Research to solve problems

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OUTLINE

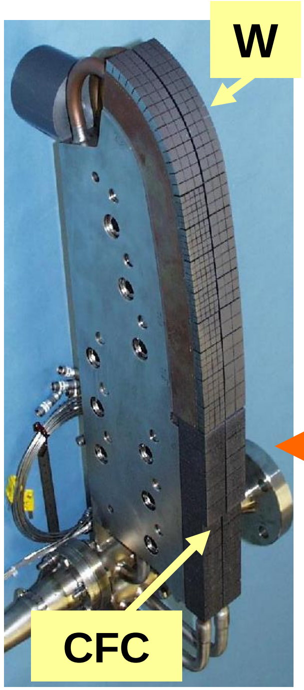
1. Motivation: ILW project

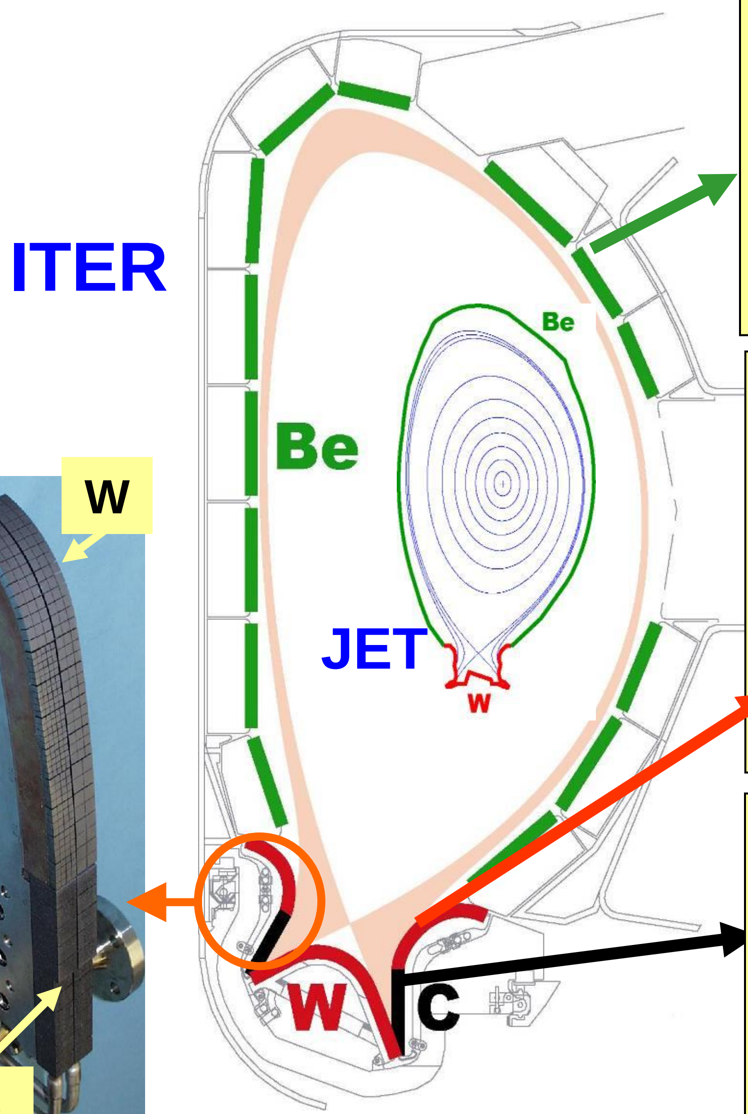
2. TVA principle

3. Be coatings on inconel and marker tiles

4. Other applications of TVA technology

JET ITER-like wall experiment





700m^2 Beryllium first wall
- low Z
- Oxygen getter

Optimise plasma performance

But large erosion & melting

100m^2 Tungsten
- Low erosion
- high melting T
- Negligible T retention

Optimise lifetime & T- retention

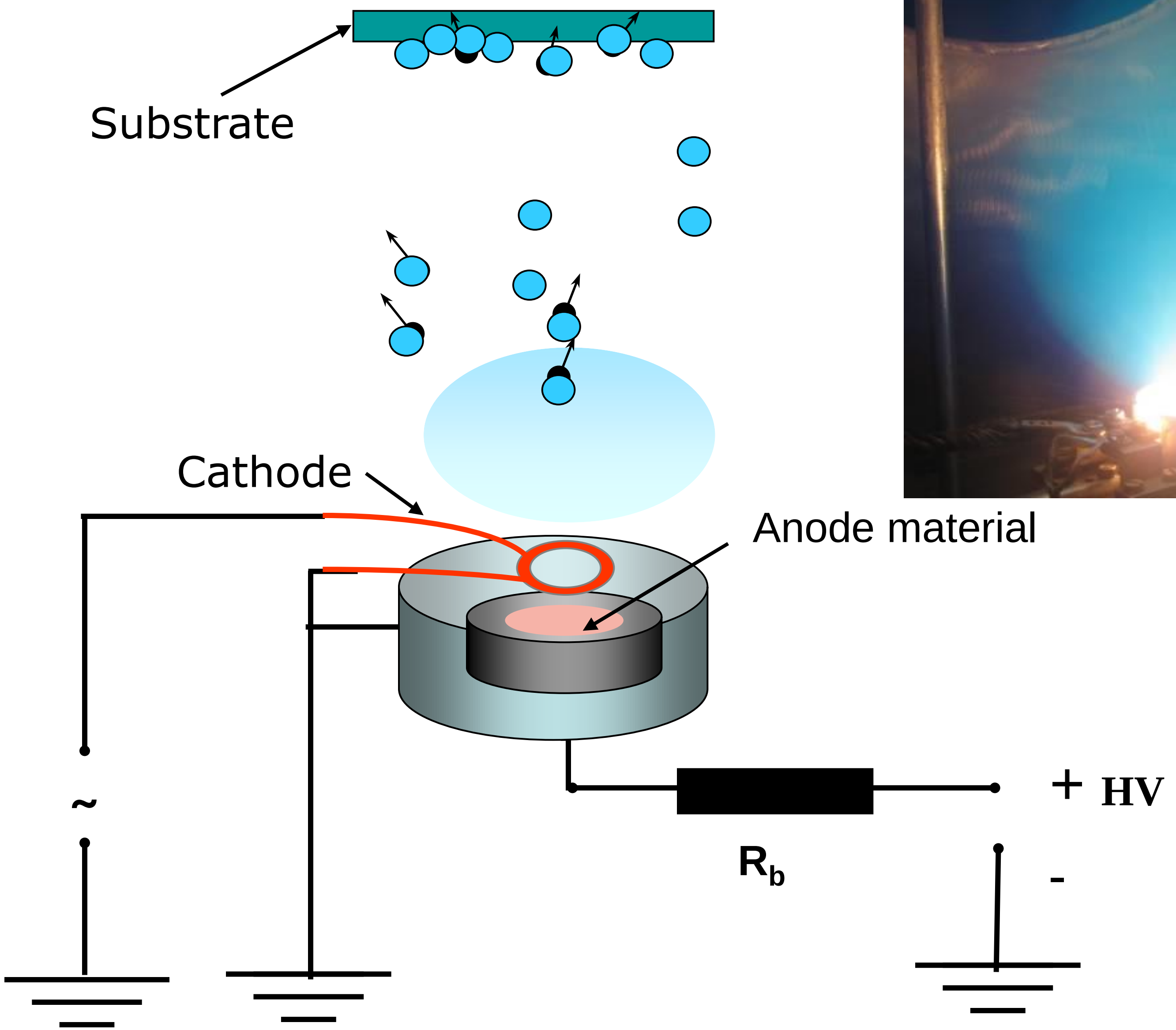
But high Z & melting

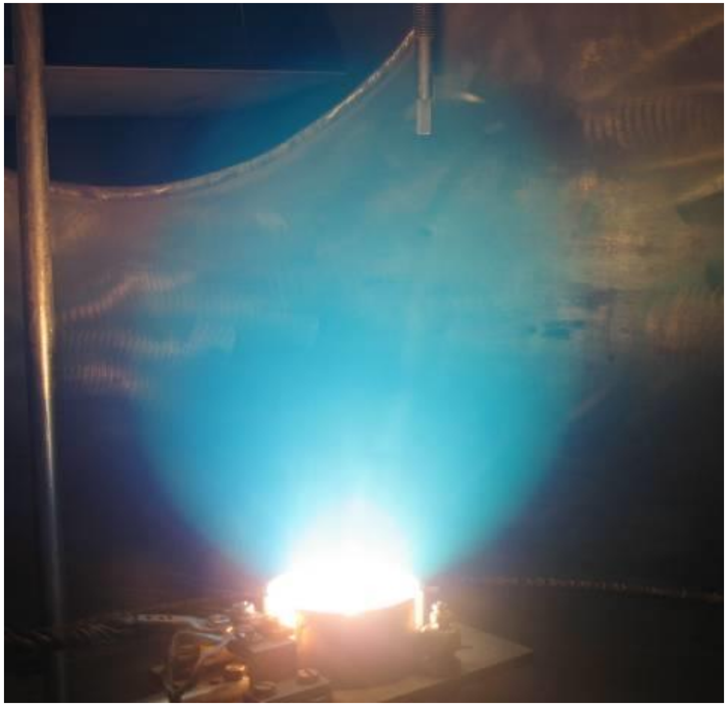
50 m^2 Graphite CFC
- Lowish Z
- No melting in transients
- Superior heat shock behaviour

Optimise heat flux resistance

But large erosion & T retention

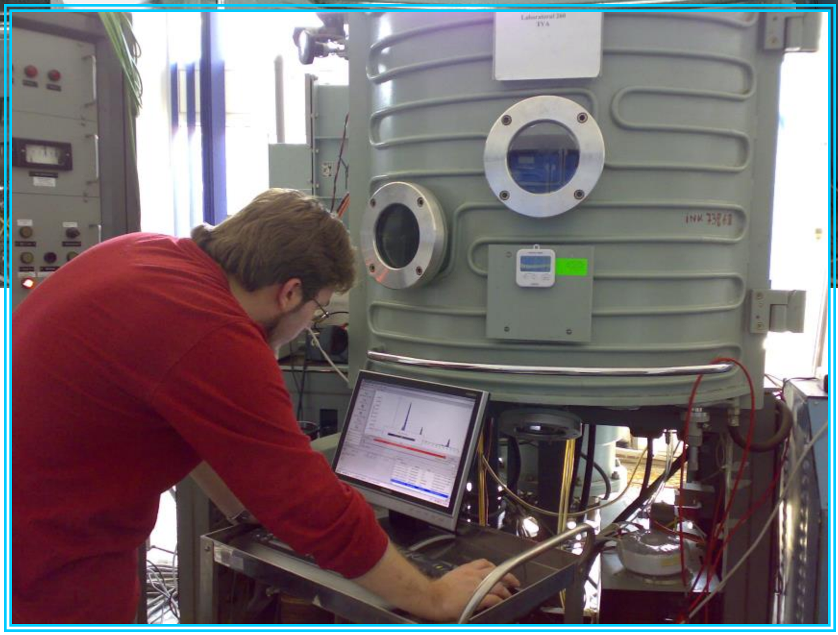
Circular TVA

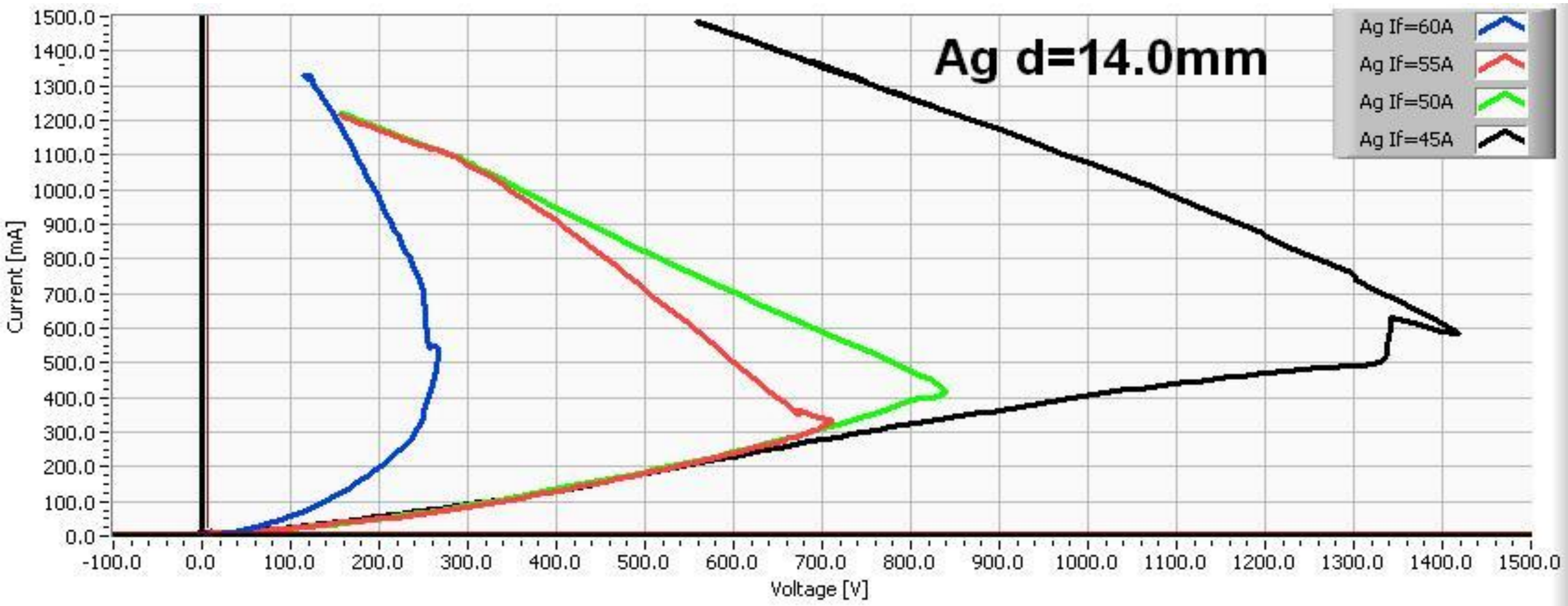




TVA DEPOSITION

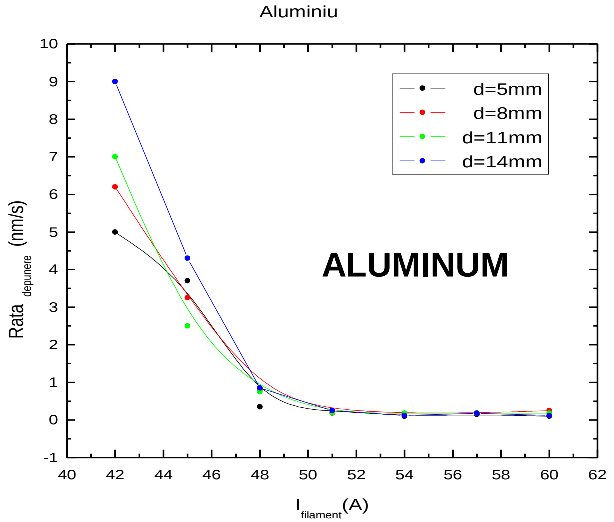
(except beryllium)

