Kazan (Volga Region) Federal University
Department of Solid State Physics, Institute of Physics
Research Laboratories
Synthesis and Analysis of Thin Film Systems (SATFS)
Physics of Magnetic Nanostructures and Spintronics (PhMNS)

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Ultra-High Vacuum Setup
Synthesis & Analysis of Thin Film Structures Research Laboratory

auxiliary tools & measurement setups from other laboratories

Commissioning in February 5, 2013

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Ultra-high vacuum setup for deposition of the ultrathin films and hetero-structures: magnetic and non-magnetic metallic, semiconductor, dielectric layers and heterostructures

Custom setup was fabricated according with custom project by German companies SPECS (http://www.specs.com/) and BESTEC (http://www.bestec.de/), Berlin, Germany

Components:

Load-lock of the substrates and samples
UHV Transfer line between the chambers
UHV MBE chamber
UHV Magnetron sputtering chamber
UHV Analytical chamber
Five control racks
Two closed-loop cooling chillers
Six turbo-pumping evacuation systems

Vacuum:

Oil-free vacuum with base pressure better than 5 $*10^{-10}$ mbar (magnetron chamber - $<5*10^{-9}$ mbar)
1 = 1000 mbar - atmospheric pressure

The setup allows to synthesize films and multi-layer hetero-structures, where their thickness can be controlled from monolayer up to microns

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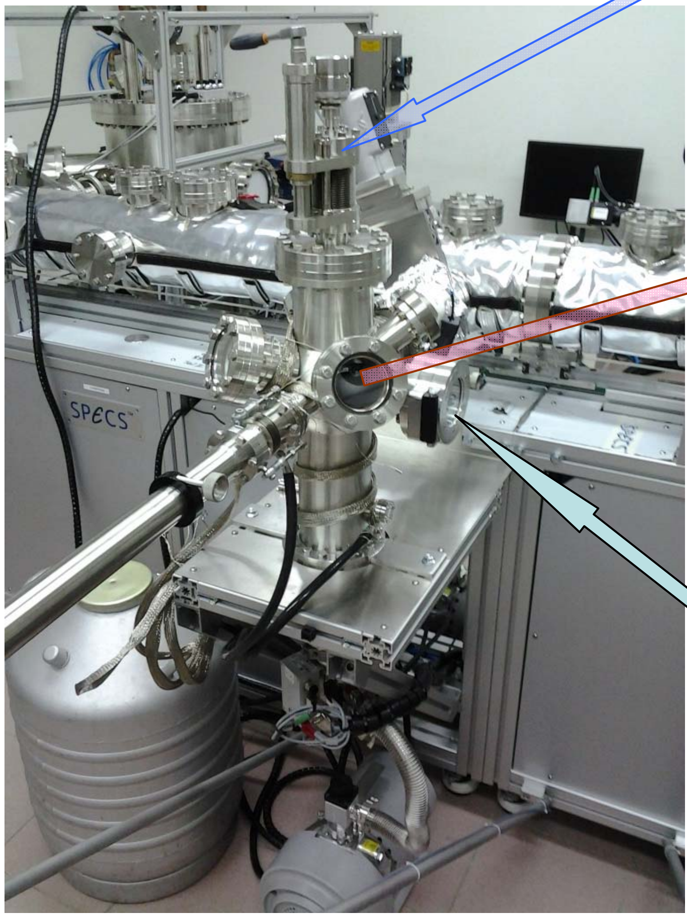
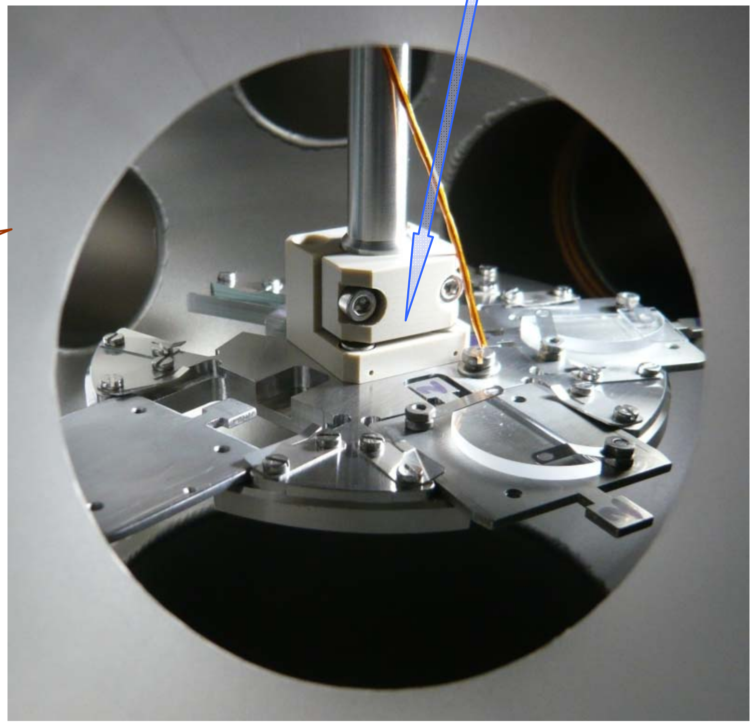
Substrates and samples loading with load-lock

