Low Temperature (LT), Ultra High Vacuum (UHV-LT) Scanning Probe Microscopy (SPM) Laboratory

The laboratory of Low Temperature, Ultra High Vacuum (UHV-LT) is specifically designed for surface science microscopy and spectroscopy methods. The aim is to cover a wide variety of problems in surface science, from molecular chemistry to atomic magnetism.

Three systems available in our laboratory are equipped with different preparation techniques under UHV conditions, as well as with a large variety of epitaxial growth facilities. Force- and Tunnel-based methodologies can be combined, allowing investigating substrates with different electronic properties. The accessible temperature range for experiments is from 0.5 K to 1300 K.

The laboratory is composed by three UHV set-ups hosting 4 different SPM heads, each with complementary characteristics:

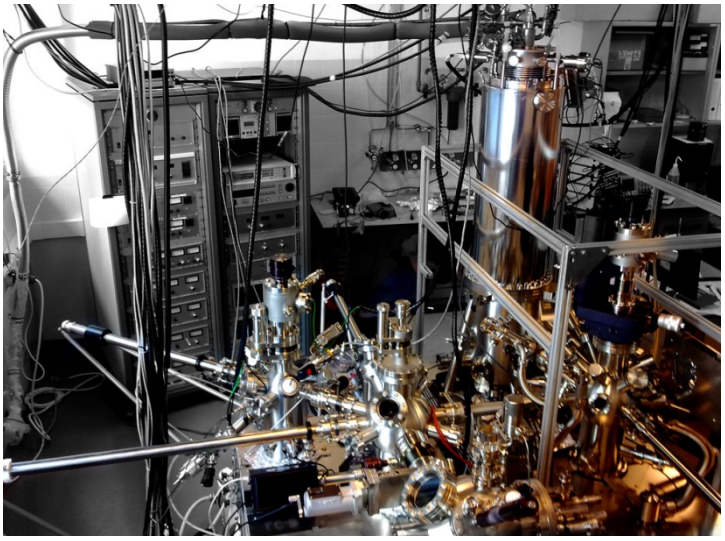
1. **Joule Thompson STM with axial magnetic field and variable temperature SPM** (called internally *Moncayo* and *Arán* instruments)**.**

2. **Low Temperature STM in UHV** (*Ordesa* instrument).

3. **Low temperature STM/AFM in UHV** (*Ainsa* instrument)**.**

1. *Ultra low Temperature STM with axial magnetic field and variable temperature SPM*

Moncayo and Aran Instruments



This equipment is specifically oriented to investigate atomic scale magnetism and to high resolution spectroscopy (0.1 meV) of molecules and atoms, as well as to study the physical-chemical phenomena of surfaces function of temperature and gas dosing.

Both aspects are covered by two UHV SPM heads connected under UHV conditions as a part of a multichamber system. One of them –Moncayo– features a base temperature of 1.1 K (can be extended down to 0.5 K by using He^3 instead of He^4 in the Joule-Thompson stage), a 3 Tesla axial field and a hold time of 100 h. Spin-Polarized STM measurements can be performed routinely. The other one –Arán– is a variable temperature STM/nc-AFM (from 100 K to 1300 K), with a fast and flexible measurement approach. Two additional chambers with independent vacuum allow the user the preparation of samples in situ and the epitaxial growth of organic and inorganic thin films on surfaces.

What kind of information can be obtained with this instrument?

- Energy spectra of the density of states and quantum energy levels of atomic scale objects.
- Electronic and structural properties of surfaces with atomic resolution.
- Spin structure and magnetization curves of magnetic nano-objects from the range of ~100 nm down to sub-atomic and sub-molecular resolution.
- Engineering functional nanostructures by atomic manipulation.
- Real time monitoring of catalytical activity as a function of temperature and reacting gases.
- Physical chemical characterization of surface steered self-assembly processes.