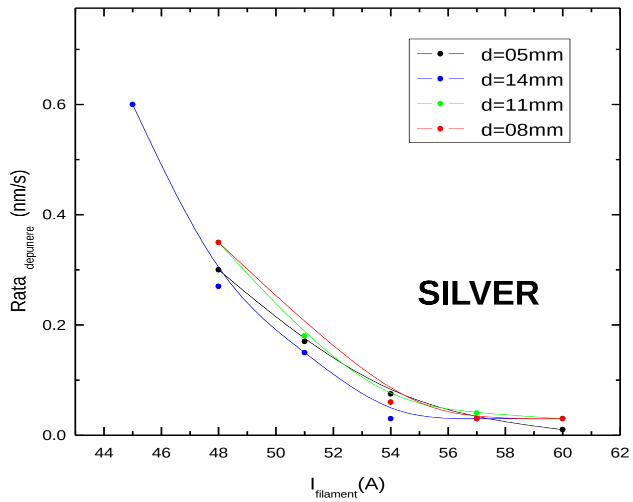


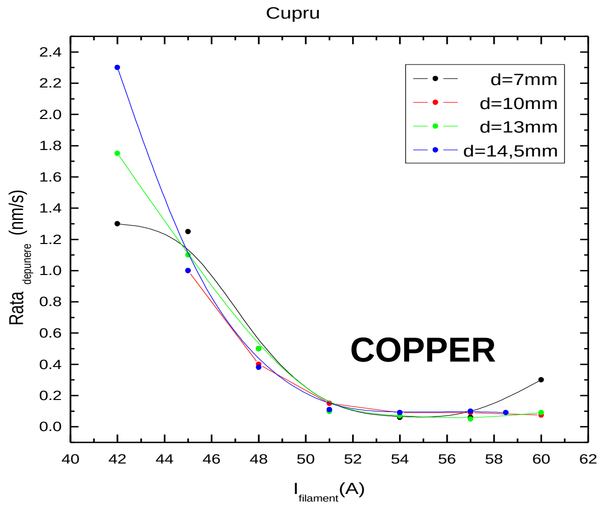


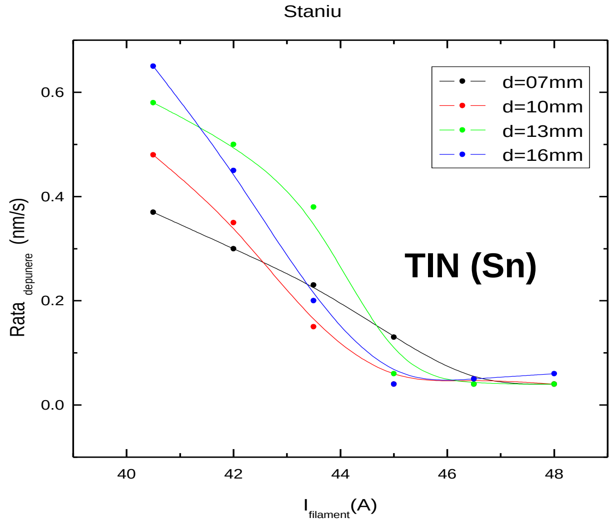
I-V characteristics of the TVA plasma running in Ag vapors for different heating currents

Deposition rate as function of the cathode heating current









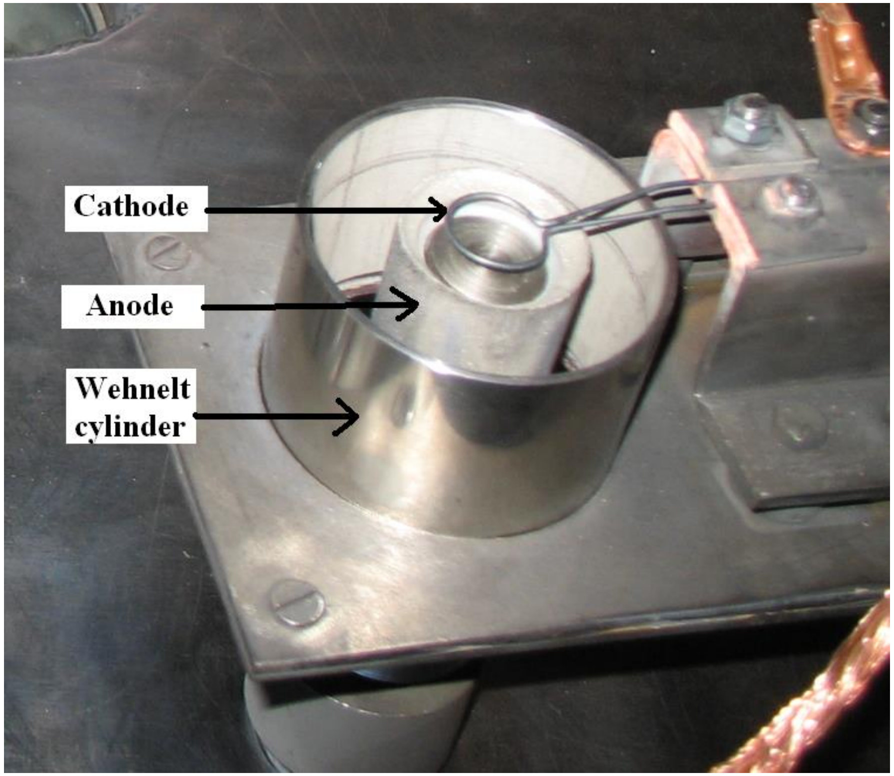
THE ADVANTAGES OF THE TVA TECHNOLOGY

- the high purity of the layers (high vacuum conditions);
- no gas consumption;
- the films are growing from the plasma created in the pure vapors of the evaporating material
- the formed films are continuously bombarded by the genuine ions and the advantages are:
    - no gas inclusions
    - good adherence
    - the ions energy can be controlled by cathode external heating and anode voltage
    - the deposition rates = 1 to 10 nm/sec.

Licensed laboratory to work with beryllium and beryllium containing composites

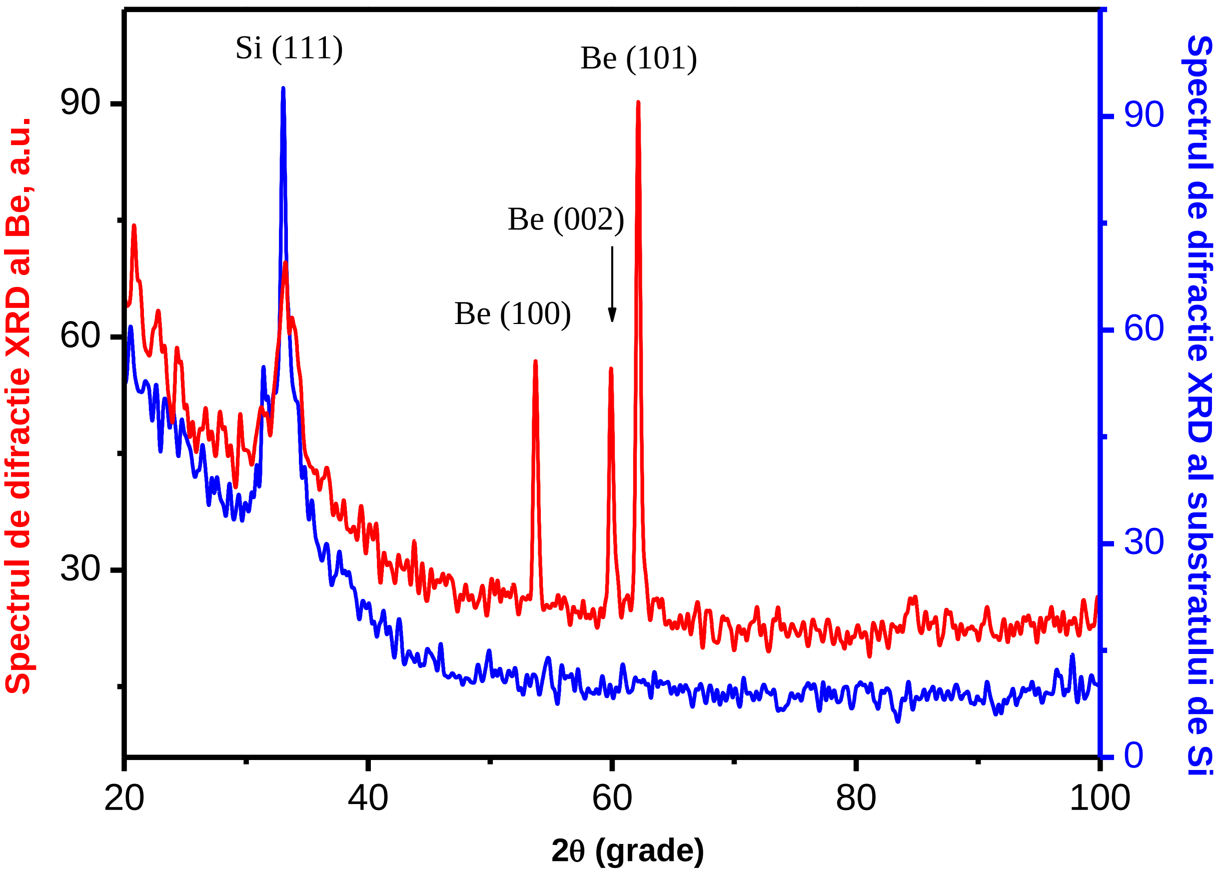
Vacuum deposition system:
- stainless steel chamber,
- glass, quartz and
- germanium windows;
- volume; 250 l,
- base pressure; $6*10^{-7}$ torr
- mechanical pump (60 m^3/h),
- buster pump (200 m^3/h),
- diffusion pump (3000 l/s)

BERILLYUM



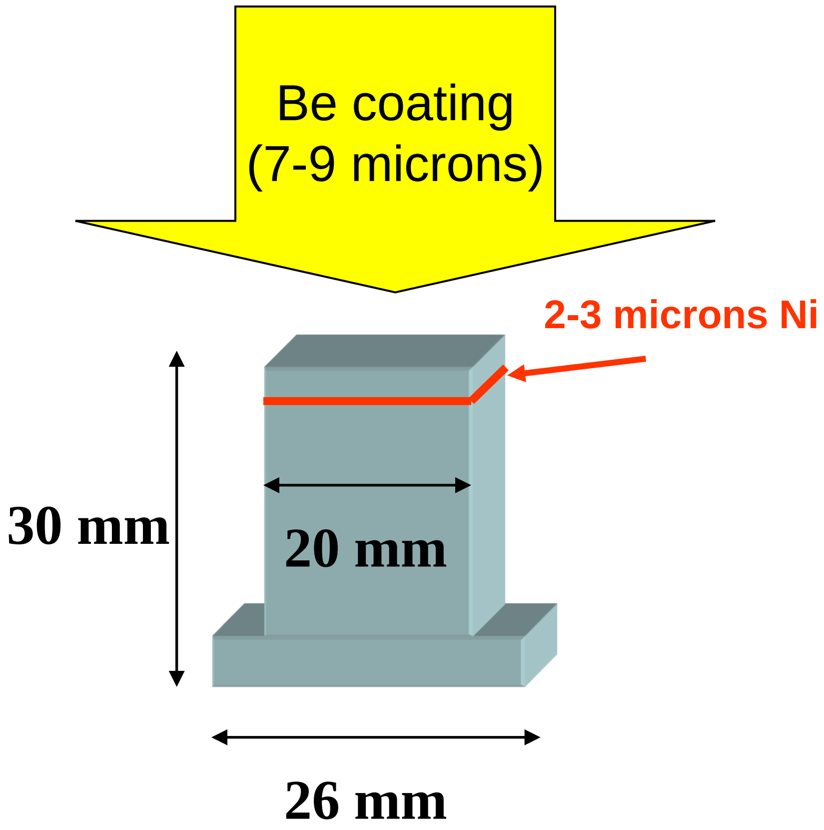
TVA evaporator and plasma running in pure Be vapors