Manipulator





The door opens when the chamber is filled by dry argon

Base pressure < 5 $*10^{-8}$ mbar; the chamber allows baking to $5*10^{-9}$ mbar

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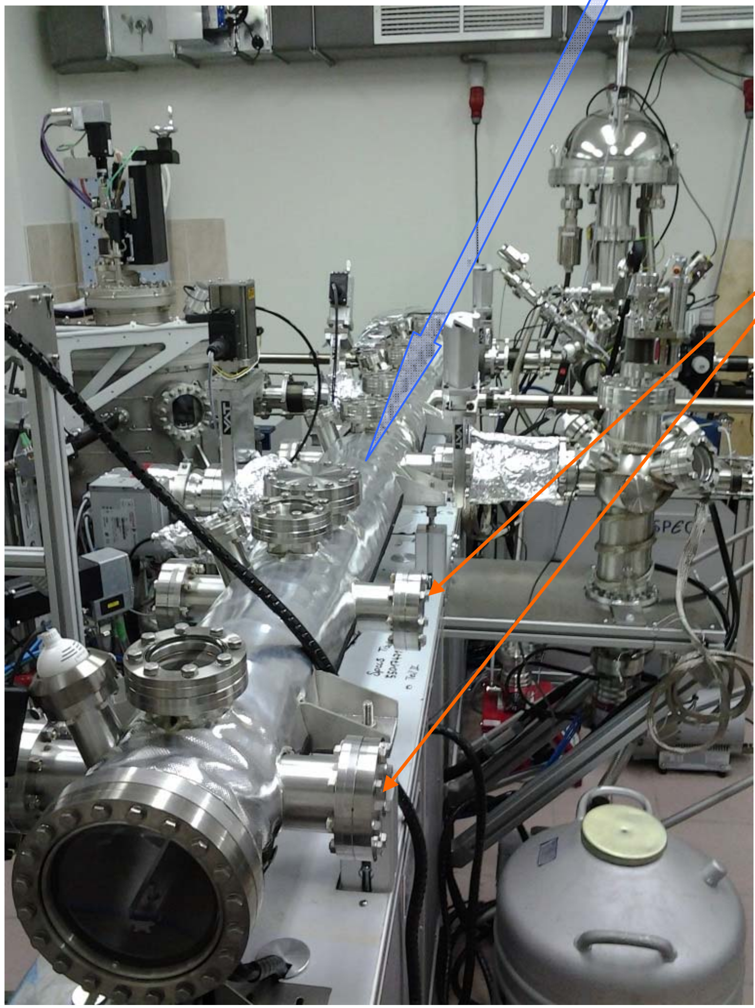
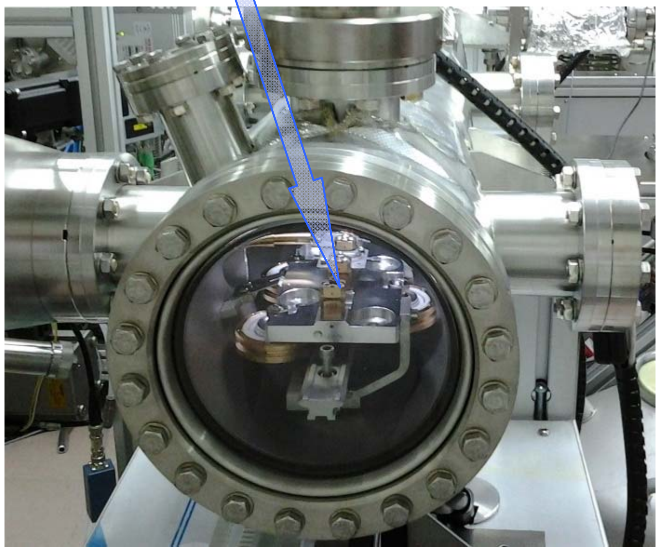
Sample Transfer Line



