CSM Instruments

/// The expert for Indentation, Scratch and Tribology testing
CSM Instruments is a spin-off of the Swiss Centre for Electronics and Micro Technology (CSEM). Our instruments were initially marketed under the name of CSEM Instruments until we became completely independent and established under the company name of CSM Instruments.

The Headquarters is based in Peseux, Switzerland, where all our instruments are Swiss made and rigorously tested to provide the highest quality. Our 30 years of experience and knowledge in manufacturing material characterization equipment has given the opportunity to our team of experts to design high quality measurement instruments for the global market.

We provide equipment that allows the mechanical characterization of a wide range of surfaces and bulk materials:

> Adhesion of paints, optical thin films or hard coatings can be measured using one of our Scratch Testers. These instruments span the nano to the macro range to test the widest range of materials.

> Dynamic Instrumented Indentation measurements can be performed to define not only the hardness of materials, but also plastic and elastic deformation, elastic modulus, creep and much more.

> CSM Instruments manufactures ball/pin-on-disc Tribometers operating in the micro and nano scales. These systems measure friction coefficient and quantifies wear resistance. Temperature, humidity and vacuum options extend their utility.

> The Calotest/Calowear line of instruments measure coating thickness and can also quantify wear rate.

> Finally, CSM Instruments offers optional 3-dimensional imaging systems. Atomic Force Microscope (AFM) provides images at the nanoscale and a Conscan chromatic optical pen provides topographical images and quantitative height data over areas of millimeter dimensions.

//// Our previous logos
CSM Instruments provides a variety of measurement options offered on multi-module platforms and also dedicated stand-alone instruments, thus assuring you of the most complete surface mechanical testing solution without compromise.

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### Applications

#### Hard Coatings

- TiN, TiC, DLC
- Cutting tools
- Forming tools
- Plasma spay coatings
- PVD and CVD Coatings

#### Semiconductor Technology

- Passivation Layers
- Metallization
- MEMS and NEMS
- Hard disk
- Low-K

#### Biomaterials

- Arterial implants (stents)
- Bone tissue
- Prosthetics
- Tablets and pills

#### Optical Components

- Eye glass lenses
- Optical coatings
- Contact lenses

#### Decorative

- Evaporated metal coatings
- Jewellery and watches

#### Automotive

- Paints and polymers
- Varnishes and finishes
- Engine valves, ejector pins
- Brake pads

#### Ceramics

- Tiles
- Concrete
- $K_{IC}$ of bulk materials

#### General Engineering

- Rubber
- Touch screens
- Lubricants and oil additives
- Sliding bearings
CSM Instruments Platform

CSM Instruments provides configuration flexibility to grow with all customer needs. Multiple testing and imaging modules are installed together on the same platform: “Compact Platform” or “Open Platform”. All the measurement and imaging modules are “synchronised” to each other, the optical microscope being included as a standard module on both platforms.

To address all your needs, you can configure your instrument as follows:

1) Choose required measurement modules

1. Ultra Nanoindentation module (UNHT)
2. Nanoindentation module (NHT)
3. Micro Indentation module (MHT)
4. Nano Scratch module (NST)
5. Micro Scratch module (MST)
6. Micro Combi module (MCT) (Micro Scratch and Micro Indentation)

2) Choose an optional 3D Imaging module

A. Wide Scan AFM
B. ConScan Confocal microscope

3) Choose your Platform:

A. Open Platform (OPX) for 4 modules maximum
B. Compact Platform (CPX) for 3 modules maximum
C. Table Top Platform (TTX) for 2 modules maximum

All OPX and CPX platforms include an optical video microscope, X, Y and Z automated tables, anti-vibration table, PC with 2 LCD screens and a sample holder.
Introduction of CSM Indentation Testers

CSM Instruments Indentation Testers are high precision instruments used for the determination of mechanical properties of thin films, coatings and substrates. Properties such as hardness and elastic modulus can be determined on almost any type of material: soft, hard, brittle or ductile. The operating principles of the instrument are as follows: an indenter tip, normal to the sample surface, is driven into the sample by applying an increasing load up to a preset value. The load is then gradually decreased until partial or complete relaxation of the material occurs.

Unique surface referencing

CSM Instruments Indentation Testers are the only commercially available instruments which use the top surface referencing technique. By performing a differential measurement between the sample surface and the indentation depth, the following unique advantages are obtained:

- High accuracy of depth measurement
- Rapid measurement cycle time
- Negligible thermal drift

The surface referencing design also eliminates common sources of measurement errors in order to provide:

- Negligible system frame compliance
- High sample mounting stability

Sinus mode analysis (DMA)

The Dynamic Mechanical Analysis (DMA) uses sine wave loading curves to obtain a complete analysis of the mechanical properties of viscoelastic materials. The method allows for a continuous acquisition of hardness, elastic modulus, storage and loss modulus data as a function of indentation depth. The sinus mode is available on our Nanoindentation and Ultra Nanoindentation Testers only.

