterisation services

Gas barrier testing

Gas barrier testing

| Functionalities | Equipment | Technical specifications | Application examples |
|-------------------------------------|--|--|---|
| Water Vapor Transmission Rate, WVTR | <p>Optical Calcium testing</p> <p>Elcometer 5100 Payne Permeability Cups</p> <p>Sempa HiBarSens 2.0 HAT</p> <p>Brugger WDDG</p> <p>MOCON Aquatran™</p> | <p>Samples Sizes: from 3 × 3 cm to 20 × 20 cm</p> <p>Possible to test according to ASTM E96/E96M - 10, ISO 15106-3, DIN 53 122-1, NIST standards, and on-demand protocols upon request</p> <p>Sensitivity down to 10⁻⁶ g/m²/d</p> <p>Possible to test under controlled RH and temperature: 23 °C / 50 % RH, 38 °C / 90 % RH, 60 °C / 90 % RH, 85 °C / 85 % RH, and on-demand conditions upon request</p> | <p>Determine the water vapour transmission rate of flexible, fully recyclable, monomaterial laminates for drink pouches (UC5).</p> <p>Determine the water vapour transmission rate of paper-based packaging for moisture-sensitive food products (UC6) and shampoo sachets (UC2).</p> <p>Determine the water vapour transmission rates of barrier films for flexible electronics applications (UC4)</p> |

Catalogue of physicochemical and functional characterisation services

Gas barrier testing

Gas barrier testing

| Functionalities | Equipment | Technical specifications | Application examples |
|-------------------------------|---|---|--|
| Oxygen Transmission Rate, OTR | <p>MOCON OX-TRAN</p> <p>MOCON OX-TRAN 2/20</p> <p>MOCON OX-TRAN 2/21</p> <p>Own-developed equipment</p> | <p>Samples Sizes: from 3 × 3 cm to 20 × 20 cm</p> <p>Possible to test according to ASTM D-3985, ASTM F-1927, DIN 53380-3, JIS K-7126, ISO CD 15105-2, and on-demand conditions</p> <p>Sensitivity down to 5 × 10⁻³ cm³/m²/d/bar</p> <p>Possible to test under controlled RH and temperature: 23 °C / 50 % RH, 38 °C / 90 % RH, 60 °C / 90 % RH, 85 °C / 85 % RH, and on-demand conditions upon request</p> | <p>Determine the oxygen transmission rate of flexible, fully recyclable, mono-material laminates for drink pouches (UC5).</p> <p>Determine the oxygen transmission rate of paper-based packaging for oxygen-sensitive food products (UC6).</p> |

Catalogue of physicochemical and functional characterisation services

Electrochemical properties

Electrochemical properties

| Functionalities | Equipment | Technical specifications | Application examples |
|------------------------|--------------------|--|---|
| Cyclic Voltammetry | Autolab PGSTAT302N | <p>Samples from 5 to 15 μL of active ink or 1 \times 2 cm to 1.5 \times 3 cm of polymer substrate with deposited active material</p> <p>Redox potential onsets (ranges: -2,5 to 0,5 V)</p> <p>Possibility to test according to EN61326-1 (1997) + A1 (1998) + A2 (2001) + A3 (2003), EN61000-3-2 (2006), EN61000-3-3 (1995) + A1 (2001) + A3 (2003)</p> | <p>HOMO-LUMO determination</p> <p>Biosensor's quality testing</p> |
| Squarewave Voltammetry | Autolab PGSTAT302N | <p>Δ-current from forward and backward pulse (Range 1 nA – 1 mA)</p> <p>Measurements up to 10 mA</p> <p>Possibility to test according to EN61326-1 (1997) + A1 (1998) + A2 (2001) + A3 (2003), EN61000-3-2 (2006), EN61000-3-3 (1995) + A1 (2001) + A3 (2003)</p> | <p>HOMO-LUMO determination</p> <p>Biosensor's quality testing</p> |