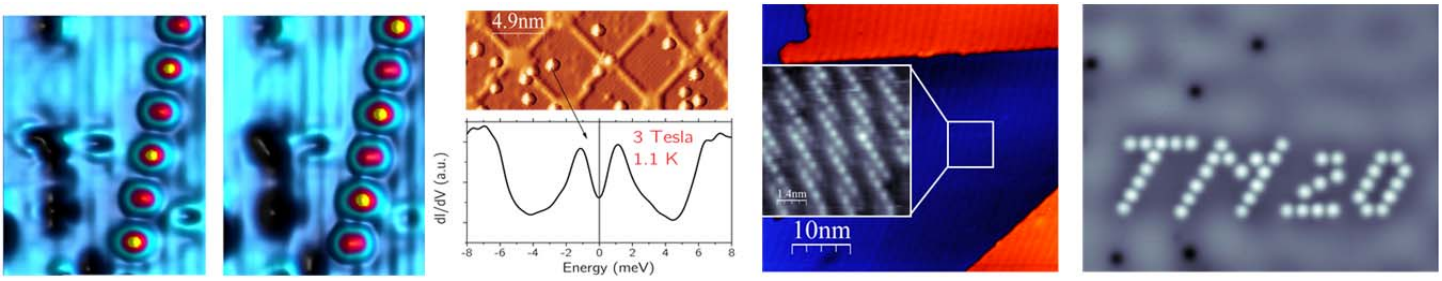
Sample requirements

- Preferably grown in-situ.
- Metallic, semiconducting or ultra-thin ($\leq$3 monolayer) insulating surfaces.
- Surface roughness < 1 nm.
- Substrate or specimen maximum size: 3 mm thick and 10 mm wide.

Technical Specifications

Low Temperature STM (internally called ***Moncayo***)	Joule Thomson cryostat (1 K - 10 K) UHV-STM; 3 T axial B field. Metal and organic epitaxy *in situ*. *Vendor: SPECS GmbH*
Variable Temperature STM Variable Temperature AFM (internally called ***Arán***)	Aarhus variable temperature (100 K -1300 K) STM; Non-contact-AFM. Vendor: SPECS GmbH
Sample preparation	LEED/Auger characterization facilities; 9 Molecular Beam Epitaxy pockets (5 of them with fast reload option), 1 effusion cell, 3 sputter guns, 4 e-beam heaters, 2 in-situ transportable resistive crucibles for deposition of organic materials, SP-STM tip preparation

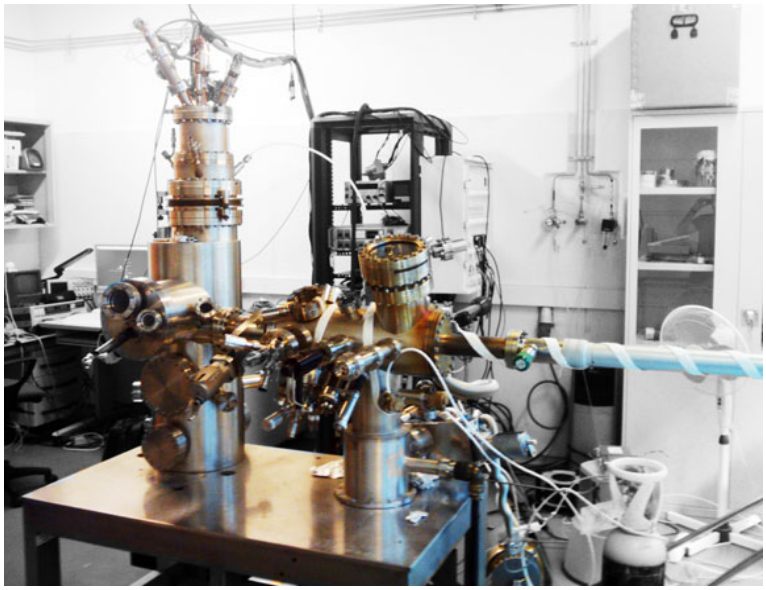
Images



Caption: From left to right. Binary information encoded in single Co atoms with up/down spin represented by yellow/red colors. The same chain with contrast reversed. Example of energy resolution in quantum spectra (Co atoms over Cu_2N monolayer). Ni_3C_4 over a Ni (111) surface stabilized by a partial pressure of 10^{-6} mbar propene at 500 ºC. Example of atomic manipulation to build the logo of 'Tercer Milenio 20' using 44 atoms.

2. *Low Temperature STM in UHV*

Ordesa Instrument



This equipment is devoted to investigate metal-on-metal epitaxy of rare earths. It is specially oriented to the growth of magnetic thin films and nanostructures.

The instrument runs at a base temperature of 4 K and has been optimized for deposition of rare-earth metals on tungsten substrates.

What kind of information can be obtained with this instrument?

- Energy spectra of the density of states of atomic scale objects.
- Electronic and structural properties of surfaces with atomic resolution.
- Atomic manipulation.