CMC™ (Continuous Multi Cycle)

CSM Instruments has developed the CMC™ (Continuous Multi Cycle) method which allows Indentation Hardness, Elastic Modulus and Stiffness to be obtained as a function of depth.

AFM and Nanoindentation

Since the Video Microscope, Indenter tip and AFM are positionally calibrated to each other, the location of the indenter imprint under either the video microscope or the AFM is automated and virtually instantaneous.

MultiFocus Image

MultiFocus image produces a picture with a very large depth of field. While capturing the video, the automated Z-table moves up and down in order to take and combine different levels of focussed images into one image in sharp focus at all depths.
The Ultra Nanoindentation tester is uniquely configured as two indenter columns in parallel. One uses the indentation tip, the other has a large radius of curvature as a reference probe. Each has its own load cell. Both are connected together very near the sample surface with a differential capacitive sensor measuring the difference in the positions of the two tips. Thus, the indentation tip is always referenced to a position on the sample surface.

### Features

- **Active top referencing (Patented Design EP 1828744 and US 7,685,868,B2)**
  The reference is removable and can be of different shapes (ball, pin, etc). The reference has its own piezo actuator and load sensor. It applies a very small feedback loop control load on the sample.
- **Unique materials design with no thermal expansion**
  The head is constructed out of ZeroDur® glass and the electronics system has a raw drift rate of < 1 ppm/°C
- **Highest possible frame stiffness: infinite frame stiffness (>> 10⁸ N/m)**
  By use of a synthetic granite frame, ZeroDur and the patented active top referencing system, frame compliance is kept at an absolute minimum.
- **Two independent depth and load sensors**
  Ultra high resolution capacitive sensors for True Depth and Load Control modes.
- **Ultra high resolution and very low noise floor**
  Depth resolution: 0.0015 nm, noise floor < 0.03 nm
  Force resolution: 0.005 μN, noise floor < 0.1 μN
- **Large range of indentation depth; up to maximum 100 μm**

### Options

- Heating and cooling stages
- Atomic Force Microscope (AFM)
- High resolution tables
- High resolution camera
- Protective acoustic enclosure
- Liquid cell
- Vacuum or environmental enclosure
- Electric contact resistance

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**UNHT module with video microscope and multi-sample holder**
Nanoindentation Tester (up to 500 mN)
The most versatile Nanoindenter

The Nanoindentation Tester is designed to provide low loads with depth measurements in the nanometer scale. The system can be used to characterize organic, inorganic, hard and soft materials.

Features
- Top referencing of the sample surface
- Automated video microscope for inspection both pre- and post-test
- Feedback control of normal force
- Lowest Nanoindenter frame compliance (0.02 μm/N)
- Design with MACOR low thermal expansion coefficient materials
- Fully compatible with liquid testing

Options
- Vacuum or environmental control
- Atomic Force Microscope (AFM)
- High resolution camera
- High resolution tables for high repositioning

Micro Indentation Tester (up to 30 N)
The largest range of Instrumented Indentation Testing

The Micro Indentation Tester is ideally suited to the measurement of thin hard coatings, thick soft coatings and bulk materials. It provides accurate and reproducible values for hardness and elastic modulus determination of materials. Our Micro Indentation Tester can be used for bulk materials and coatings such as PVD and CVD hard coatings and ceramic surface layers.

Features
- Unique top referencing method
- Positioning synchronization
- Feedback control of normal force
- Easy testing with the mapping mode
- Large range of forces

Options
- Upgrade for Micro Combi Tester (MCT) Micro Indentation and Micro Scratch Testers
- Temperature controlled stage
- ConScan objective
- High resolution camera
- Vacuum or Environmental control
/// Indentation Software

Full software package for data acquisition and analysis including:

/// Measurement modes
> Complete control of indentation parameters: load and depth control
> Real time display of force and depth data during acquisition
> Sinus mode (with UNHT and NHT only)
> Full user access rights management
> Automated indenter tip calibration
> Automated positioning between indentation and imaging analysis
> Full integration of AFM and Video imaging into the control software
> MultiFocus Imaging
> Constant strain rate measurements controlled in depth (dh/h=c)
> Multi language support

/// Data analysis
> Powerful, fully integrated statistics module (data and graphics tools)
> Automated measurement report generator
> Multi language support
> Data export in ASCII format
> Graphical overlay of the fitted curve and calculated parameters

/// Mechanical properties results
> Automatic calculation of Hardness (H<sub>n</sub>), Elastic Modulus (E<sub>n</sub>),
recalculated Vickers (H<sub>v</sub>), Creep (C<sub>n</sub>), Relaxation (R<sub>n</sub>), Stiffness (S)
> Display of all nanoindentation data results : hm, hc, ...
> Display of Hardness, Elastic Modulus or Martens vs. penetration depth
> Multiple models for hardness and elastic modulus evaluation
> Standard evaluation according to ISO 14577 and ASTM E2546