Setup was built as open architecture: additional ports are available, and segments space can be extended up to a few meters.

3 sockets for the sampleholders move with a help of the non-contact drive



Base pressure < 5 $*10^{-8}$ mbar and $5*10^{-10}$ mbar after backing

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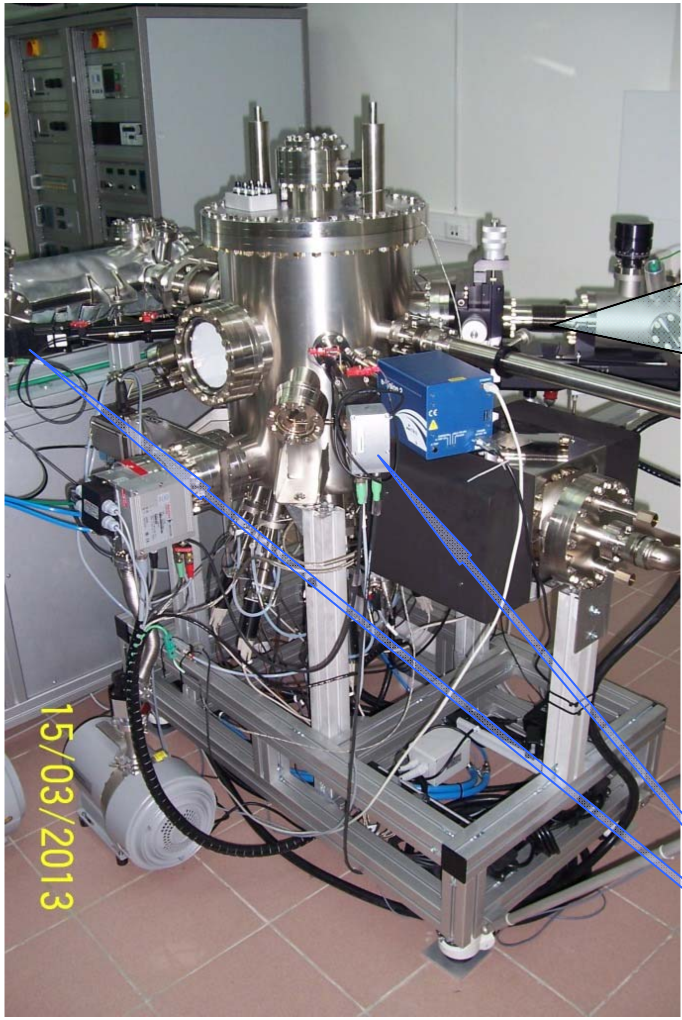
Molecular Beam Epitaxy (MBE) chamber



Supports up to 9 targets: two installed are electron-beam (temp. up to 3300C); 4 are effusion cells up to 2000C, and one is for low melting-point metals with the chilled flange.

Manipulator with 6 degrees of freedom

Reflection High-Energy Electron Diffraction (RHEED)
Low Energy Electron Diffraction (LEED)

There is ion-gun with a wide beam for cleaning and etching.

