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.

### Properties of interest

<table>
<thead>
<tr>
<th>Hardness</th>
<th>Indentation</th>
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<tbody>
<tr>
<td>Elastic modulus</td>
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<tr>
<td>Storage/loss modulus</td>
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<tr>
<td>Creep</td>
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<tr>
<td>Fracture toughness</td>
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<tr>
<td>Compliance</td>
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<table>
<thead>
<tr>
<th>Coating adhesion</th>
<th>Scratch</th>
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<tbody>
<tr>
<td>Scratch resistance</td>
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<tr>
<td>Mar resistance</td>
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<table>
<thead>
<tr>
<th>Friction coefficient</th>
<th>Tribometer</th>
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<tr>
<td>Wear rate</td>
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<tr>
<td>Lifetime studies</td>
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<tr>
<td>Tribological behaviour</td>
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<table>
<thead>
<tr>
<th>Coating thickness</th>
<th>Calotest</th>
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<tr>
<th>Nano microscopy</th>
<th>AFM</th>
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<tr>
<td>3D topography</td>
<td>ConScan Confocal Profilometer</td>
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</table>

### 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<sub>1C</sub> 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.
Features of the Indentation Testers

- Unique top surface referencing technique
- Hardness & Elastic modulus determination down to a few nm
- Automated multi-sample handling
- Berkovich, Vickers, Spherical, Cube corner, Knoop, more on request
- Sinus Mode Analysis (DMA) for viscoelastic properties
- Creep, fatigue and fracture toughness tests
- Flexibility and upgradability
- Very high throughput and reproducibility
- Video microscope with multifocus
- Optional AFM or ConScan objective
- Complies with ISO 14577 and ASTM E2546
- Handling system for large samples (up to 300 mm)
- Ease-of-Use software

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.
Ultra Nanoindentation Tester (up to 100 mN)
The highest resolution and highest thermal stability Nanoindenter

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

UNHT module with video microscope and multi-sample holder
**NHT² 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 $(0.02 \, \mu\text{m/N})$
- 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

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**MHT 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
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
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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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
/// 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
Pin-on-Disk Tribometer (up to 60 N)
The reference in tribology

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

High Temperature Tribometer (up to 1000°C)
Highest stability at elevated temperature

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