/// Possible additional analysis for specific material properties
> Analysis of fracture toughness, creep and stress-strain behavior
> Analysis of plastic-elastic energy work
> Storage Modulus and Loss Modulus calculation for viscoelastic materials
(with Sinus mode option only)
> Always included: Material deformation modeling software

/// Accessories and Consumables
> Various indenter geometries
> Vacuum, humidity and temperature controlled options
> Application kits (biomaterials, polymers, bones, ...)
Features of the Scratch Testers

- Proven method to quantify adhesion of coatings
- Acoustic emission, friction, penetration depth and optical observation
- Feedback control of normal force
- Patented panorama image
- Multi Focus image and panorama
- Characterization of large (300 mm) samples
- Wear testing in multipass mode
- Automated video microscope inspection
- Automated, unattended multi sample testing
- ISO and ASTM compliant

Introduction to the Scratch Testers

CSM Instruments Scratch Testers are ideal instruments for characterizing the surface mechanical properties of thin films and coatings, e.g. adhesion, fracture and deformation. These instruments can be used for all kinds of industrial coatings from the plasma processed layers used in semiconductor and optical technology to the decorative and protective coatings used for consumer goods and automobile parts.

The ability of the scratch tester to characterize the film - substrate system and to quantify parameters such as friction force and adhesive strength, using a variety of complementary methods, makes it an invaluable tool for research, development and quality control.

The technique involves generating a controlled scratch with a diamond tip on the sample under test. The tip is drawn across the coated surface under constant, incremental or progressive load. At a certain load the coating will start to fail. Critical loads are very precisely detected by means of the frictional coefficient, the penetration depth, and the acoustic emission sensors together with observations from a built-in optical microscope.

The critical load data is used to quantify the adhesive properties of different film - substrate combinations by using different sensors (acoustic emission, penetration depth, friction force) and video microscope observations.

Active Force Feedback Loop Control

Force feedback is now available on many instruments but the unique design of the CSM Instruments control unit allows an active force feedback which is electronically controlled (and not corrected by the software). The unique design of the Nano Scratch measurement head includes force and depth sensors associated with a state-of-the-art piezoelectric sensor. These unique features provide fast response time (down to 5 ms), greater accuracy and greater flexibility for all types of Scratch measurement.

Video Microscope & dual screen PC

Scratch Testers are delivered with an integrated video microscope. Standard available objectives are x5, x20, x50 or x100 leading to a total magnification ranging from x200 to x4000. A camera with a resolution of 1280 x 1024 is included with all Scratch testers for a very high sensitivity. In addition, a LCD dual screen PC is delivered enabling a simultaneous and synchronised view of the scratch data and images.

Patented Synchronized Panorama

Panorama mode digitally stitches together multiple images along the length of the Scratch to generate a panoramic view of the entire scratch. This view is perfectly synchronized with the data below it. As you scroll laterally through the data, a cursor tracks the position, friction, load and penetration in the scratch track.
Nano Scratch Tester (0 - 1000 mN)
The highest accuracy Nano Scratch Tester on the market

The Nano Scratch Tester is particularly suited for the characterization of the practical adhesion failure of thin films and coatings, with a typical thickness below 1000 nm. The Nano Scratch Tester can be used in the analysis of organic and inorganic coatings, as well as soft and hard coatings.

/// Features

> Patented double cantilever beam combined to piezoelectric actuator
> Active force feedback loop control
> High precision profiling
> Automated video microscope with patented synchronized multi-focus panorama
> Patented true penetration depth measurements for elastic recovery studies
> Scratch depth measurement with both pre and post scan corrections
> High quality optical imaging (optical video microscope turret with 4 positions)
> Accurate wear testing
> Compatible to ISO and ASTM standards

/// Options

> Nanoindentation, Micro Indentation or Micro Scratch measurement modules
> Vacuum, humidity or temperature controlled
> AFM and ConScan 3D imaging
> High resolution table for high repositioning
> Verification kit for load, friction force and penetration depth

Nano Scratch Tester module with video microscope
**Micro Scratch Tester (up to 30 N)**

The wide range tester for demanding users

The Micro Scratch Tester is widely used to characterize the practical adhesion failure of thin films and coatings, with a typical thickness below 5 μm. The Micro Scratch Tester is also used in the analysis of organic and inorganic soft and hard coatings.

### Features
- Diamond-stylus scratch method
- Automated video microscope with synchronized multi-focus panorama
- Active force feedback control
- Scratch depth measurement with pre and post scan corrections
- Numerous Scratch testing capabilities
- Acoustic emission sensor

### Options
- Swinging module for lateral oscillations while scratching
- High resolution video
- AFM or ConScan 3D imaging
- Wide range of indenter tips
- Indentation option
- Verification kit for load, friction force and penetration depth

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**Revetest® Macro Scratch Tester (up to 200 N)**

The industry reference

The REVETEST® Scratch Testing instrument is widely used for characterizing hard-coated materials, with a typical coating thickness exceeding 1 μm.