Catalogue of physicochemical and functional characterisation services

Electrochemical properties

Electrochemical properties

| Functionalities | Equipment | Technical specifications | Application examples |
|--|---|--|---|
| Electrochemical Impedance Spectroscopy | Autolab PGSTAT302N | <p>Working electrode diameter 4 mm -10 mm</p> <p>Resistance measurement 0.1 - 10 kΩ in PBS solution</p> <p>Possibility to test according to EN61326-1 (1997) + A1 (1998) + A2 (2001) + A3 (2003), EN61000-3-2 (2006), EN61000-3-3 (1995) + A1 (2001) + A3 (2003)</p> | <p>HOMO-LUMO determination</p> <p>Biosensor's quality testing</p> |
| Sheet resistance | <p>Custom-developed equipment</p> <p>Jandel 4-point probe stand</p> | <p>Adaptable sample sizes and testing protocol</p> <p>Measurement range 0.1 Ω/square - 100 kΩ/square</p> | Applications in use cases |

Catalogue of physicochemical and functional characterisation services

Mechanical properties, integrity, and durability

Mechanical properties, integrity, and durability

| Functionalities | Equipment | Technical specifications | Application examples |
|---------------------|--|--|---|
| Abrasion resistance | CrockMaster Custom-made devices | Possible to test according ASTM D3363, DIN ISO 3537:2018-02, ISO 9352-2018, and on-demand protocols Testing up to 100 mm × 100 mm; spot for sand trickling: diameter of ≤ 10 mm Pencil hardness test: 6B to 6H; Abrading wheels CS10F; 500 gf; 1000 revolutions; measurement of haze | Coating resistance to mechanical damage by rubbing, scraping, etc (UC4) |
| Adhesion strength | Peel tester Sebastian V Universal tensile testing machine with video recording (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 | Determination of adhesion strength in packaging films (UC2, 5, 6) |

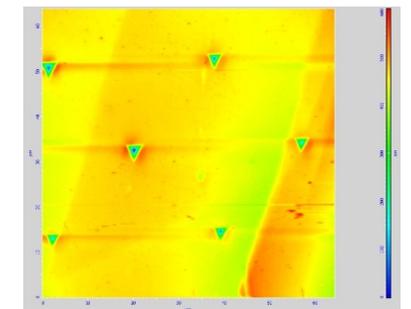
Catalogue of physicochemical and functional characterisation services

Mechanical properties, integrity, and durability

Mechanical properties, integrity, and durability

| Functionalities | Equipment | Technical specifications | Application examples |
|--|------------------------------------|--|---|
| Bending / rolling testing | Self-made equipment | Testing surface up to 400 mm × 200 mm On-demand protocols Bending and rolling testing with inline electrical measurements | Bending Strain and Bending Fatigue of flexible films incorporating metal electrodes |
| Multi-axial mechanical failure testing (shear, flexion, traction, Charpy, Izod, dynamic) | 4 Dynamometers (Zwick and Instron) | Load cells ranging from 200N up to 250kN, Climatic chambers (-70 °C up to 250 °C), and extensometers. Multiple test fixtures for shear, bending, tensile, drop, compression... | Determination of elastic modulus, breaking force, elongation at break of plastic samples |
| Nanoindentation | Nano Indenter XP | Testing up to up to 50 mm × 50 mm 100 mN maximum applied load, 20 µN lower normal applied load Testing according DIN EN ISO 14577 and on-demand protocols | Testing of thin films (metallic and polymeric) and protective (barrier) coatings. Calculation of hardness and Young's modulus. Scratch test: coatings cohesion adhesion to substrate, friction coefficient measurement |

Atomic Force Microscopy image of nanoindentation imprints (triangles in the image) acquired at AUTH with a Berkovich-type diamond indenter on top of an aluminum coated membrane. The maximum penetration depth of the indenter was 500 nm.



Catalogue of physicochemical and functional characterisation services

Mechanical properties, integrity, and durability

Mechanical properties, integrity, and durability

| Functionalities | Equipment | Technical specifications | Application examples |
|--------------------|--|---|--|
| Tensile Properties | <p>Instron 3342</p> <p>Universal tensile testing machine with video recording (Zwick Z005)</p> <p>Self-made equipment with Zeiss microscope and AXIO-Vision camera set up and heating module</p> | <p>Testing according DIN EN ISO 1924, DIN EN ISO 527, and on-demand protocols</p> <p>Typical sample sizes: 10 mm × 60 mm / 150 mm × 40 mm</p> <p><5 kN load capacity (0.5 % load accuracy);</p> <p>Determination of elastic modulus up to 150 °C</p> | <p>Determination of elastic modulus, breaking force, elongation at break of films and paper (UC1, 2, 5, 6)</p> |