Two shutters controlled by step motors to produce films of varying thickness or different doping in 2 crossed directions.

Oil-free vacuum of better than $3*10^{-10}$ mbar after baking up to 120 ° C for 48 hours

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Control of the MBE

The left-hand rack (top to bottom)
- **control of power**
- **control of the electron beam evaporators (2)**
- **manual control valves evaporator (in the middle)**
- **temperature control of the effusion cells (five sections below)**

The right-hand rack (top to bottom)
- **control of power;**
- **turbo pumping system and pressure control**
- **quartz deposition rate and film thickness**
- **management and control of the substrate temperature**
- **mode control - ion gun**
- **control unit - low energy electron diffraction**
- **control unit - diffraction high-energy electrons in the reflection mode**
- **ion-sublimation vacuum pump**
- **annealing of the MBE chamber**

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Magnetron sputtering chamber

Supports up to 9 targets:
Power sources:
2 for DC
2 for AC
1 for the pulsed DC sputtering (5 outputs)

Supports argon plasma and two reactive gases such as nitrogen or oxygen

Manipulator with 6 degrees of freedom

Two crossed shutters with stepl motors

Quartz control of the thickness of the deposited films

Automatic control of the substrate temperature

Oil-free vacuum of better than $3*10^{-9}$ mbar after baking to 120°C for 48 hours

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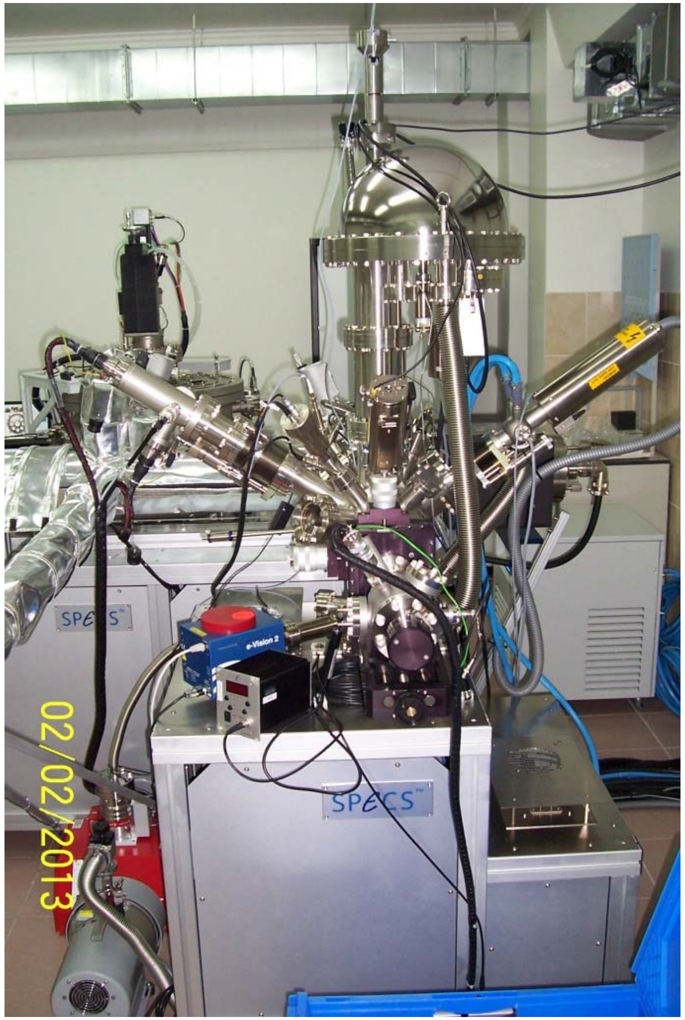
Analytical chamber



Research methods:

- photoemission spectroscopy with X-ray (XPS)
- Auger spectroscopy (Auger)
- mass spectrometry of secondary ions (SIMS)

Technological preparation and processing of substrates and samples:

- ion beam etching and scan area of 5x5 mm^2 with a variable energy argon ions
- cleaning of the surface of the sample by ion beam of argon with variable energy
- annealing of the samples in vacuum