### Features
- Diamond-stylus scratch method
- Feedback controlled normal force
- Acoustic emission detection
- Video microscope with patented synchronized panorama mode
- Long term stability of calibration
- Conventional Hardness mode included
- Complies with ASTM C1624, ISO 20502 and ISO EN 1071

### Options
- Verification kit for load, friction force and penetration depth
- High resolution video camera
- Wide range of indenter tips
/// Scratch Software

Full software package for data acquisition and analysis including:

/// Measurement modes
> Unique patented synchronized panorama mode
> MultiFocus Image
> Real time display of force and depth data during acquisition
> Fully user definable scratch modes:
  single and multiple scratches; constant, incremental or progressive loads; user-defined load profiles, ...
> Large range of testing modes: scratch, wear, indentation
> Programmable system setting for every single scratch in a Multi Scratch experiment
> Fully customized user access rights management
> Automated positioning between the tip and imaging module
> Full integration of AFM and Video imaging into the same software
  (for NST and MST)
> Multi language support

/// Data analysis
> Critical loads, Lc, as a function of normal loads
> Powerful and fully integrated statistics module (data and graphics)
> Automatic measurement report generator with unlimited templates
> Logging of all operations executed on the instrument
> Data export in ASCII format. Open files with Excel or text editor
> Material deformation modeling software

/// Accessories and Consumables
> Various indenter geometries (knife, spherical, blade, ...
> Vacuum, humidity and temperature controlled options
> Verification kit for load, friction and penetration depth sensors
> ISO 20502 parts (all certified per ISO requirements)

Please contact us with your requirements
Features of CSM Instruments Tribometers

- High resolution obtained with unique frictionless force sensor design
- Easy and automated calibration procedures
- High-precision feedback controlled motor
- Linear and Rotating sample displacement
- Environmental configuration (heating and vacuum)
- Automatic switch off at friction coefficient threshold or total number of cycles
- Tests compliant to ASTM G99, G133 & DIN 50324
- Tests in liquids, controlled humidity or inert gases within plexiglas enclosure

Introduction to CSM Tribometers

In tribometry, a sphere, a pin or a flat section is loaded onto the test sample with a precisely known force. The probe is mounted on a stiff cantilever, designed as a frictionless force transducer. The friction coefficient is determined during the test by measuring the deflection of the elastic arm. Wear coefficients for the pin and disk materials are calculated from the volume of material lost during the test. This simple method facilitates the study of friction and wear behaviour of almost every solid material combination with or without lubricant. Furthermore, the control of the test parameters such as speed, frequency, contact pressure, time and environmental parameters (temperature, humidity and lubricant) allows simulation of the real life conditions of a practical wear situation.

Tribometers are unique instruments designed for high precision force measurement. They operate in both linear reciprocating and rotational modes. The tribometer is supplied with an enclosure so that controlled atmospheres of varying humidity or composition can be used. Specialized versions of the Tribometer have been developed for high and low temperature operation and testing in high vacuum conditions.

Reciprocating Tribometer (linear or angular)

The Linear Tribometer reproduces the reciprocating motion typical of many real world mechanisms. The instrument measures a friction coefficient for both the forward and backward displacement of the stroke and the software generates data on Hertzian pressure, static partner and sample wear rates. The reciprocating technique is also very useful for studying the variation over time of the static coefficient of friction - as opposed to the dynamic coefficient measured with the Pin-on-Disk configuration.

All rotative tribometers can use the optional “Multi Cycle Angular - Reciprocating mode” corresponding to an oscillating mode where both directions of friction are measured.

Vacuum Tribometers

All CSM Instruments Tribometers are available in a high vacuum configuration. These fully automated instruments allow tribological testing under high vacuum conditions. Turbomolecular pumping produces a vacuum down to 5 x 10^{-7} mbar.

Optional Compact Profilometer

The Compact Profilometer is a very user-friendly tool, dedicated to fast and easy profile measurements of the sample track section created by the tribological tests.
The CSM Instruments Nano Tribometer has been designed specifically to investigate the surface interactions at low contact pressures, especially where soft layers or lubricants are of interest. This instrument allows significant contact areas to be investigated, whilst maintaining a high accuracy and measurement of very low forces and displacements.

The Nano Tribometer is based on a stiff cantilever, which acts as a frictionless force transducer in both vertical and horizontal directions. The static partner (flat/pin/sphere) is loaded onto the test sample with a precisely known force using piezo-actuation. The friction coefficient is determined during the test by measuring the deflection of this elastic arm in both horizontal and vertical planes with two high precision displacement sensors. Through a feedback loop, the piezo-actuation maintains the normal load independent of any surface irregularities.