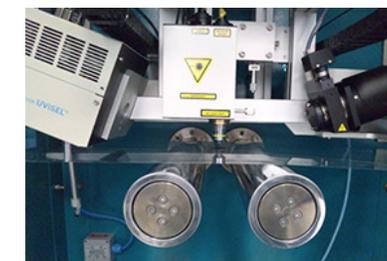
Catalogue of physicochemical and functional characterisation services

Optical properties

Optical properties

| Functionalities | Equipment | Technical specifications | Application examples |
|--|--|--|--|
| Spectroscopic ellipsometry (thin film thickness; refractive index, dispersion) | HORIBA: UVISEL-VASE | <p>Samples Sizes up to 10 × 10 cm</p> <p>Spectral Range: 250 -1100 nm</p> <p>Possibility of in-line measurements in R2R pilot line</p> <p>Variable angle, 0.6-6.5 eV, real-time measurements</p> | Determination of thin film thickness and optical constants for optical-grade functional coatings (UC4) |
| Gloss, colorimetry, and Haze characterisation | <p>Erichsen Picogloss master 500</p> <p>BYK Haze-gard plus</p> <p>Spectro-guide sphere gloss BYK Gardner</p> | <p>Gloss range 0 to 199.9 GU, 60°</p> <p>Haze range from 0.1 to 30 %</p> <p>Testing according to DIN EN ISO 2813, ASTM D1003, and on-demand protocols</p> <p>Colorimetry : CIELab and CIELCH;</p> <p>Spectro colorimetry with spectral range : 400 - 700</p> | <p>Quality control in surface treated optical-grade display covers (UC4)</p> <p>Plastic films and samples quality control (UC3), surface aesthetics characterisation</p> |

In-line optical metrology tools (UV-Vis Spectroscopic Ellipsometer, Raman Spectrometer) on the AUTH R2R pilot line for real-time optical characterisation of nanomaterials printed on flexible polymeric membranes for printed electronics applications.



Catalogue of physicochemical and functional characterisation services

Optical properties

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| Functionalities | Equipment | Technical specifications | Application examples |
|---------------------|--|--|--|
| UV VIS Spectroscopy | <p>PerkinElmer Lambda900</p> <p>PerkinElmer LS50B</p> <p>HEIOSa Scan Intelliscan</p> | <p>Samples Sizes: up to A4 size</p> <p>Possible to test according to DIN 10 050 Part 9 and on-demand conditions</p> <p>Optical characterisation within the UV-VIS-NIR range (220 nm - 2500 nm; 175 nm - 3300 nm in transmission mode)</p> <p>Measurements in transmission, reflection, and diffusion mode.</p> <p>Angle-dependent measurements inside integrated sphere. VN-accessory for measurement of absolute reflectance</p> <p>Optical density of band-stop filters to the limit of OD6</p> <p>Emission and excitation spectra of materials within a spectral range of 200 to 850 nm</p> | <p>Determination of UV-VIS barrier for light-sensitive food products (UC5, UC6)</p> <p>Optical characterisation and quality control in optical-grade films and coatings (UC1, UC4)</p> |

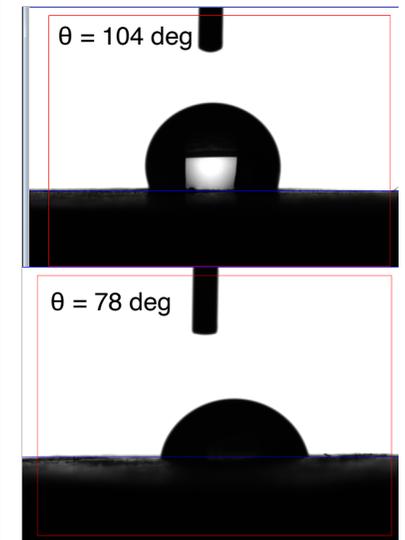
Catalogue of physicochemical and functional characterisation services