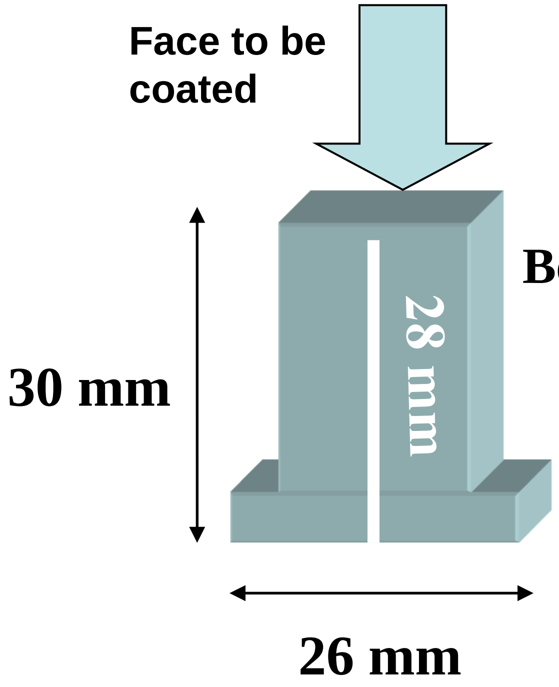
XRD



Be film: polycrystalline

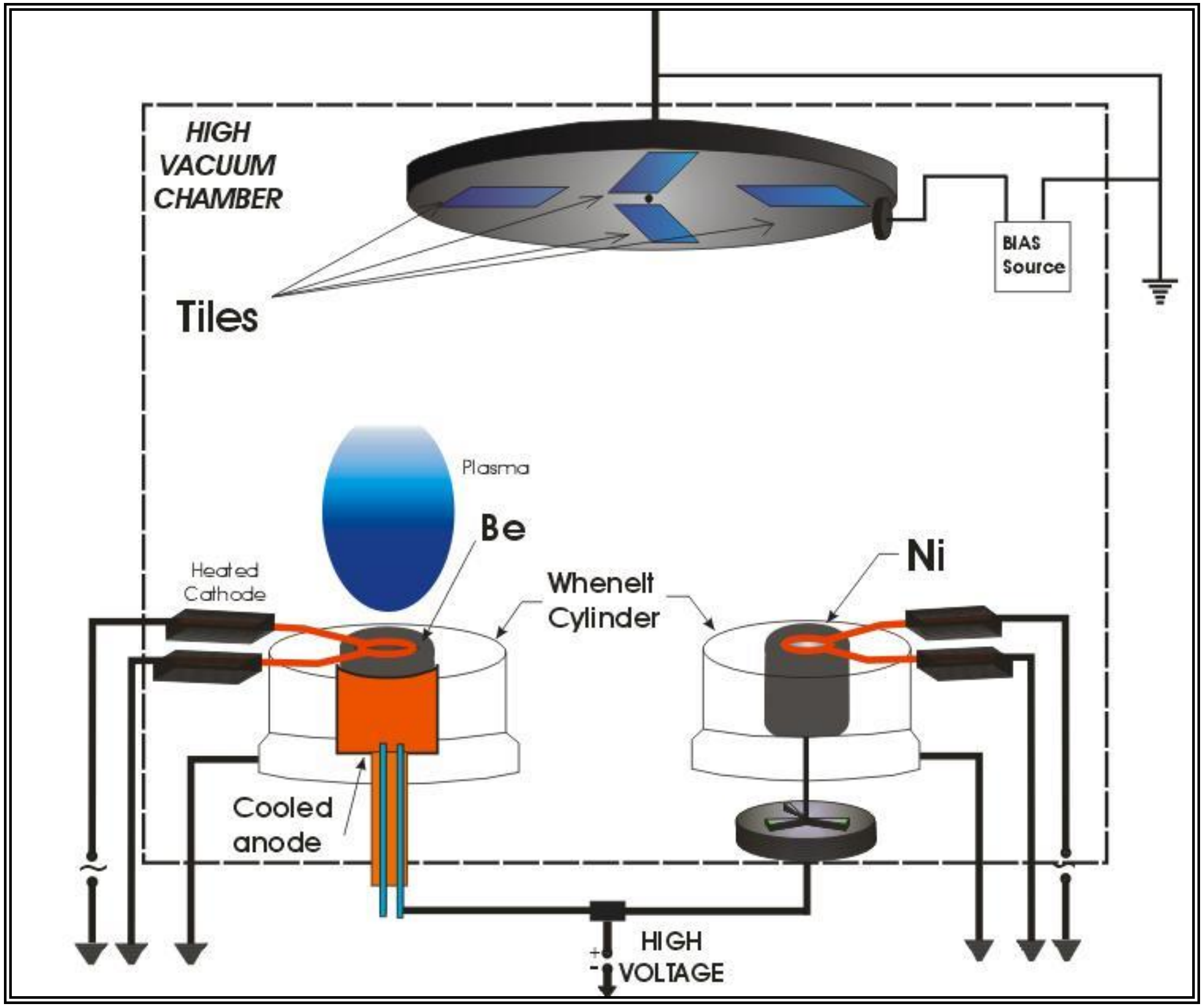
Be Marker coated tiles for ILW



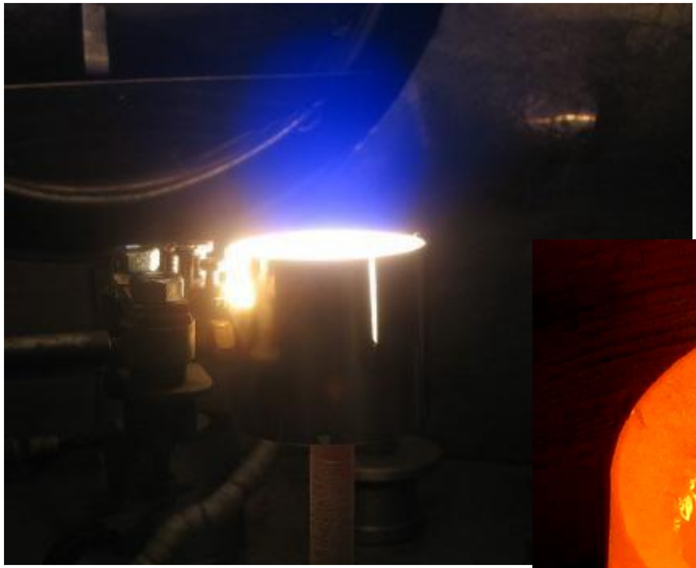


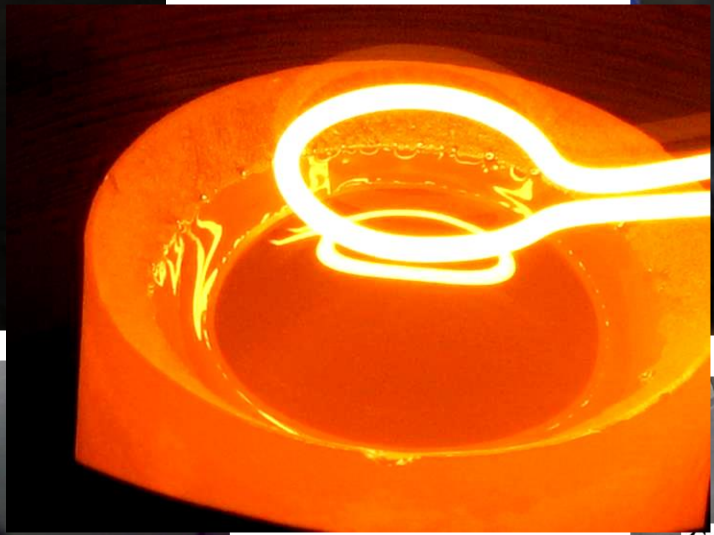
Be block for High Heat Flux (HHF) testing with a hole for thermocouple

Principle of Ni and Be depositions on MARKER tiles

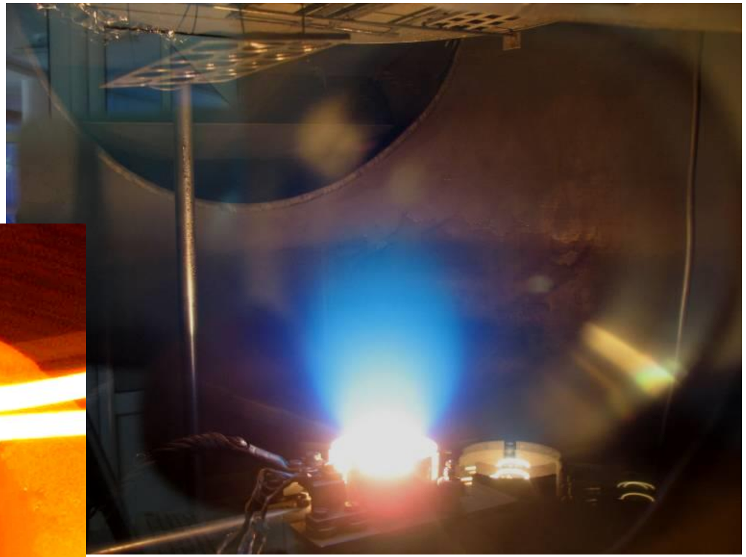


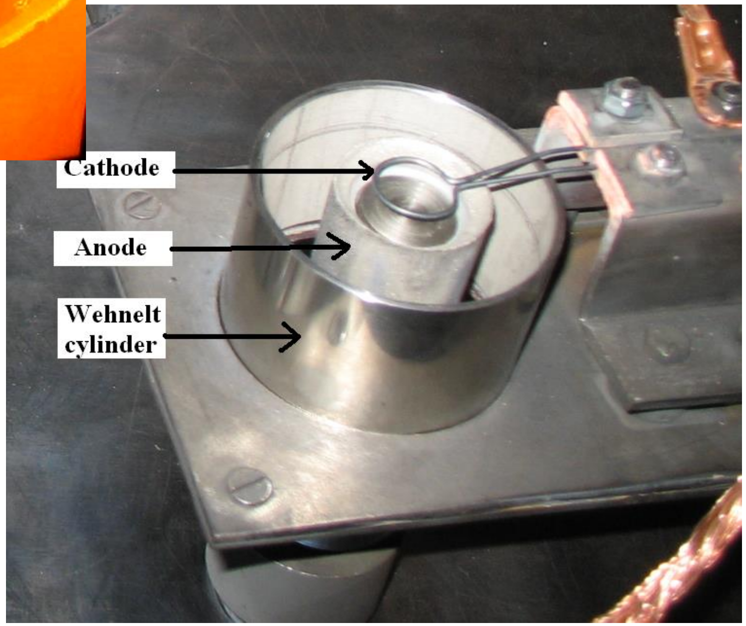
Be plasma





Ni plasma





Ni and Be evaporators

Cross-section of Be blocks

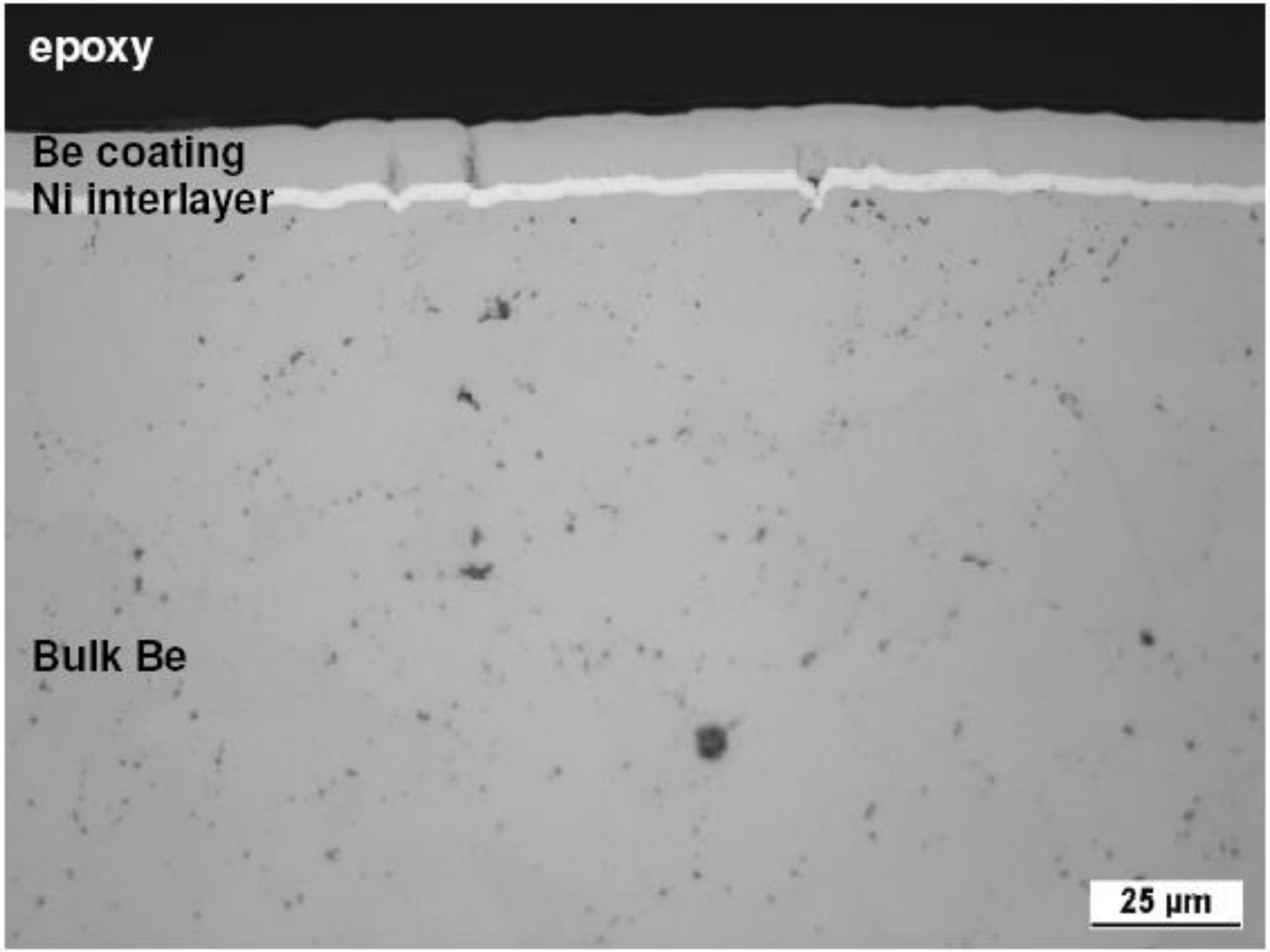


Fig. 16 TC28, 50 cycles of 3.5 MW/m^2 for 10s, optical image.