Determine the material composition with accuracy up to 0.1%
Depth profiling of hetero-structures

Oil-free vacuum better than 3*10^{-10} mbar after baking to 150 ° C for 48 hours

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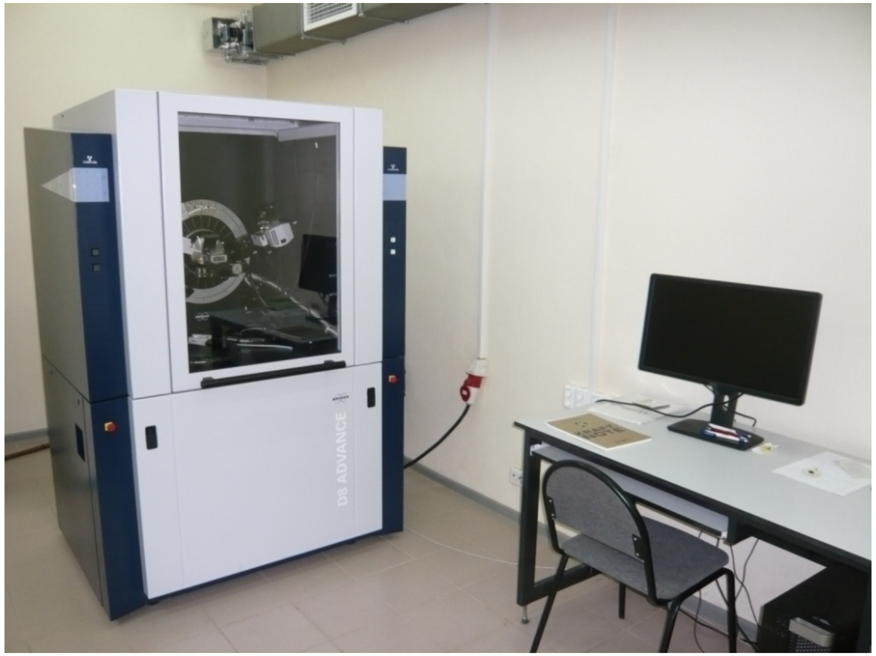
Characterization equipment available in KFU (Inst Phys)

X-ray diffractometer with small-angle measurement of the thin films (XRR) (BRUKER Advance D8, Germany, special assy, Lab SCS)



<u>X-ray diffractometer</u> is adapted to use for powders, polycrystalline samples, large single crystals, single-layer and multilayer nano-structures.

- Low temperature cryostat (cooling down to 80 K)
- Furnace (heating up to 1000 K)

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Characterization equipment available in KFU

Quantum Design PPMS-9, (USA)

Measurement of the physical properties in wide range of temperatures and magnetic fields (Lab SCS)

The range of magnetic fields:
± 9 Tesla,

temperature range - 1.5-1300 K.

VSM magnetometer, transport, heat capacity, thermal conduction

Important optional measurements of the ultra-soft magnetic materials with compensation of the Earth's magnetic field.

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Our recent research utilizing the UHV setup

- **The series of samples of different alloys were analyzed, e.g. palladium-iron, palladium-nickel, palladium/nickel/iron ultrathin multilayers as the material for spintronic applications;**
- **the series of ultrathin (<10 nm) films of refractory metals (W, Mo, Nb, Ta, Ti) for plasmonics; 0.4-2 nm – for physics in low-dimensions;**
- **the series of ultrathin (<10 nm) films refractory metal nitrides (W, Mo, Ta, Ti) for plasmonics;**
- **Calibration samples for the magneto-optical and Mössbauer measurements (thicknesses from 4 to 30 nm);**

Example of the synthesized and measured samples:

palladium alloy film-iron; ZnO/Co co-sputtered composites, barium titanate, strontium titanate, titanium dioxide, zinc oxide implanted with ions of the iron group - XPS; topological insulator Bi_2Se_3, $NbSe_2$ - XPS studies, zirconium irradiated by hydrogen isotopes and others.