The Nano Tribometer combines the resolution of an Atomic Force Microscope (AFM) with the stability, robustness and ease-of-use of a pin-on-disk tribometer.

CSM Instruments is proud to announce the release of its new version which provides measurements of higher resolution and the following additional new features:

### Features

- Unique dual beam cantilever with normal load applied up to 1000 mN (resolution 5 nN)
- 2 independent high resolution capacitive sensors for normal load and friction force
- Rotative and/or linear reciprocating motion
- High resolution capacitive sensors combined with piezo actuator
- Low noise floor for microtribological measurements
- Rotative module with angular sensor
- Advanced linear module with displacement sensor
- Wide range of cantilevers available

### Options

- Adhesion measurements
- Optical video microscope or AFM
- X and Y motorized stage
- Temperature and relative humidity sensor
- Continuous wear depth measurement
- Dedicated sample holders
The control of friction and wear in moving machine parts is a critical issue facing the manufacturing industry. It is important to have comparable analysis data obtained over a period of time, at varying humidity and temperature with or without the presence of lubricants. CSM Instruments Tribometers have proven their reliability worldwide in over 1000 laboratories, for studying materials for research or quality control.

**Features**
- > 20 N of friction force
- > Motor speed up to 1500 rpm
- > Linear and rotative modules easily exchangeable
- > Automatic shut-off at selected track length or friction coefficient threshold
- > Testing conforms to DIN 50324, ASTM G99 and ASTM G133

**Options**
- > Electrical contact resistance (ECR)
- > Profilometer
- > Linear or angular reciprocating mode
- > Optical imaging
- > Tribo-corrosion kit
- > Vacuum setup
- > Online Wear Depth measurement
- > Heating and cooling stage

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**THT**

**High Temperature Tribometer (up to 1000°C)**

The analysis of friction and wear properties of materials at elevated temperatures is becoming increasingly important, especially for the development and quality control of combustion engines and power plants. To meet the resulting demand for instrumentation, CSM Instruments has extended its range of pin-on-disk Tribometers with a powerful high-temperature version which can accurately simulate in-service conditions.

**Features**
- > Differential friction sensors for perfect stability at all temperatures
- > Efficient heating/cooling system to accurately maintain desired temperature
- > Angular sensor for reciprocating multicycles
- > Automatic shut-off at selected track length or friction coefficient threshold
- > Room temperature measurement
- > Testing conforms to DIN 50324, ASTM G99 and ASTM G133.

**Options**
- > Electrical contact resistance (ECR)
- > Continuous wear depth measurement
- > Vacuum setup
/// TriboX Software

Full software package for data acquisition and analysis including:

//// Measurement modes
> Continuous real time data acquisition of friction (Ft) signal during a test
> Tangential force Ft sampling rate: adjustable frequency in Hz
> Automatic generation of reports for a set of measurements
> Real time display of temperature, controlled via software
> Automatic calibration procedures:
  - Force measurement calibration
  - Speed calibration
  - Radius calibration
> First lap synchronization:
  - Each test can be started at the same angular position
> Advanced measurement settings:
  - Setup and configuration of tribometer experiments

//// Data analysis
> Friction force, sliding lifetime behaviour
> Autocalculation of sample wear rate and ball wear rate
> Powerful and fully integrated statistical module (data and graphics)
> Automatic measurement report generator
> Data export in ASCII format. Open files with Excel or text editor
> Material deformation modeling software (ModelX)

/// Accessories and Consumables
> Vacuum setup
> Different ball materials (Alumina, Silicon Nitride, Hard Metal, 100Cr6 Steel, Ruby, Sapphire, etc...)
> Container for liquid testing (with or without temperature control)
> Weights (0.25, 0.5, 1, 2, 5, 10, 20, 30 and 60 N)
> Temperature sensor
> Relative humidity sensor
Calotest principle

The Calotest provides quick, simple and inexpensive determination of coating thickness. A rotating sphere with a known diameter is pressed on the coating surface with a preselected load. Both the position of the sphere relative to the center of the sample and the contact load are constant. Upon adding abrasive slurry to the contact zone, a depression of a spherical shape is abraded into the coating and the substrate.

Optical inspection of the depression reveals the projected surfaces of the abraded coating and substrate sections. By measuring X and Y, the thickness of the coating, S, can be calculated by simple geometry.

The Calotest produces a three-body wear system. As a steel ball rolls on the surface of the sample, a slurry consisting of water and fine abrasive particles drips continuously onto the ball at the contact region. The slurry wears the substrate in a controlled manner and thus assures highly reproducible results.

The Calotest can also be used for investigating the abrasive wear resistance of coatings and bulk materials.

\[ S = \frac{1}{2} \left( \sqrt{4R^2 - d^2} - \sqrt{4R^2 - D^2} \right) \]
The CALOTEST is widely used for analyzing coatings with thicknesses between 0.1 and 50 μm. The simple ball-cratering method is a fast and accurate means of checking the thickness of any kind of coatings, whether a single or multilayered stack. Typical examples include CVD, PVD, plasma spray coatings, anodic oxidation layers, surfaces treated by ion sputtering or ion plating, chemical and galvanic deposits, polymers, paints and lacquers.