Impurity analysis of Be blocks

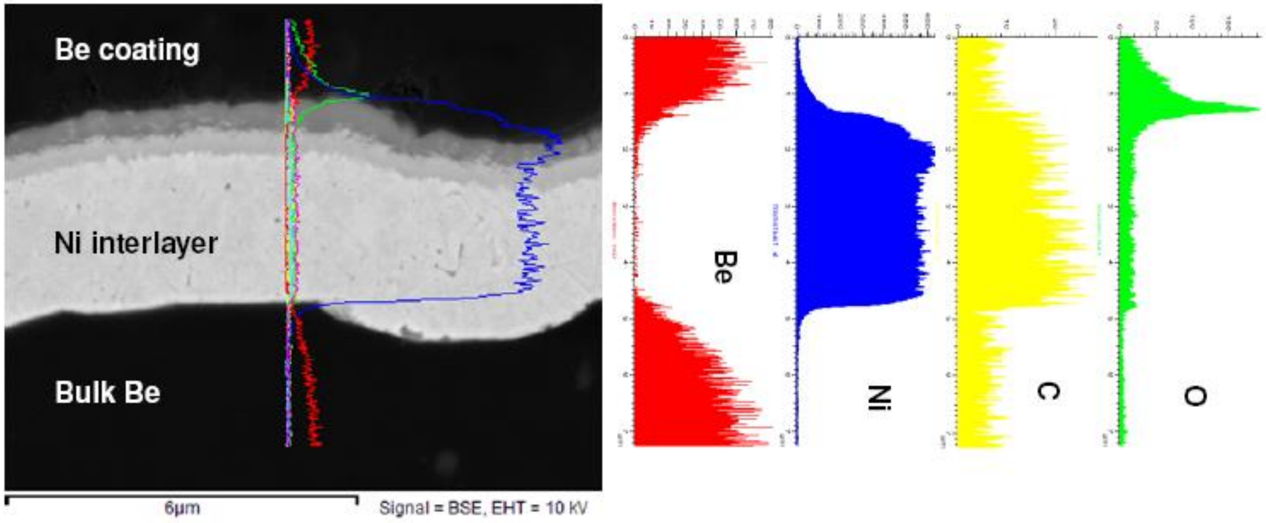
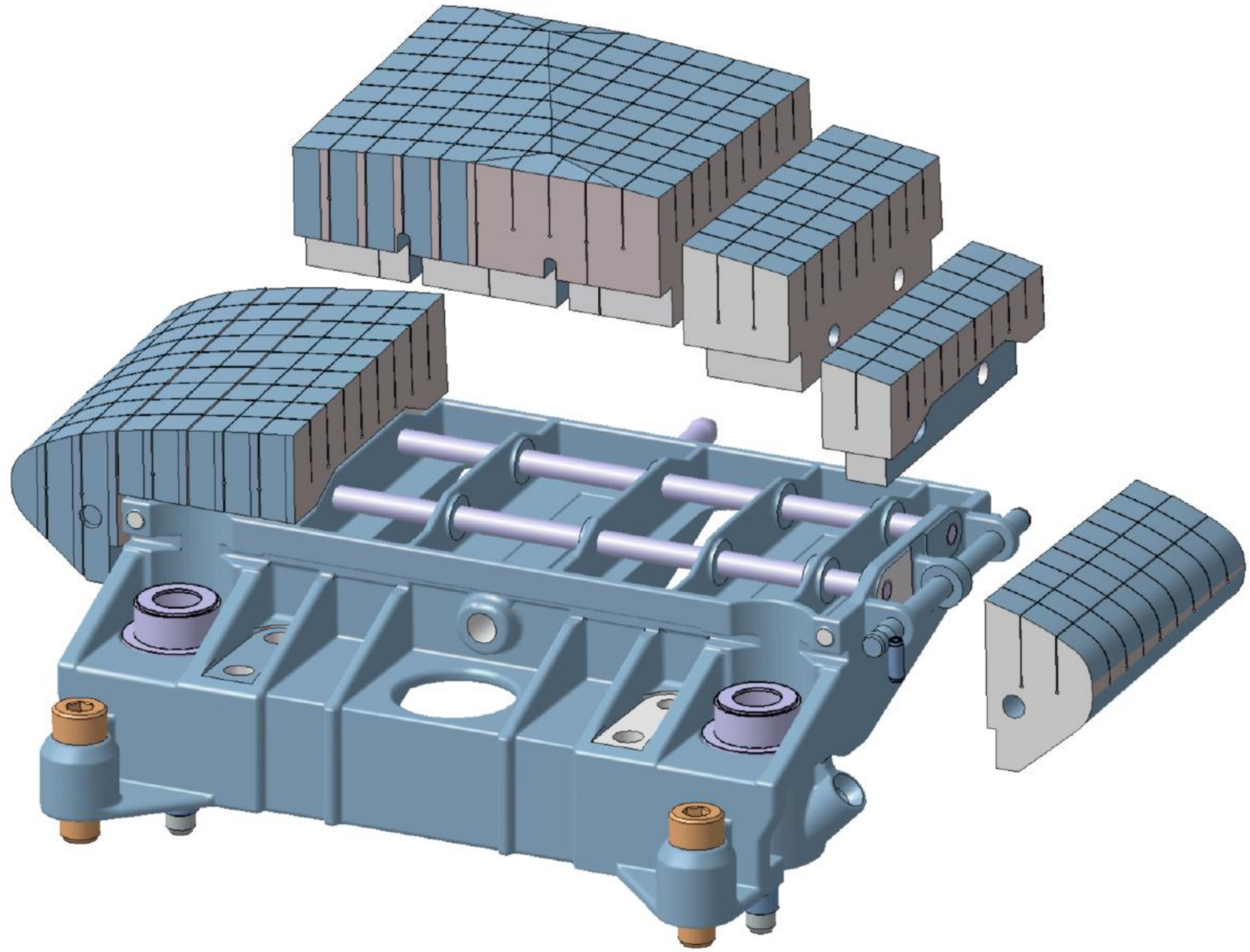
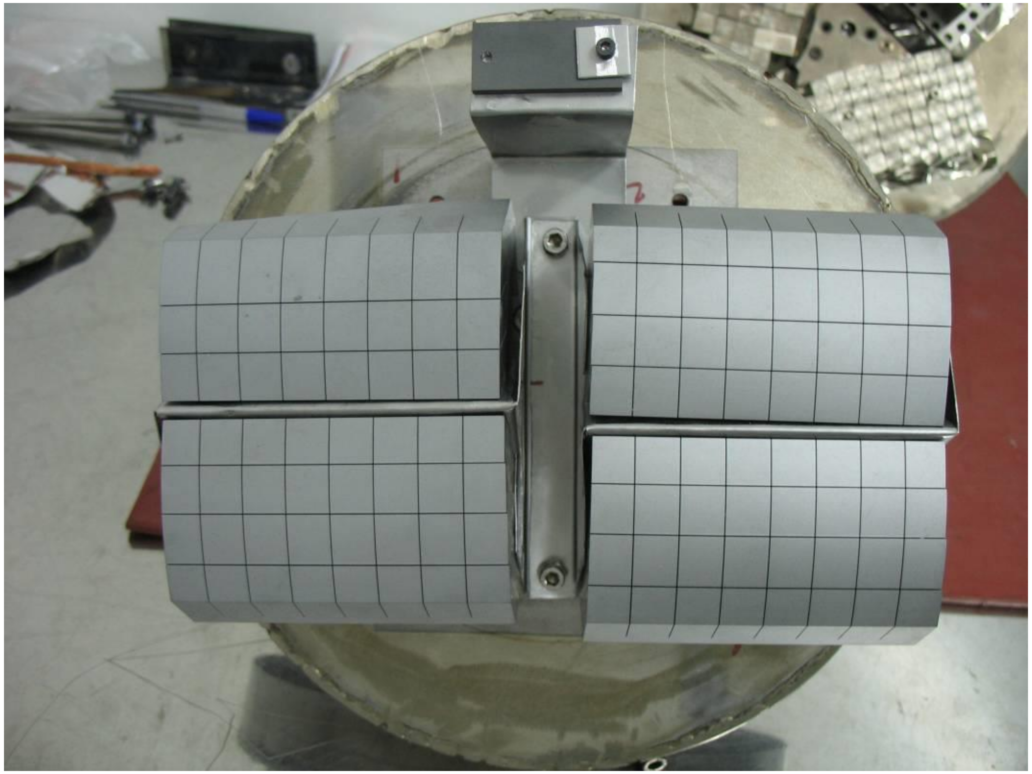
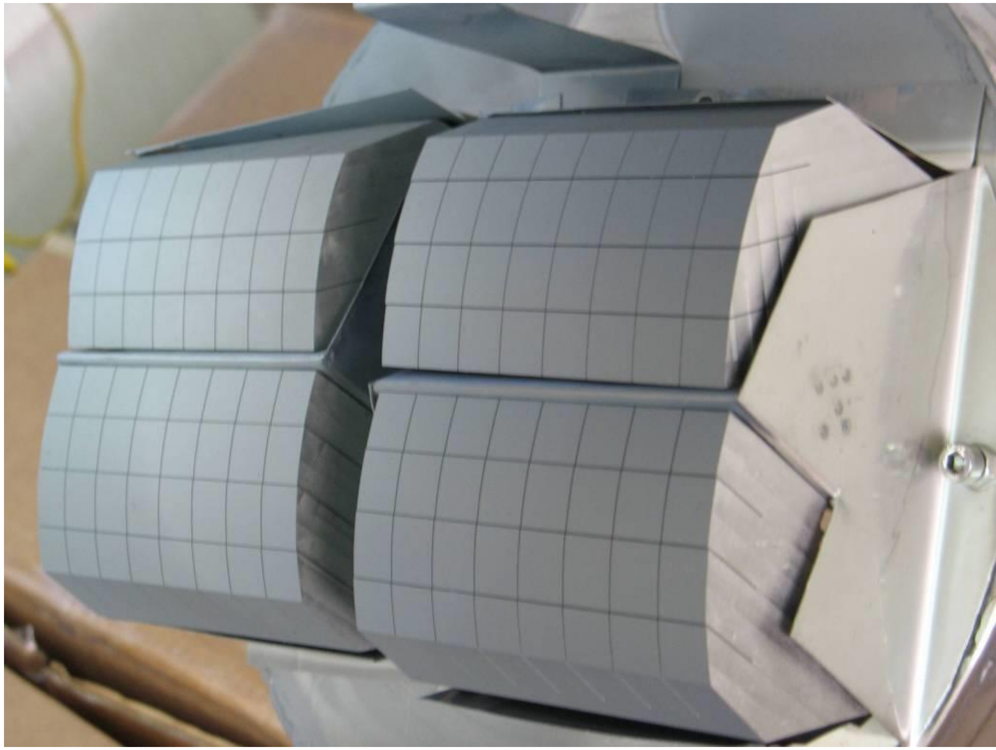
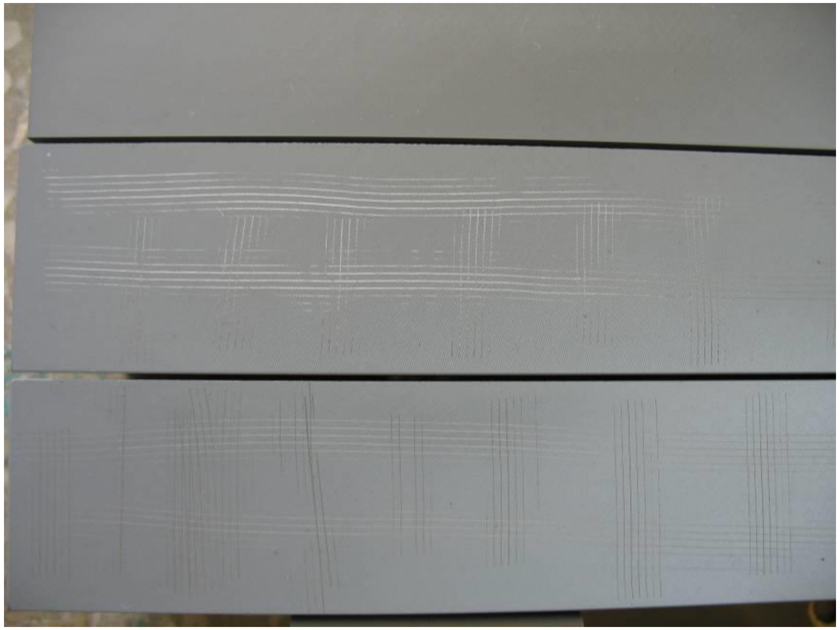
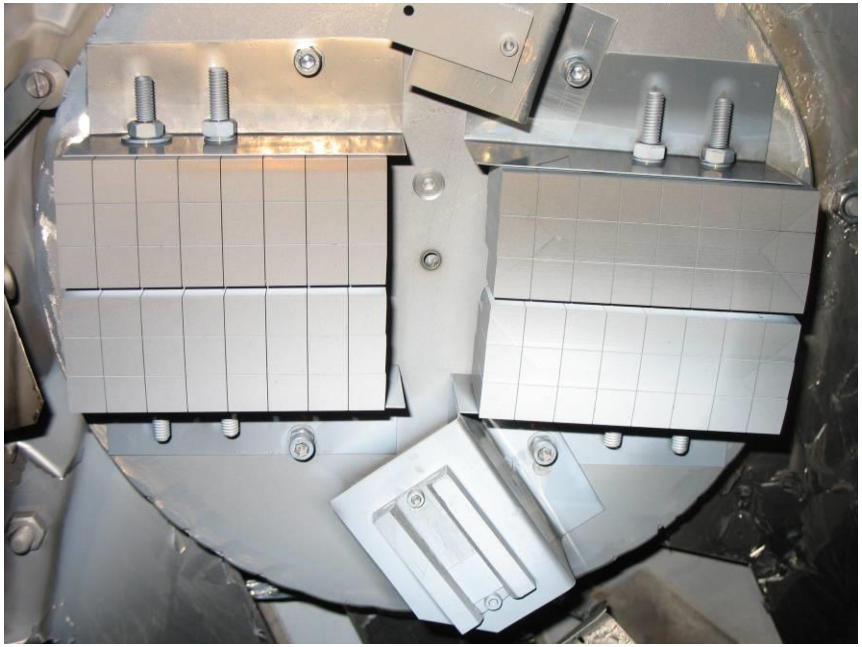
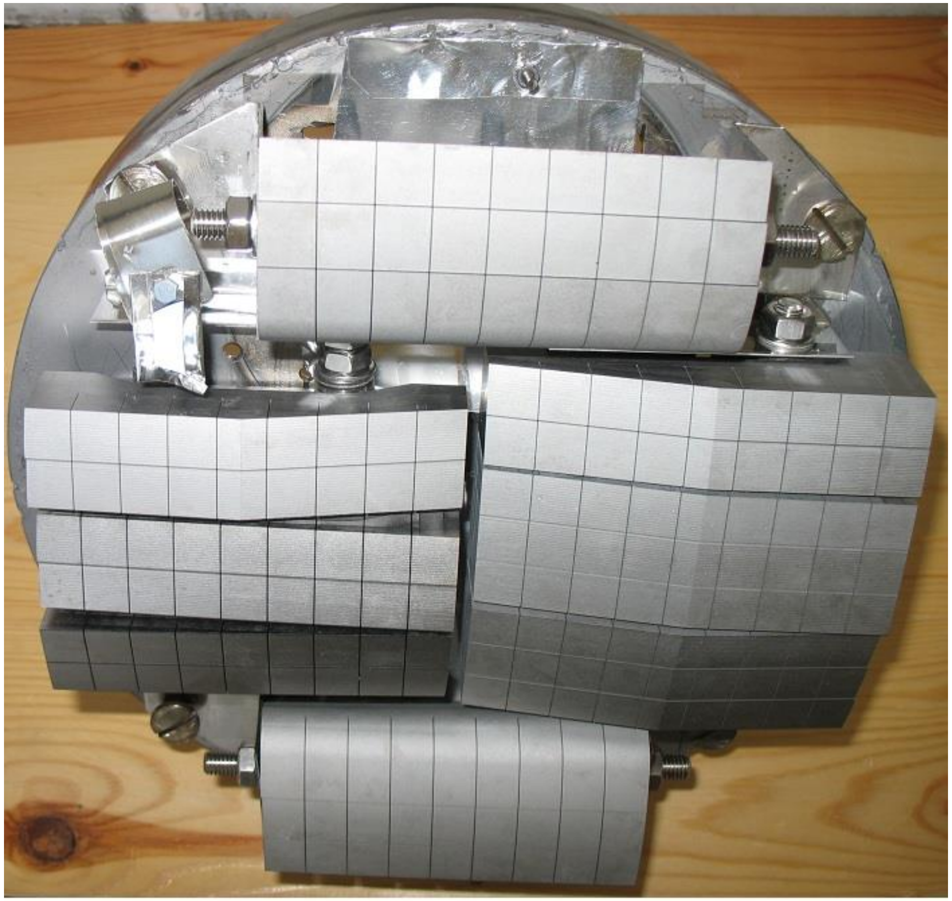