Surface and microstructure analysis

Surface and microstructure analysis

| Functionalities | Equipment | Technical specifications | Application examples |
|--------------------------------|--|---|---|
| Atomic Force Microscopy (AFM) | Bruker Dimension 3000 Park Systems NX20 Nanosurf Easy Scan 2 NT-MDT NTEGRA SPM Platform | Measurement modes: non-contact mode (topography), Conductive AFM, Piezo Force Microscopy (PFM), and Nanoindentation up to $100\ \mu\text{m} \times 100\ \mu\text{m}$ scan area Scan height up to 200 nm | Surface topology characterisation, and surface physical properties at the nano-range |
| Contact Angle Measurement (CA) | Krüss DSA100 Krüss DSA 100E KVS Cam 200 GBX photo goniometer | Up to A4 sheet size Range: $0\text{-}180^\circ$, 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) | Surface energy determination and hydrophilicity/hydrophobicity characterization of packaging materials Effectiveness of corona /plasma treatment (ability of surfaces to hold a coating) |

Contact angle measurements for surface wettability characterization. Acquired on a Krüss DSA 100E at INL



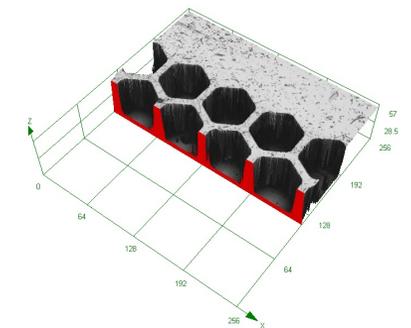
Catalogue of physicochemical and functional characterisation services

Surface and microstructure analysis

Surface and microstructure analysis

| Functionalities | Equipment | Technical specifications | Application examples |
|---------------------------|--|---|---|
| Confocal laser microscopy | OLYMPUS LEXT 3D Measuring laser microscope OLS4000 | Motorized table 100 mm × 100 mm Magnification ranges from 108× - 17,280× 3D measurement - Mapping - Non-contact roughness | Plastic films surface characterisation, quality control |
| Contact roughness | MAHR PERTHEN Perthometer S4P | Probing length = 17.5 mm max Ra - Rz - Rmax - R3z - Pt - Wt and more | Plastic films surface characterisation, quality control |

3D mapping of the microstructure of 8 µm filters with confocal microscopy at IPC



Catalogue of physicochemical and functional characterisation services

Surface and microstructure analysis

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| Functionalities | Equipment | Technical specifications | Application examples |
|--|---|--|--|
| Fourier Transform Infrared Spectroscopy (FTIR) | Bruker VERTEX 80v vacuum FTIR spectrometer Tensor 27 ATR-FTIR spectrometer from Bruker Optics PerkinElmer Spectrum 2000 Nicolet iS10 FTIR Nicolet iN10 μ FTIR | PEAK resolution up to 0.06 cm^{-1} Spectral Range: $7900\text{ to }370\text{ cm}^{-1}$ Modes: transmittance, reflectance, ATR (attenuated total reflection) | Polymer fingerprinting and quality control of plastic and paper films (UC1, 2, 5, 6) |
| Large-Area Laser Scanning 3D Confocal Microscopy | Keyence VK-X1050 + Custom-made platform for large area measurements | Up to $300 \times 600\text{ mm}$ scanning area X, Y-resolution: 200 nm Z-resolution: 10 nm | Depth profiling and defect density characterisation in masters for nano/micro patterning and quality control of nano-imprinted films (UC1) |

Catalogue of physicochemical and functional characterisation services

Surface and microstructure analysis

Surface and microstructure analysis

| Functionalities | Equipment | Technical specifications | Application examples |
|----------------------------------|---|---|--|
| Optical (R2R) surface Inspection | ISRA-VISION Camera Optical Inspection | Inline optical inspection Defect size detection limit > 40 µm @ 1 m/min; on 300 mm width | Quality control, Surface optical inspection in roll-to-roll applications |
| Optical microscopy | KEYENCE Microscope VHX-7000 | Motorized table 100 mm × 100 mm High resolution lenses from 20× to 2,500× Polarizing filter | Optical characterisation and quality control of materials, films and coatings |
| Raman spectroscopy (RS) | Witec alpha300 R In-line Raman in R2R coating pilot line | Full Raman spectrum at every image pixel for static substrates In-line Raman analysis | Chemical composition mapping and layer analysis, structural analysis (including polymorph distributions, crystallinity and orientation), and structural integrity of barrier films (UC5) |

Optical microscopy image of an anti-counterfeiting pattern (height: 100 to 300 nm; size of structures: 250 to 2000 nm) obtained at IPC.