/// Features

- Spherical abrasion test method
- Determination of coating thickness
- Applicable to a wide variety of materials
- Fine and extra fine polishing slurries
- Available in Compact or Industrial configurations

/// Options

- Optical measuring system with automatic thickness calculation
### Features of the AFM

- Large scan area 110 x 110 μm and 22 μm in Z range
- Optical top and side view of the cantilever and sample for ease of use
- Compact and perfect integration on all CSM Instruments platforms
  - Synchronised Positioning of AFM, Dual View Microscope and Nano head module
- EXCLUSIVE rights on a higher resolution camera
  - Optics system has a resolution of 2048 x 1536 pixels
- Easy Tip Exchange
- No laser alignment upon cantilever exchange
- High quality at an attractive price
- Dynamic mode measurement optional

### AFM Principle

Atomic force, or scanning probe microscopy (AFM, SPM), is an extremely accurate and versatile technique for measuring surface structures, topography and surface forces. A very fine sensor tip mounted to the end of a small deflecting spring - known as a cantilever - is brought into contact with the sample surface to be investigated.

The deflection of the cantilever is measured by an incident laser beam. The optical path difference between the two reflected beams provides an accurate distance measurement used by the Atomic Force Microscope for nanometer-scale imaging.

The sensor tip is then moved across the surface in numerous line scans. Due to the surface roughness (topography), the tip and cantilever move up and down. This movement can be measured with high resolution and the resulting data provides a three-dimensional image of the surface.
Atomic Force Microscopy, or Scanning Probe Microscopy (AFM, SPM), is an extremely accurate and versatile technique for measuring surface topography at the nanoscale. This technique is especially useful for imaging residual scratches, indentations or other nanoscale surface features as well as for accurately measuring their dimensions.

/// Features

> The combination of optical and Scanning Probe Microscopy (SPM) opens up new possibilities in quantitative visual surface characterization
> Optical inspection of large sample areas with the ability to zoom in on interesting structures with sub-nanometer resolution
> Analysis of micro or nanostructures
> Critical Dimension (CD) measurements
> Investigation of structures and roughness
> Profile analysis of coatings and thin films
> Measurements of surfaces with low optical contrast
> Characterization of fragile biological tissue as well as many other applications in materials and surface research

/// Options

> Dynamic mode measurement for:
  - Non Contact
  - Phase Contrast
  - Force Modulation
  - Magnetic Force

/// Examples of Nanoindentation analysis

Acquisition / topography  Measurement of profile  3D imaging
Features of the ConScan Confocal Objective

- Ideal addition to CSM Instruments micro-range products for analyzing the 3D topography of micro-scratches and micro-indentations
- ConScan chromatic image provides a non-contact topographical 3D view
- No sample preparation required
- In situ, fast real time measurements on all types of materials and surfaces
- Totally passive optical pen: no mechanical part in motion in the optical pen
- Interchangeable optical pen allowing different measuring range and axial resolution
- Large range of XY scanning (using X and Y instrument table)
- Profile measurement (direct or extracted)
- Create 2D and 3D images
- Image surface defects and test deformations

ConScan principle

White light ConScan Imaging

ConScan imaging consists of taking polychromatic white light, and passing it through a chromatic lens normally incident to the sample. This lens is specifically designed to have a wide variation of refractive indices for differing wavelengths of light. This effect thus produces a focal point that varies spatially in the Z direction to the wavelength. A pinhole type spatial filter insures that only the light that is in focus at a specific Z height will reach the detector. This detector is actually a spectrometer and records the wavelength of the incoming signal.

This wavelength is accurately correlated to the chromatically dispersed focal point in space, and hence, to the height of the sample area which reflected it.

Therefore, the resultant spectrum can be regarded as a spectrophotometric signature of the material surface; spectral peaks represent the “height” of the sample at that focus point. The system scans over the surface of the sample, creating these spectral height signatures at sub-micron intervals, summatung to an overall image with axial accuracy in the nanometer range.

Image acquisition

A single-point white light source directs polychromatic light through a filter towards the sample surface. The light then passes through a chromatic lens which separates the white light into its component bands. Each wavelength is represented along the optical axis at a unique position from the lens.

The wavelength-coded light bounces off the sample surface and travels through a pinhole to the spectrometer.

The spectrum result is correlated to the height of the sample at that point.