Fig. 25, TC26, 50 cycles of 3.5 MW/m^2 for 10s, BSE image and line scan across the interlayer. O and O background signal at Ni interlayer is caused by artificial effect (high background signal from Ni (high Z) compared with Be (low Z)).

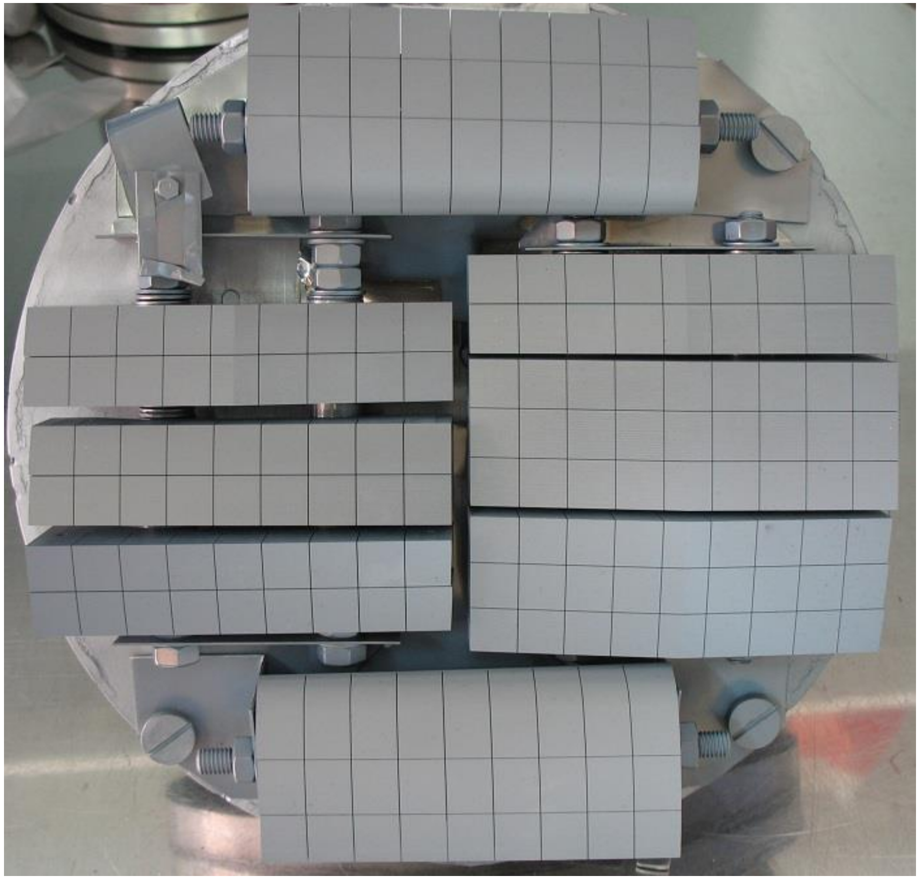




PRODUCTION-Run 5/13.05.2010

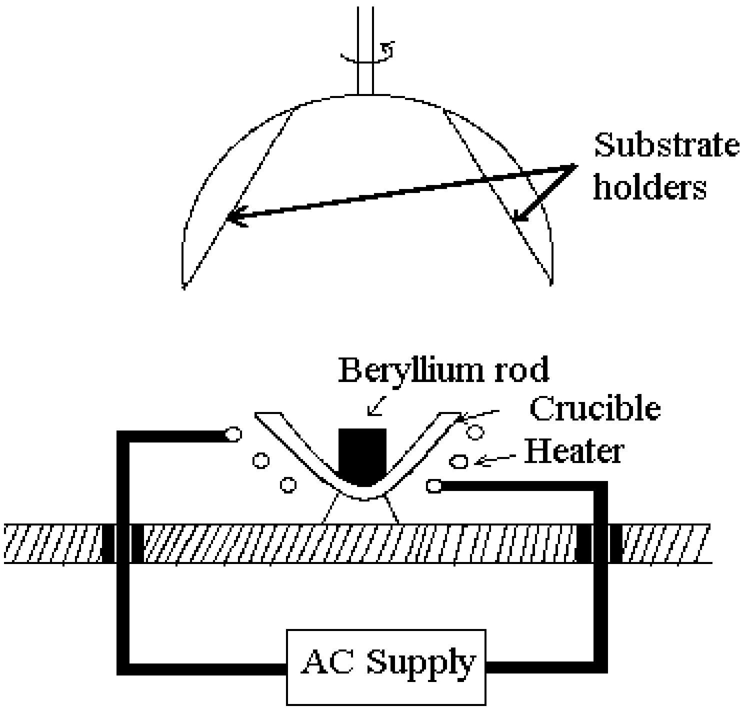
IMG_4155 (**Before** Ni+Be deposition)



PRODUCTION-Run 5/13.05.2010

IMG_4185 (**After** Ni+Be deposition)

Thermal evaporation in vacuum of Be (Manufacturing of Be / inconel tiles)
(in cooperation with **NUCLEAR FUEL PLANT** (NFP) Mioveni-Pitesti, Romania



Schematic arrangement for thermal evaporation in vacuum

Photograph of the substrate holder

Scanning Electron Microscopy,

Microscope XL 30 ESEM PHILIPS (1000 x and 5000 x)

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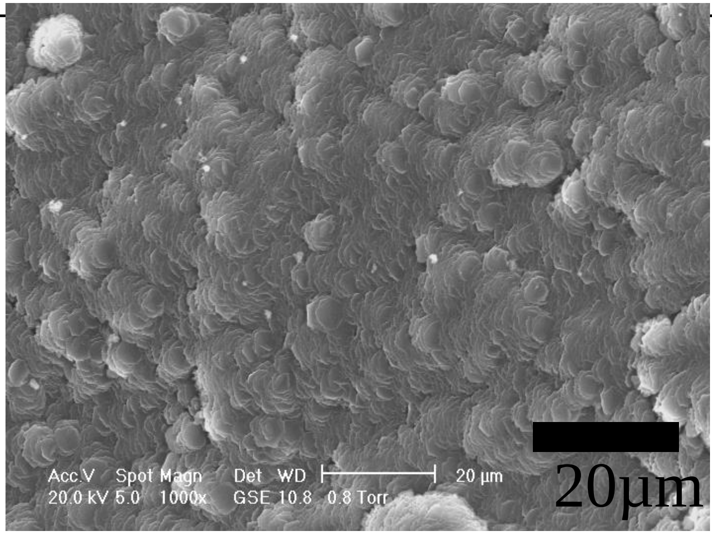
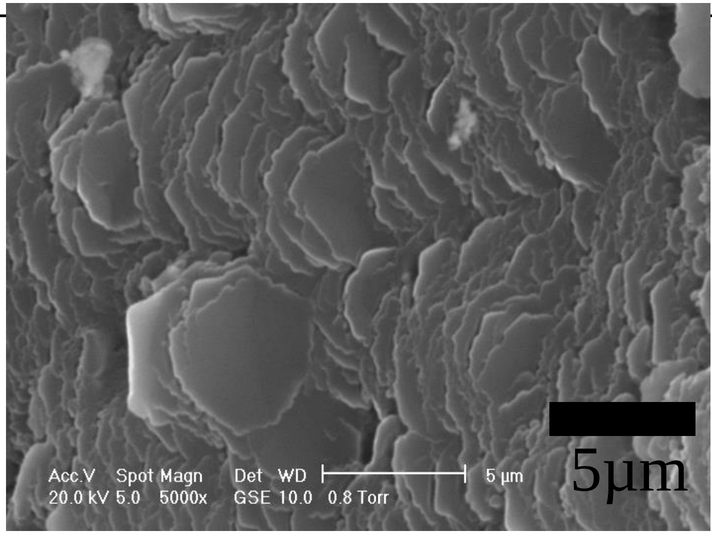
<tr><td>Inconel substrate (THERMAL)</td><td>
</td><td>
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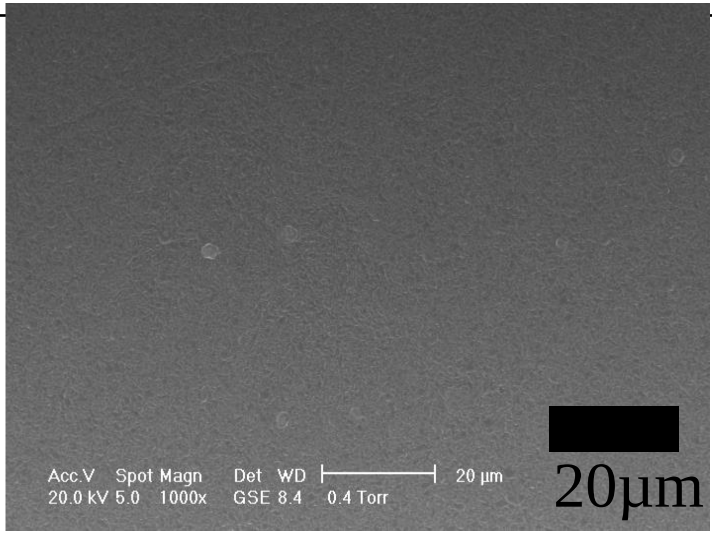
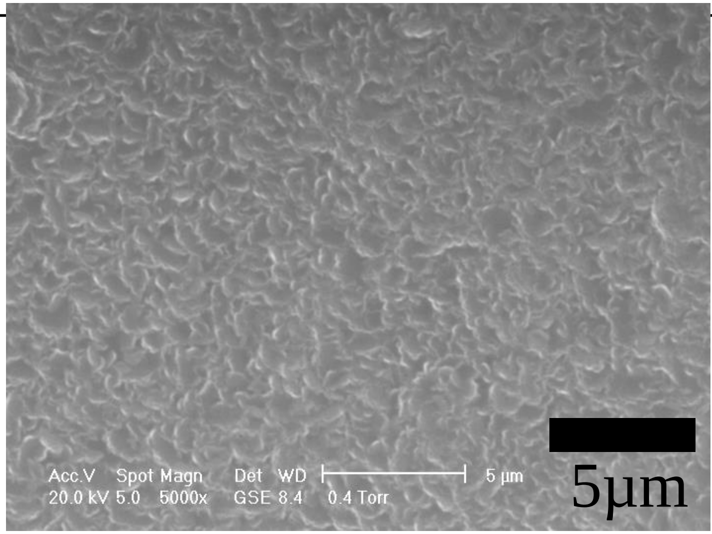
<tr><td>Stainless steel substrate (TVA)</td><td>
</td><td>
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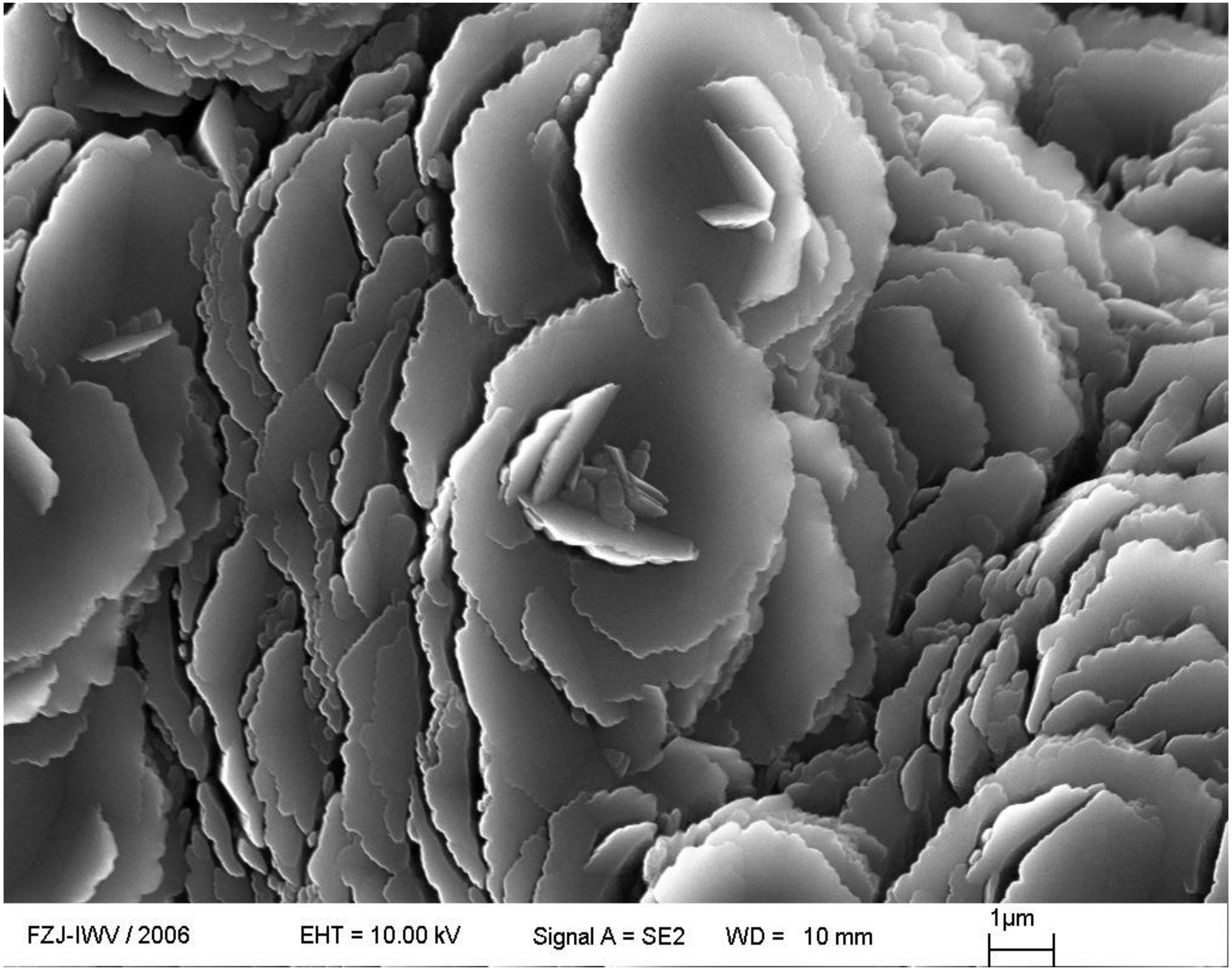
SEM images: microstructure of the Be/Inconel coating from TOP surface