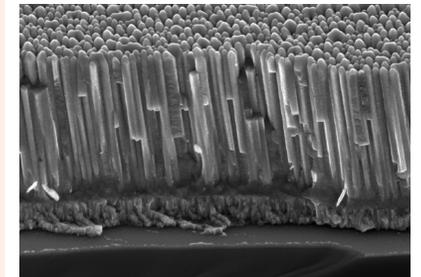
Catalogue of physicochemical and functional characterisation services

Surface and microstructure analysis

Surface and microstructure analysis

| Functionalities | Equipment | Technical specifications | Application examples |
|--|--|---|---|
| Scanning Electron Microscopy (SEM) and Environmental SEM | FEI Quanta 650 FEG Environmental SEM (including Peltier and Heating Stage) Hitachi SU-8000 JEOL JSM-IT-300LV JEOL Neoscope JCM-5000 | Voltage: 1 – 30 kV SEM Imaging (Resolution 1 nm) Low vacuum and Environmental SEM Imaging for sensitive materials and non-coated samples EDXS (Chemical analysis) Cooling/Heating stage (in-situ): –20 °C – 1500 °C SE/BSE detectors (Topographical/Structural analysis) | Ultra-high resolution surface imaging for morphological/topographical characterization, failure analysis and or contamination detection |

SEM image of a magnetron sputtered TiAlSiN thin film (courtesy of S. Calderón). Acquired on FEI Quanta 650 FEG at INL



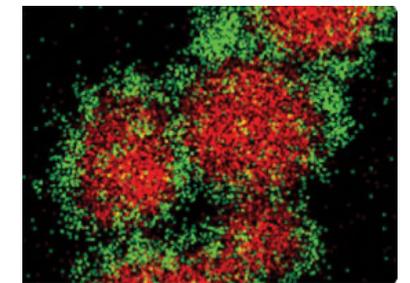
Catalogue of physicochemical and functional characterisation services

Surface and microstructure analysis

Surface and microstructure analysis

| Functionalities | Equipment | Technical specifications | Application examples |
|--|--|---|--|
| Transmission Electron Microscopy (TEM) | Probe-Corrected FEI Titan G2 80-200 kV ChemiSTEM | TEM point resolution ≤ 0.24 nm at 200 kV AC-STEM information limit ≤ 80 pm (200 kV) | Internal structure of thin films including chemical and crystallographic information |
| | Double-Corrected FEI Titan G3 Cubed Themis 60-300 kV | Super X energy resolution ≤ 136 eV – 140 eV | Size, morphology, and distribution of nanomaterials within films and resin coatings |
| | JEOL JEM 2100 80-200 kV | Alpha tilt: $\pm 70^\circ$ (Tomography holder) Corrected TEM and STEM Imaging (Resolution 63 pm) Diffraction (Crystallographic analysis) EDX – Super X (Chemical analysis) Electron Holography Differential Phase contrast (DPC) imaging | Determination of metallised layer thickness in coated films |

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



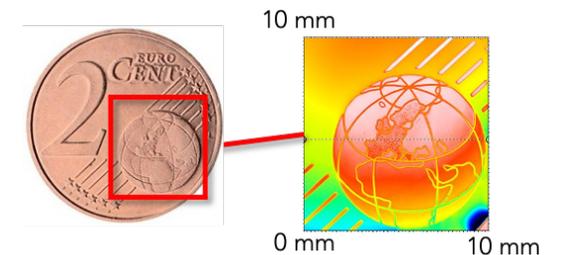
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Surface and microstructure analysis