Using the system tables, the sample is moved under the scanning objective to produce an image of the entire surface.
**ConScan Confocal Objective**

The ConScan objective opens up new possibilities in quantitative 3D topographical imaging in the range of a few microns to hundreds of microns of Z-axis variation of the sample surface. It is the perfect addition to a CSM Instruments Platform testing system, especially for the topographic analysis of CSM Instruments micro-range indentation imprints and scratch tracks. By scanning the sample surface in the X-Y directions, the ConScan provides the micro-topographic structure of any type of surface (rough as well as polished) for any type of material. This includes glossy, matt, transparent and opaque materials, which can be extremely difficult to image with other conventional imaging systems.

//// Features

> Non-contact measurement
> Large XY scanning range (using platform XY tables)
> High Z-axis dynamic range (up to 400 microns)
> Accurate measurement of 2D profiles, 3D topography and surface roughness
> Wide range of objectives for different height ranges

//// Options

> Six different chromatic lenses (ranging from 100 μm to 24 mm depth of field).

//// Examples of Scratch analysis

Acquisition / topography  Measurement of profiles  3D imaging

//// Additionnal possible analysis

Profilometry microtopography  Roughness measurement  Autofocus vibrometry  In-line inspection quality control  Thickness of transparent materials

3D Imaging
Features of CSM Instruments Environmental Platform

- Adapted for all our CSM Instruments frame and accessories
- Computer control and monitoring by dedicated software
- Primary or secondary Vacuum system (down to $5 \times 10^{-7}$ mbar)
- Complete mechanical solution under H$_2$ available
- Humidity and Temperature Chamber
  - Conditioner with air-handling unit for 10 - 40 °C, 10 - 95 % RH
- Stainless steel chamber
- Adapted vibration isolation table
- Various heating stages up to 450 °C

Mechanical Characterization under environmental conditions

Mechanical properties can be highly dependent on environmental conditions such as pressure, temperature, humidity, and gases present.

CSM Instruments has developed a full range of environmental control options. The most discriminating applications require the investigation of the influence of these parameters on materials and real-world end products.

CSM Instruments has developed special versions of conventional instrumentation for use in high and medium-vacuum, humidity and temperature conditions.

Applications such as aerospace, military defense, micro-electronics, MEMS devices, and automotive often require high vacuum for realistic measurements.

Medium vacuum is also regularly used in combination with temperature-controlled analysis in order to reduce the amount of oxidation occurring.
Vacuum Enclosure

///// Vacuum Platform

Our automated Platform Systems, equipped with Nano or Micro-scale Indentation or Scratch Tester modules can be integrated with vacuum control in both the high-vacuum (to $10^{-7}$ mbar) and medium-vacuum ranges. The CSM Instruments vacuum module is designed to comply with the modular design of the CSM Instruments Compact Platform instrument series. This allows adaptation of a wide range of CSM Instruments sensor heads for measuring under primary or secondary vacuum conditions.

The medium-vacuum configuration can also be used with a heating stage for sample temperature control up to 450°C.

///// Vacuum Tribometer

The Vacuum Tribometer is used to determine the sliding life of self-lubricating coatings as well as friction and wear behavior of bulk materials or protective coatings by varying the contact pressure, lateral velocity and temperature while under vacuum conditions. The system can reach a pressure of $10^{-7}$ mbar.

This system also allows remote control of gas concentration within the chamber, e.g. hydrogen control for studying hydrogen fuel cell materials.
Mechanical properties can also be affected by the temperature and humidity of the surrounding environment. In order to study the influence of these parameters on the material of interest or to investigate material behavior under precise environmental conditions, CSM Instruments has created integrated solutions for use with a wide range of high-performance mechanical testing instruments.

Civil engineering applications like geomaterials, natural composites, cement pastes, concrete, shales, clay, sandstone, tobermorite are highly affected by temperature and humidity. Similarly, metallic composites having a complex heterogeneous structure, polymeric materials, microelectronics and semiconductor usually require temperature and humidity control in order to understand the structural role of water and temperature.

Nano or Micro Indentation or Scratch Testers, configured within a temperature and humidity control chamber, can reach a humidity range of 10 to 95% RH and a temperature range of 10 to 40°C.

The solution provided by CSM Instruments allows material measurements of mechanical properties measurement “in-vivo”, with fully integrated control of various environmental conditions.

// Key Features

- Conditioner with air-handling unit for 10 °C - 40 °C and 10 - 95 % RH
- Adapted for our Tribometer and Compact Platform frame and accessories
- Robust thermally insulated door (with window and glovebox)
- Dual wall thermally insulated Stainless steel chamber
- Adapted vibration isolation table

CPX platform inside humidity chamber
Temperature stages

Heating modules have been designed to offer additional capabilities of measurements at high temperatures on CSM Instruments equipment. These heating modules can be used on different instruments as an add-on.

Testing at elevated temperatures allows measurement of materials properties that are temperature-dependent.