- Consists of platelets, occasionally hexagonal morphology, which originated from crystallographic structure

- Size of platelet ~5 µm



SEM image obtained at FZJ Juelich

2 high heat flux (HHF) test schemes:
✓(i) screening tests,
✓(ii) cyclic heat load tests

JET requirements: 0.5 MW/m^2 for 20 s (10 MJ/m^2)

(i) **Screening** tests

Aim: determine the allowable energy density limit of the Be coating

Tests: energy density of 4 MJ/m^2 to **20 MJ/m^2**, (0.4 MW/m^2 to 1.8 MW/m^2 for 10 s ; **2.6 MW/m^2** for 6.2 s)

(ii) **Cyclic** heat load tests

Aim: study the degradation of the Be coatings by thermal fatigue

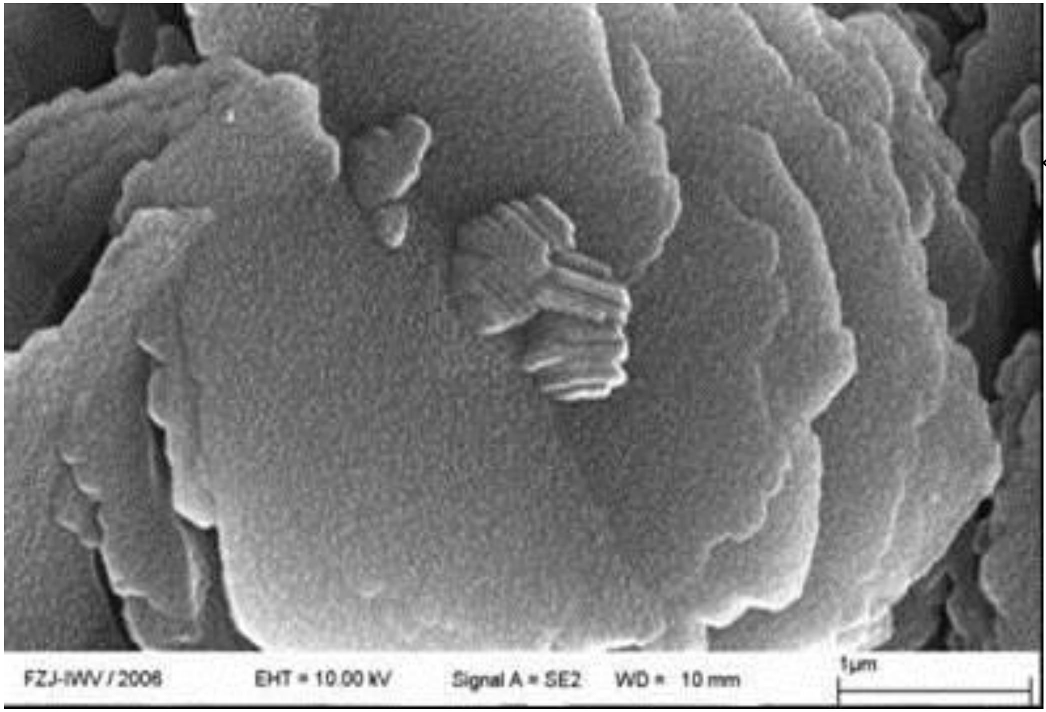
Tests: 50 cycles of 1 MW/m^2 in 10 s corresponding to **10 MJ/m^2**.

✓ **Observation during the high heat flux testing**

• Surface temperature was monitored with a **10 Hz infra-red (IR) camera**

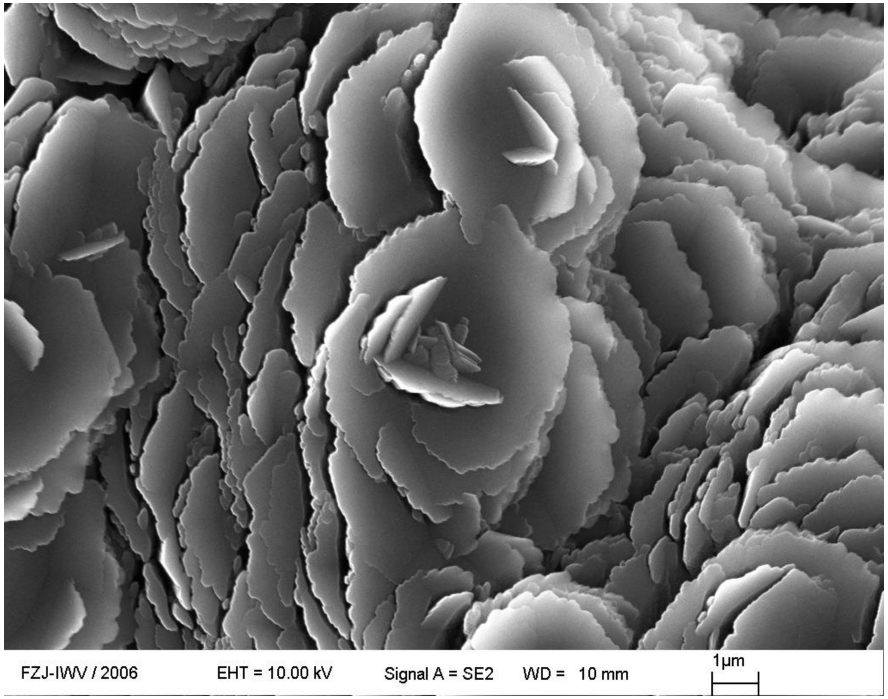
• Surface temperature was measured at a black-coloured surface with an emissivity of 0.85.

- ➢ Surface morphology of Be/Inconel (Inconel_2) after 50 thermal cyclic loads at **1 MW/m^2, 10 s (10 MJ/m^2)**.

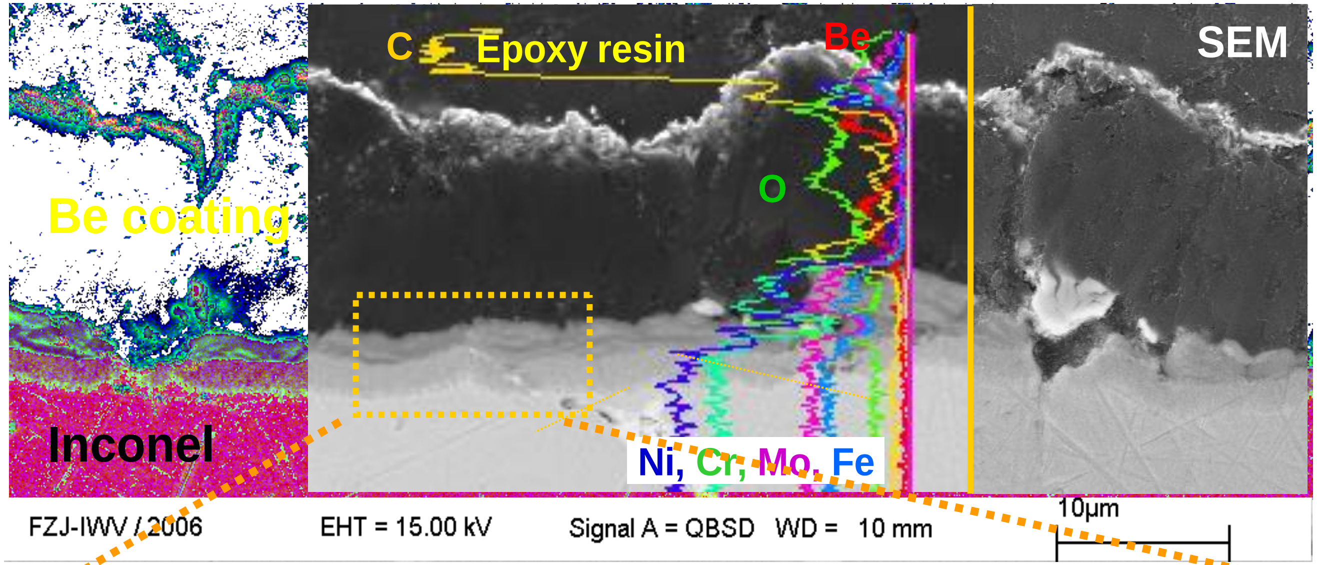


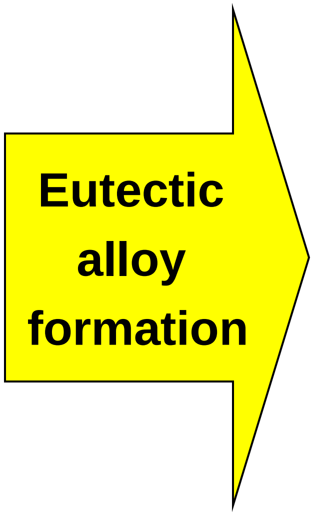
After test

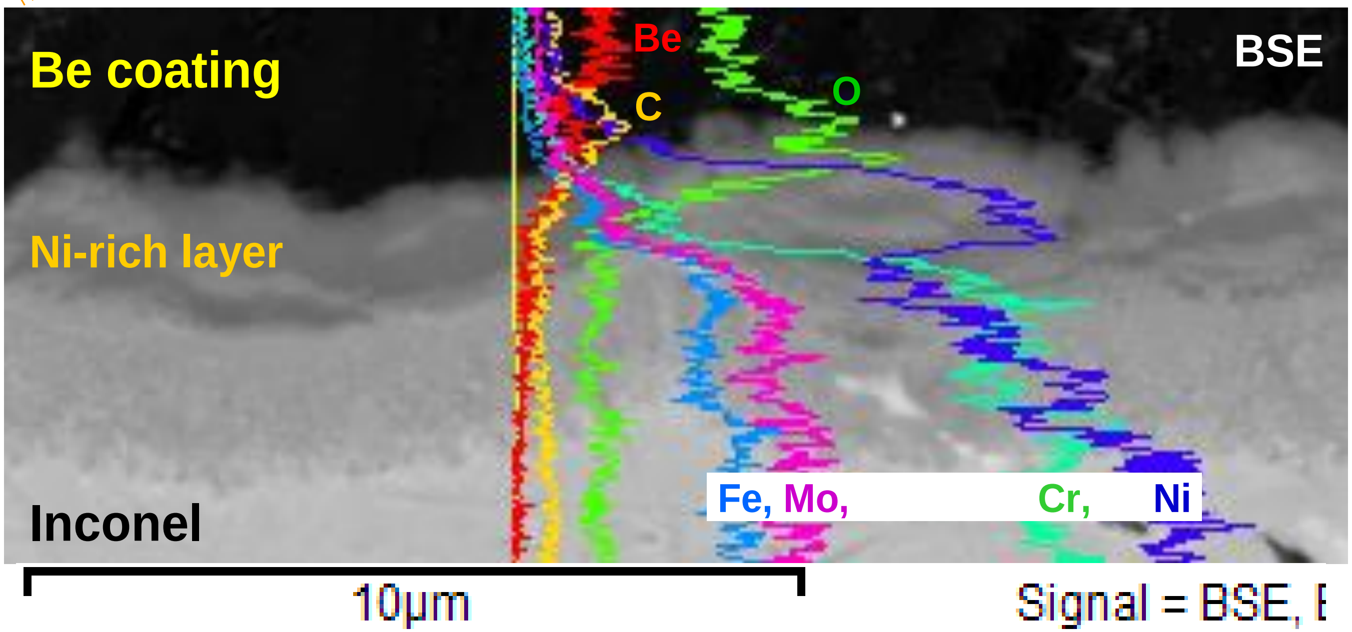
Before



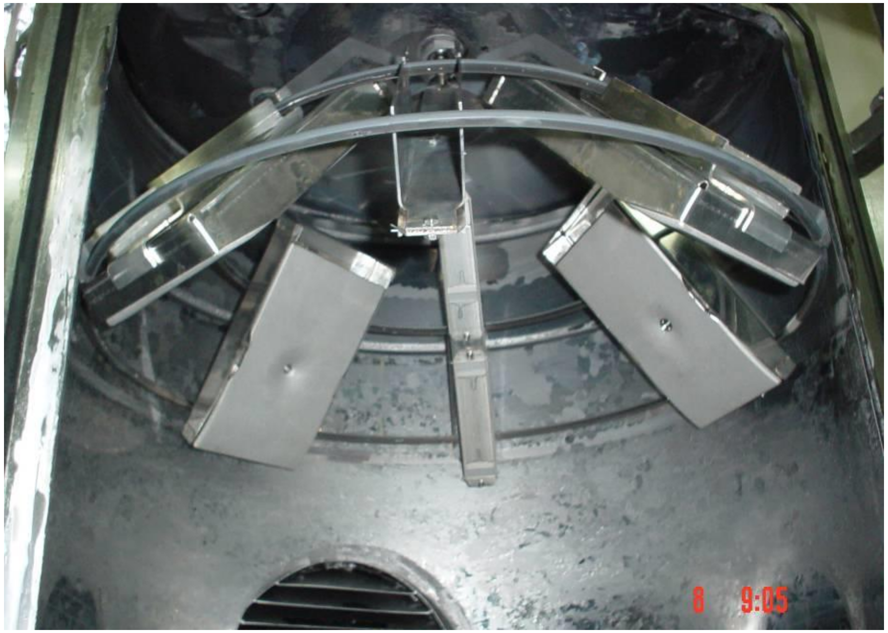
➢ Cross section of Be/Inconel (Inconel_2) after 50 thermal cyclic loads at **1 MW/m², 10 s (10 MJ/m²)**.