Surface and microstructure analysis

| Functionalities | Equipment | Technical specifications | Application examples |
|----------------------------|-------------------|---|---|
| White Light Interferometry | Smart WLI | Up to 100 mm × 100 mm Sub nanometre height resolution | Surface characterisation, micro/nanostructure characterisation; surface roughness; defect characterisation; layer thickness determination |
| X-Ray Fluorescence (XRF) | SPECTRO XEPOS III | Element analyses from Na to U For flat and solid samples (powder and liquid samples on-demand) | Determination of and trace elements in materials |

False color image of the surface profile of a 2 Euro Cent coin acquired at FEP with the Smart WLI white-light interferometer



Catalogue of physicochemical and functional characterisation services

Surface and microstructure analysis

Surface and microstructure analysis

| Functionalities | Equipment | Technical specifications | Application examples |
|--|--|--|---|
| X-Ray Photoelectron Spectroscopy (XPS) | <p>Thermo Scientific Escalab 250 Xi</p> <p>Omicron + own construction (DAR 400 X-ray source, XM 500 quartz crystal monochromator)</p> <p>Axis 165 - Auger (SAM/AES) (Kratos)</p> | <p>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</p> <p>Electron Analyser (0 – ±5000 eV)</p> <p>X-ray Sources (Monochromatic Al Kα and twin anode Mg Kα / Al Kα)</p> <p>Heating and Cooling of Specimen</p> <p>UV Source</p> <p>Flood Sources (Charge compensation and REELS)</p> <p>Monoatomic and Gas Cluster Ion Source for depth profiling "soft" (cluster mode) and solid (monoatomic mode) materials</p> | <p>Bonding state analysis and quantitative elemental composition of materials</p> <p>Composition uniformity in thin films</p> <p>Analysis of residues in surfaces and coatings, surface contamination penetration</p> |

Catalogue of physicochemical and functional characterisation services

Thermal and rheological properties

Thermal and rheological properties

| Functionalities | Equipment | Technical specifications | Application examples |
|---|----------------------------|--|---|
| Differential scanning calorimetry (DSC) | TA Instrument Q100 and Q20 | -80 °C to 725 °C Inert atmosphere Typical heating rate = 10 or 20 °C/min | Thermal properties characterisation, identification of melting, cristallisation and glass transition temperatures |
| Thermal gravimetric analysis (TGA) | TA Instrument Q500 and Q50 | Ambient to 950 °C Inert or oxidizing atmosphere Typical heating rate = 20 °C/min | Thermal resistance assessment, decomposition, adsorption and desorption characterisation |
| Heat deflection temperature (HDT) | CEAST HDT-Vicat 3 posts | Max temperature : 300 °C Heating rate : 50 °C/h and 120 °C/h | Assessing the thermo-mechanical properties of a wide range of plastics materials and specimens |

Differential Scanning Calorimetry (DSC) measurement performed at IPC



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Thermal and rheological properties

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| Functionalities | Equipment | Technical specifications | Application examples |
|---|------------------------|--|---|
| Melt Flow Index (MFI) & Melt Volume Index (MVI) | Göttfert MI40 | Max temperature = 500 °C 1.2kg - 2.16 kg - 3.8 kg - 5.0 kg - 10.0 kg - 21.6 kg | Thermal properties characterisation, identification of melting, crystallisation and glass transition temperatures |
| Rheology | TA Instrument AR2000ex | Heating rate up to 20 °C/min Angular Velocity Range CS : 0 to 300 rad/s Normal/Axial Force Range : 0.005 to 50 N Peltier Plate up to 200 °C | Characterisation of low viscosity fluids, polymer melts, solids and reactive materials |

Parallel-plate rotational rheometry measurement performed at IPC



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Specimen preparation

Specimen preparation

| Functionalities | Equipment | Technical specifications | Application examples |
|----------------------------|---|--|--|
| Cross section polishing | Jeol SM-09010 | Up to 1 mm preparation width | Broad ion beam preparation of polished cross sections of multilayers |
| Microtome cross sectioning | RMC-Cryo-Ultramicrotome Modell PT-XL with Cryoequipment CxL | Recommended sample size: ~ 1-2 cm ² | Determination of adhesion strength in packaging films (UC2, 5, 6) |

Cross section of a three-layer thin film stack (gas barrier coating on plastic web by Fraunhofer POLO® alliance) prepared with the Jeol SM-09010 cross-section polisher and scanning electron microscopy