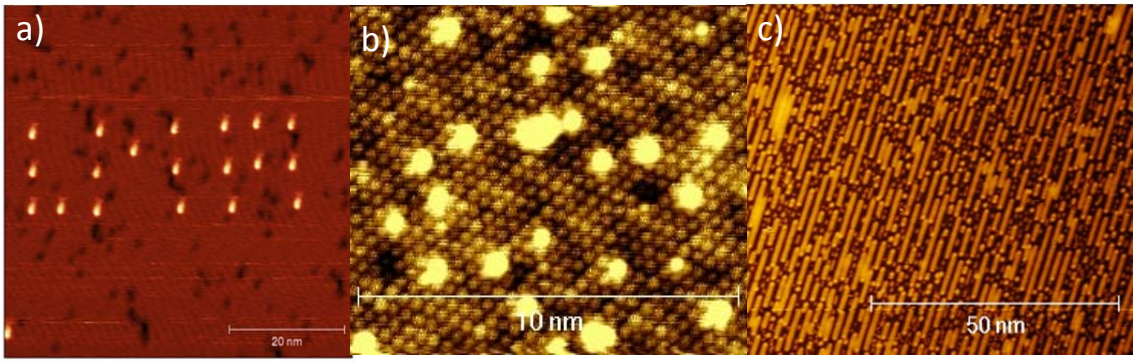
Sample requirements

- Preferably grown *in-situ*.
- Metallic, semiconducting or ultra-thin (≤3 monolayer) insulating surfaces.
- Surface roughness < 1 nm.
- Substrate or specimen maximum size: 3 mm thick and 10 mm wide.

Technical Specifications

Low Temperature STM (internally called ***Ordesa***)	Low temperature (5K) UHV STM. Vendor Omicron GmbH
Sample preparation	Metal epitaxy, and LEED/Auger characterization facilities.

Images



(a) Atomic manipulation: Tm adatoms on W(110)
(b) A quasi-hexagonal Tm monolayer (ML) on W(110), showing some Tm adatoms on it.
(c) Tm nanowires, single-atom width, on a Tm ML/W(110).

3. *Low temperature STM/AFM in UHV*

Ainsa Instrument

This set up includes the last development in UHV non-contact AFM. Working at a base temperature of 4.5 K, the use of a qPlus sensor allows to simultaneously acquire electron tunneling signal and forces in the picoNewton range. Measurement of both forces and conductance is especially interesting in the field of molecular physics on surfaces. Force microscopy is also especially suitable to work on insulating surfaces. This experimental set up has been equipped with various methods to deposit organic materials on inorganic surfaces. The research lines are oriented to molecular interactions, self-assembly and magnetic, electronic and structural properties of hybrid metal-organic films.

What kind of information can be obtained with this instrument?

- Energy spectra of the density of states of atomic scale objects.
- Electronic and structural properties of surfaces with atomic resolution.
- Engineering functional nanostructures by atomic manipulation.
- Atom resolved structural characterization of macromolecular complexes.
- Mapping of electronic charge (surface potential) down to submolecular resolution.
- Preparation and characterization of metalorganic networks.

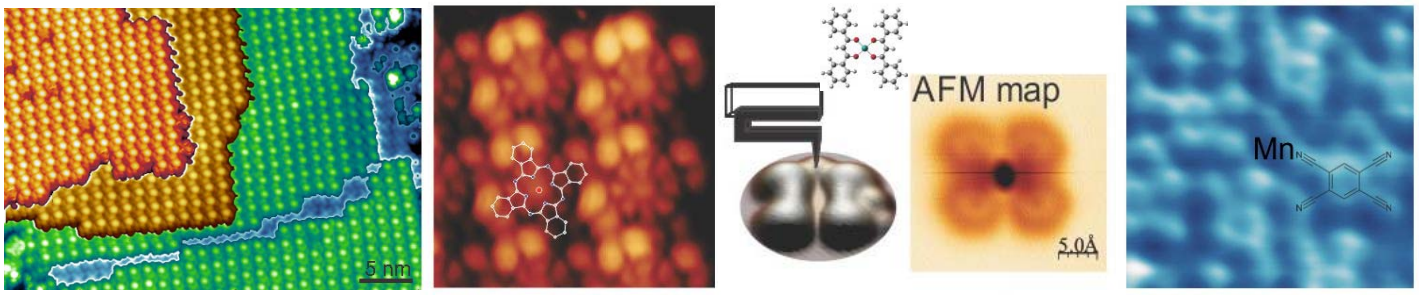
Sample requirements

- Preferably grown *in-situ*.
- Conducting or insulating samples.
- Surface roughness < 1 nm.
- Substrate or specimen maximum size: 3 mm thick and 10 mm wide.

Technical Specifications

Low Temperature STM/AFM (internally called ***Ainsa***)	Low temperature (4.5 K) UHV STM equipped with a tunning fork head for simultaneous STM and high-resolution AFM.
Sample preparation	1 fast reload Molecular Beam Epitaxy pocket, 1 Knudsen-cell and 1 fast reload crucible for sublimation of organic material, cryogenic sample preparation stage.

Images



Caption: From left to right. STM topography of a 3 layer thick π-stacked FePc film. Zoom into one of the layers. STM topography and simultaneous force map of a Ruthenium based complex. Atomically resolved force map of a Mn-Tetracyanobenzene coordinated network.