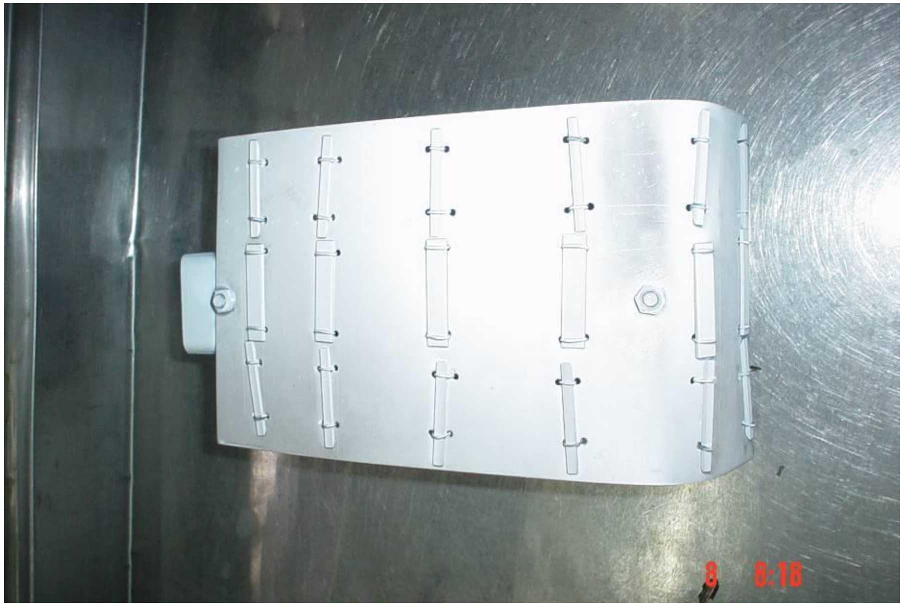


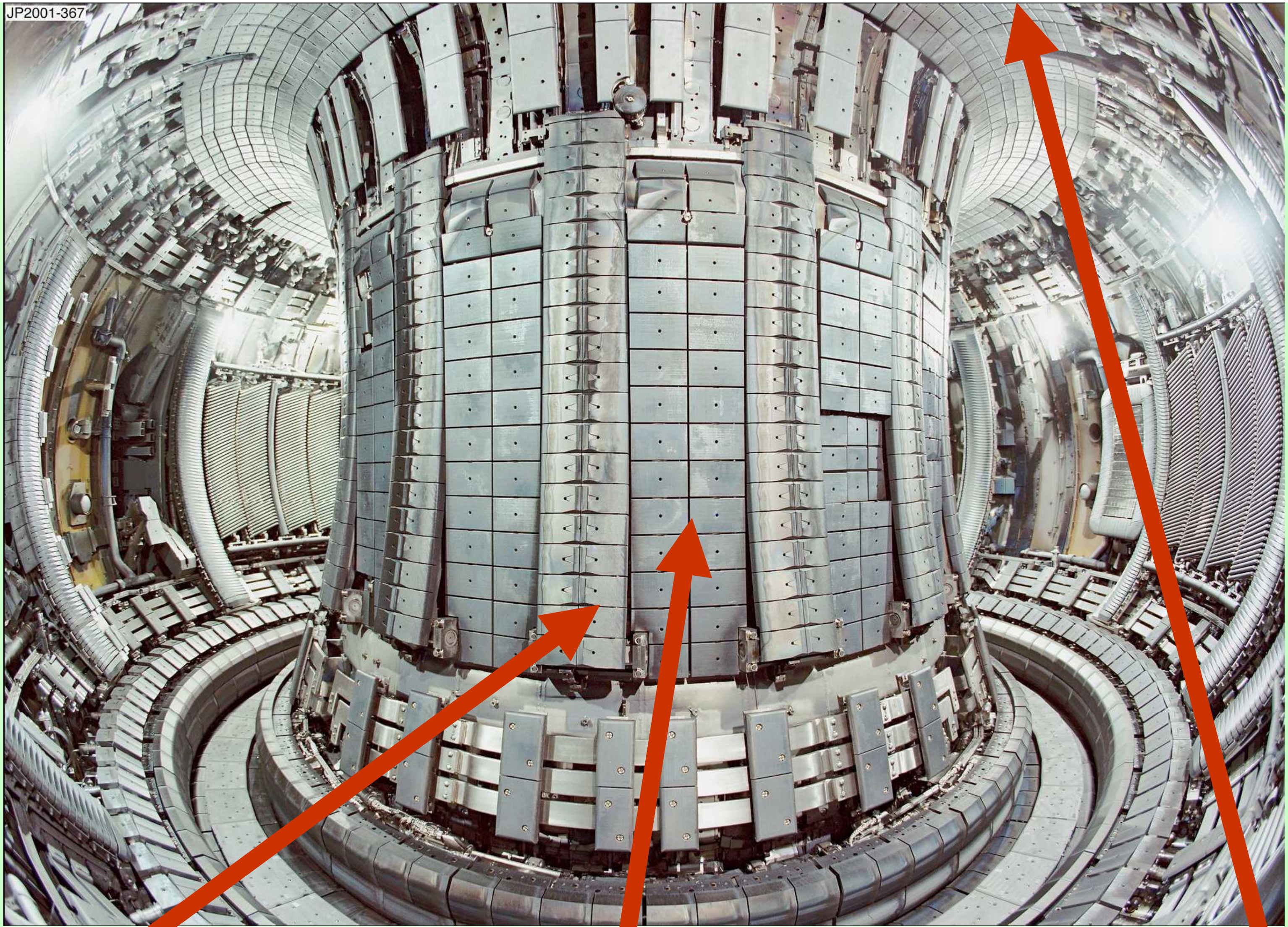




PRODUCTION OF BERYLLIUM COATED INCONEL TILES







Inner Wall Guard Limiter
112 Be Coated Inconel Tiles

Inner Wall Cladding Tiles
272 Be Coated Inconel Tiles

Dump Plates: 512 Be Coated Inconel Tiles

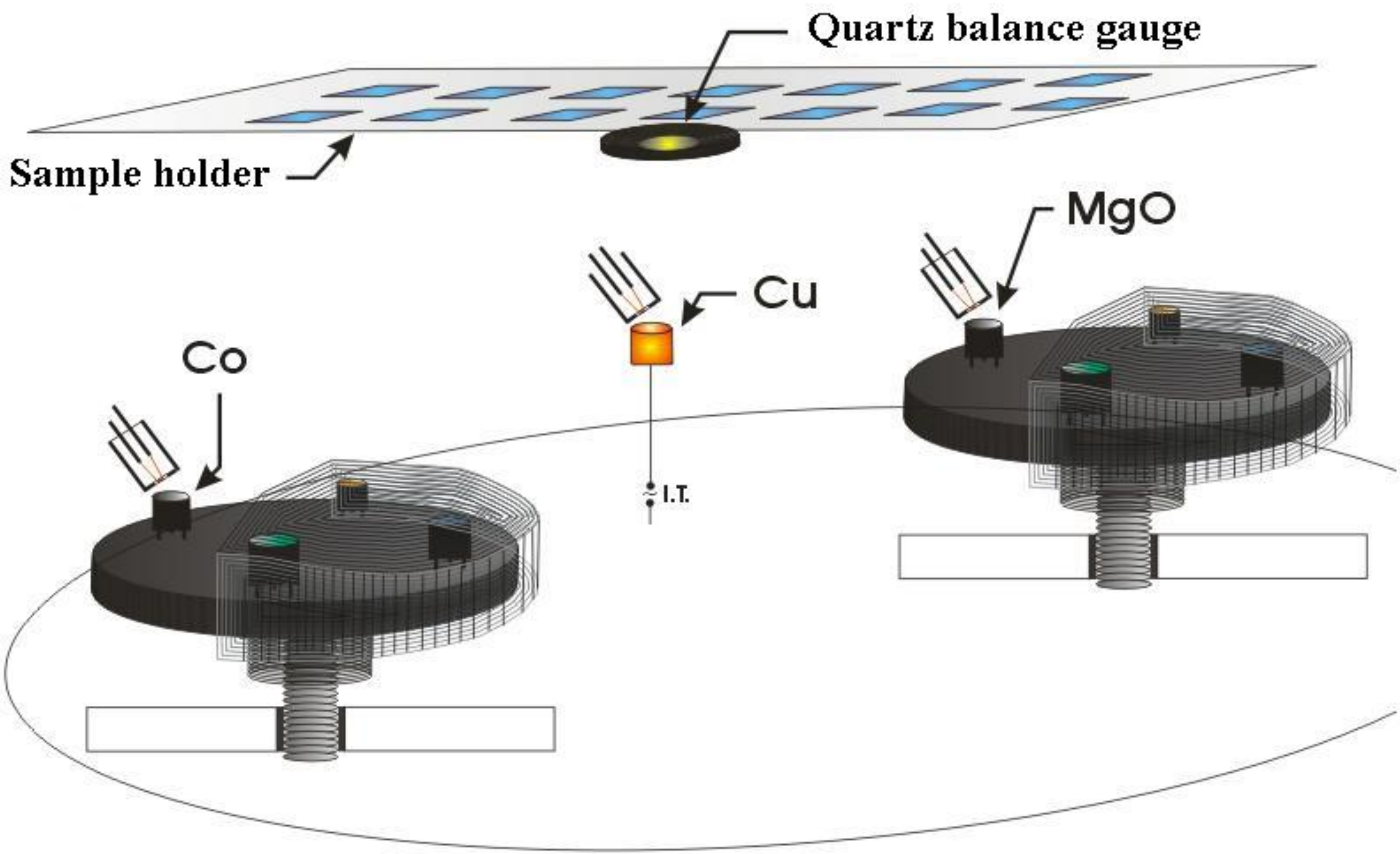
Summary

- Thermionic vacuum arc (TVA) method developed at the National Institute for Laser, Plasma and Radiation, Bucharest, Romania, was used for:
    - Optimization of deposition of pure films: 2-3 µm Ni, 7-9 µm Be
    - Preparation of marker tiles: test samples, test coupons, qualification of the deposition method, pre-production run, production runs
- Thermal evaporation in vacuum method developed at Nuclear fuel Plant, Mioveni-Pitesti, was used for:
    - Production of Be coatings 7-9 µm on inconel tiles: test samples, qualification of the deposition method, pre-production run, production runs