A typical example of such applications is indentation on polymers where evolution of hardness and elastic modulus with temperature is observed. Materials with shape memory effect can be studied at temperatures which bring them back to initial non-deformed state. Furthermore, many other materials showing temperature transformations can be studied and the corresponding properties of such phases can therefore be measured. A non-exhaustive list of typical applicable materials and applications including scratch tests is mentioned below:

- Polymers (properties below and above glass transition temperature)
- Special alloys (properties of phases present at different temperatures)
- Evolution of coatings properties designed for elevated temperature
- Shape memory alloys (properties at temperature above martensite phase)
- Scratching resistance at elevated temperatures

Range of Temperatures

The proposed configurations are based on two possible heating stages:

- Heating module
  - Temperature range of the heating block: room temperature to 600°C
  - Option for cooling down to -150°C

- Peltier heating module
  - Temperature range of the heating block: -10°C to 120°C

(*) The temperature, which can be reached at the surface of the sample, is highly dependent on sample size (diameter and thickness), materials properties (thermal conductivity) and atmospheric conditions (vacuum).
PLATFORM Configuration

Features of the Platform
- Sample mounted in horizontal direction (easy to fix)
- Fully automated system
- Sample translation table performance:
  - X motorized table up to 245 mm
  - Y motorized table up to 120 mm
  - Z motorized table up to 30 mm
- Vibration isolation system
- Standard active air table including compressor: Resonance frequency of 1.5 Hz
- Microscope and e2v CMOS Camera
  - The measuring head and the microscope are mounted side-by-side and linked by the two X- and Y- translation tables
- Up to 4 objectives on turret
- Maximum of 4 different modules on our Open Platform (OPX)

Open, Compact or Table Top Platform

CSM Instruments provides excellent configuration flexibility to grow with all customer needs.

Multiple testing and imaging modules are installed together on the same platform: "Open Platform", "Compact Platform" or "Table Top".

All the measurement and imaging modules are "Positionally Synchronised" to each other, the optical microscope being included as a standard module on the platform.

Humidity or vacuum chamber capability is available on all our platforms.

Acoustic enclosure are available for ultra high resolution applications.
Choose your measurement module(s)

- Ultra Nano Indentation (UNHT)
- Nano Indentation (NHT)
- Micro Indentation (MHT)
- Nano Scratch (NST)
- Micro Scratch (MST)
- Micro Combi (MCT) (MHT-MST)

Add your Imaging module(s)

- Optical Video Microscope
- Atomic Force Microscope
- ConScan Profilometer

Select your platform

- Open Platform (OPX)
- Compact Platform (CPX)
- Table Top Platform (TTX)

> Acoustic enclosure, humidity or vacuum chambers are available as options
International Standards

///// Indentation Testing:

ISO 14577  Metallic materials – Instrumented indentation test for hardness and material parameters
ISO 6508  Metallic materials – Rockwell hardness test
ISO 6507  Metallic materials – Vickers hardness test
ISO 4516  Metallic and related coatings – Vickers and Knoop micro hardness tests

ASTM E2546  New standard practice for instrumented indentation testing
ASTM B933  Standard test method for micro indentation hardness of powder metallurgy materials
ASTM D785  Standard test method for Rockwell hardness of plastics and electrical insulating materials
ASTM E140  Standard hardness conversion tables for metals
ASTM B578  Standard test method for micro hardness of electroplated coatings

DIN 50359  Testing of metallic materials – Universal hardness test
DIN 55676  Paint and varnishes – Universal hardness of coatings

JIS B7734  Knoop hardness test – Verification of testing machines
JIS R1607  Testing methods for fracture toughness of high performance ceramics
JIS Z2255  Method for ultra-low load hardness test

SAE J417  Hardness tests and hardness number conversions

///// Calotest and Calowear Testing:

ISO EN-1071-2  Determination of the abrasion resistance of coatings by a micro-abrasion wear test
VDI 3198  Thickness of cold forging tool coatings (PVD, CVD)
/// Scratch Testing:

ISO 20502  Fine ceramics – determination of adhesion of ceramic coatings by scratch testing
ISO 1518  Paints and varnishes - scratch test
ISO EN 1071-3  Advanced technical ceramics
Determination of adhesion and other mechanical failure modes by a scratch test

ASTM D7027  Evaluation of scratch resistance of polymeric coatings and plastics using an instrumented scratch machine
ASTM G171  Standard Test Method for Scratch Hardness

/// Tribology Testing:

ISO 20808  Determination of friction and wear characteristics of monolithic ceramics by ball-on-disc method
ISO 7148  Testing of the tribological behaviour of bearing materials
ISO EN 1071-13  Advanced technical ceramics
Methods of test for ceramic coatings - Determination of wear rate by the pin-on-disk method

DIN 51834  Testing of Lubricants - Tribological Test in the translatory oscillation apparatus
Part 1: General Working Principles

ASTM G 99  Standard test method for wear testing with a pin-on-disk apparatus
ASTM G 133  Standard test method for linear reciprocating Ball-on-flat sliding wear
ASTM G115  Standard Guide for Measuring and Reporting Friction Coefficients
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