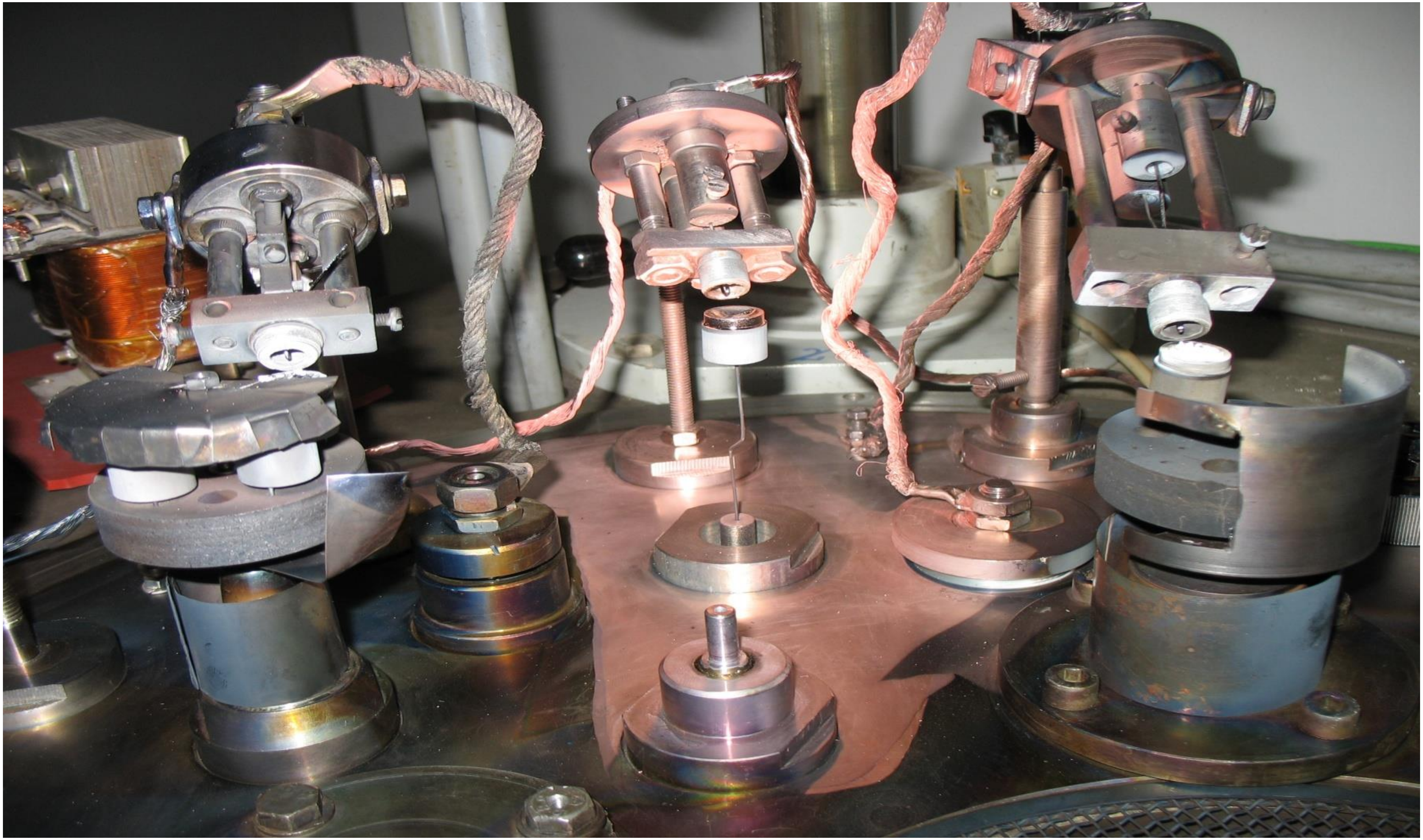
Other applications of the TVA method

- GMR – TMR films
- High temperature resistant to oxidation films
- Low friction carbon based composites
- CIS Solar Cell Electrodes Deposition and Characterization
- Preparation and characterization of hard antireflective coatings

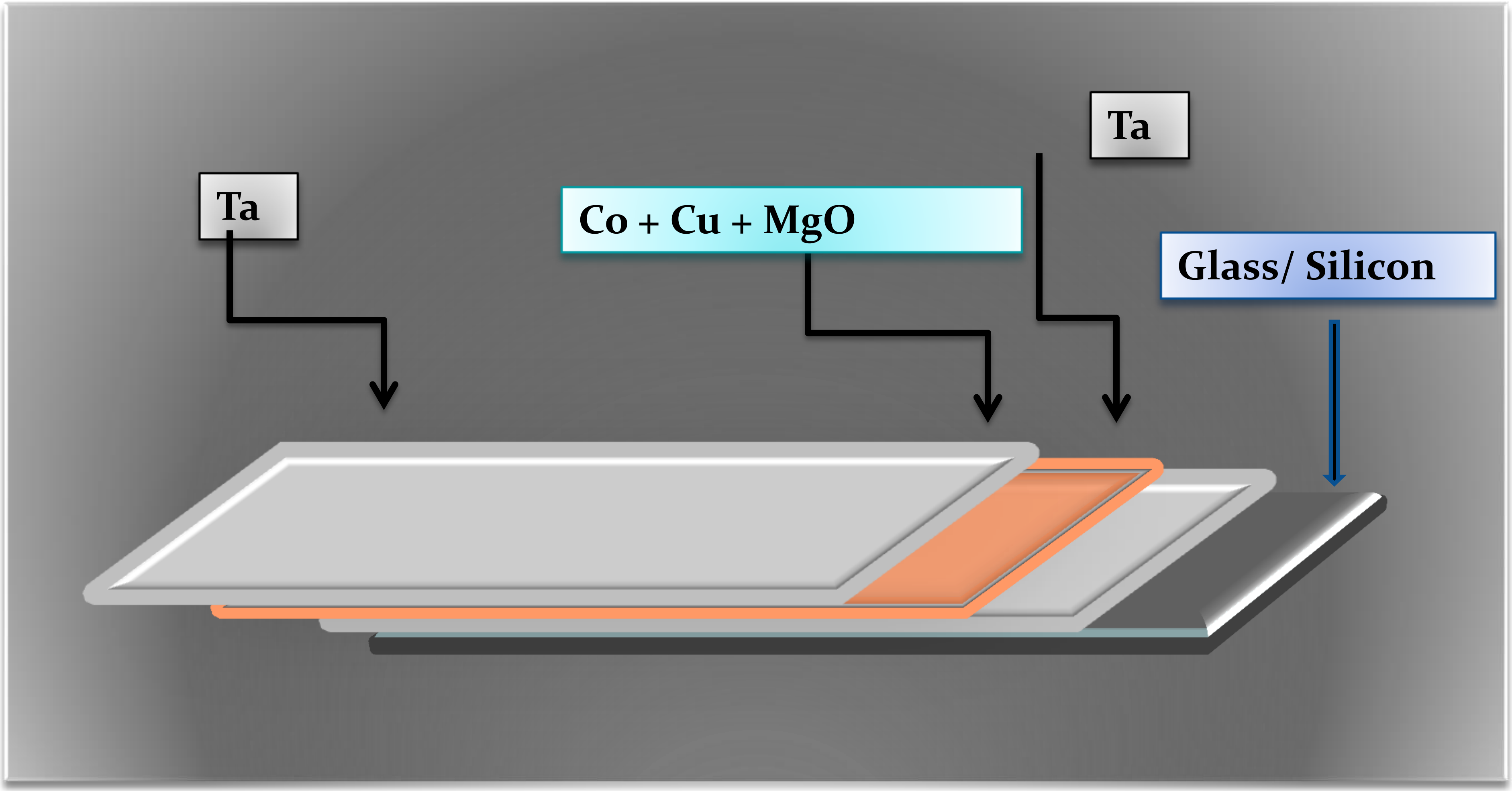
Giant and tunneling magnetoresistive (GMR, TMR) films



Multi elements deposition system

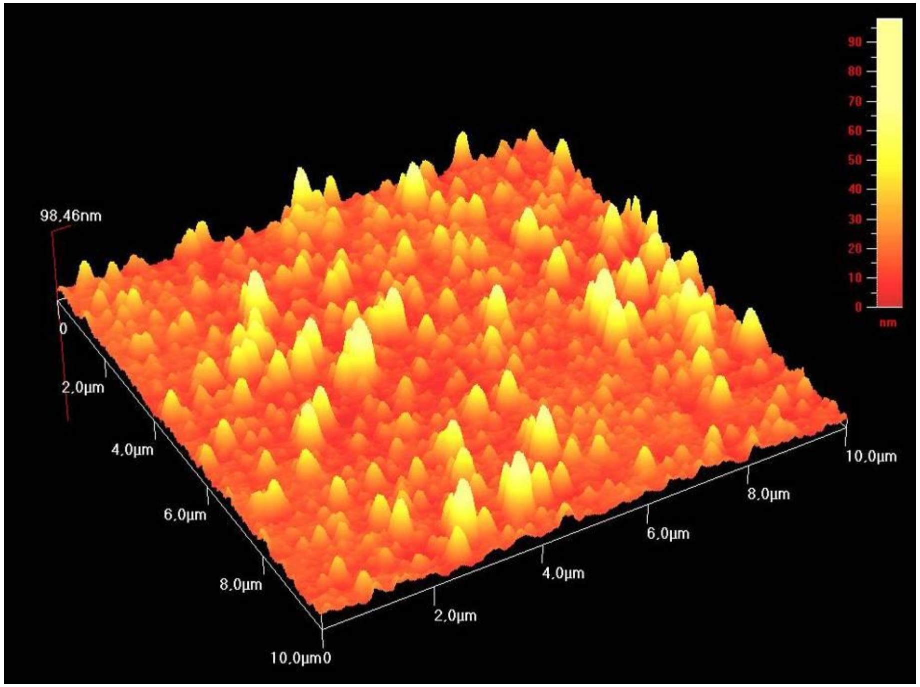


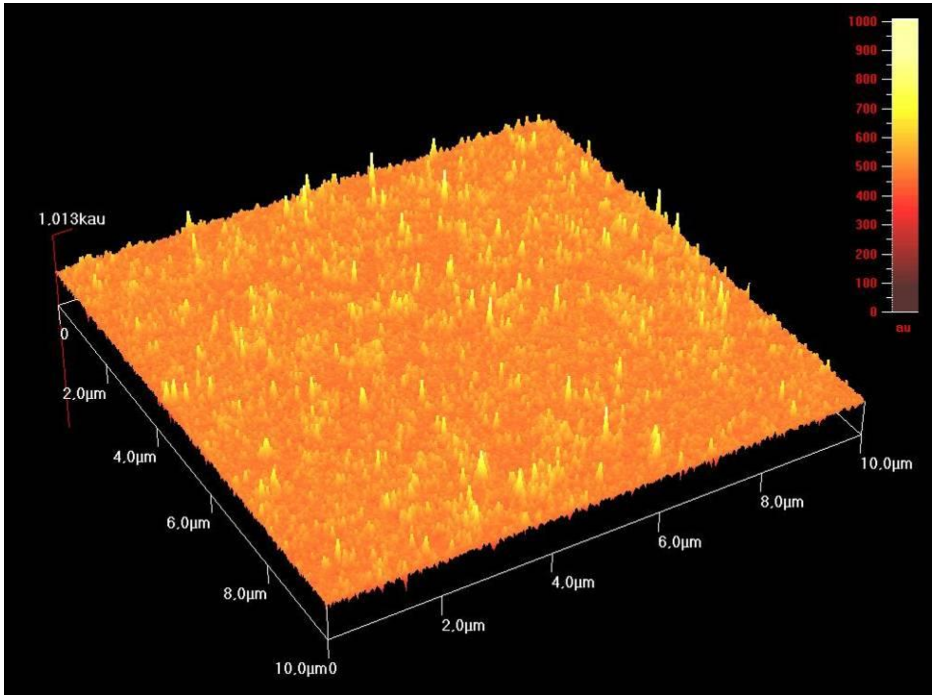
Composite and multilayer coatings

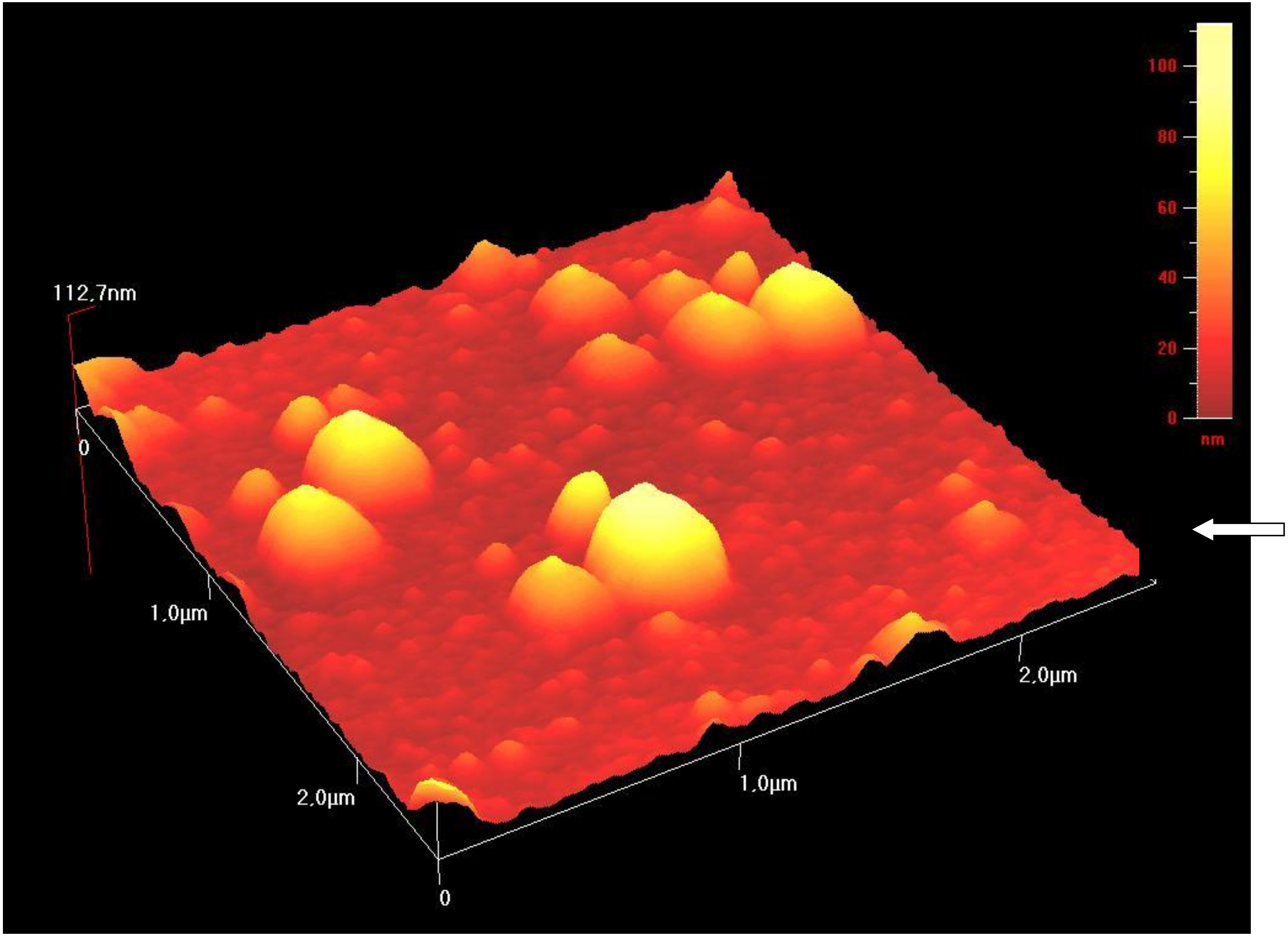


Magnetic force microscopy (MFM):

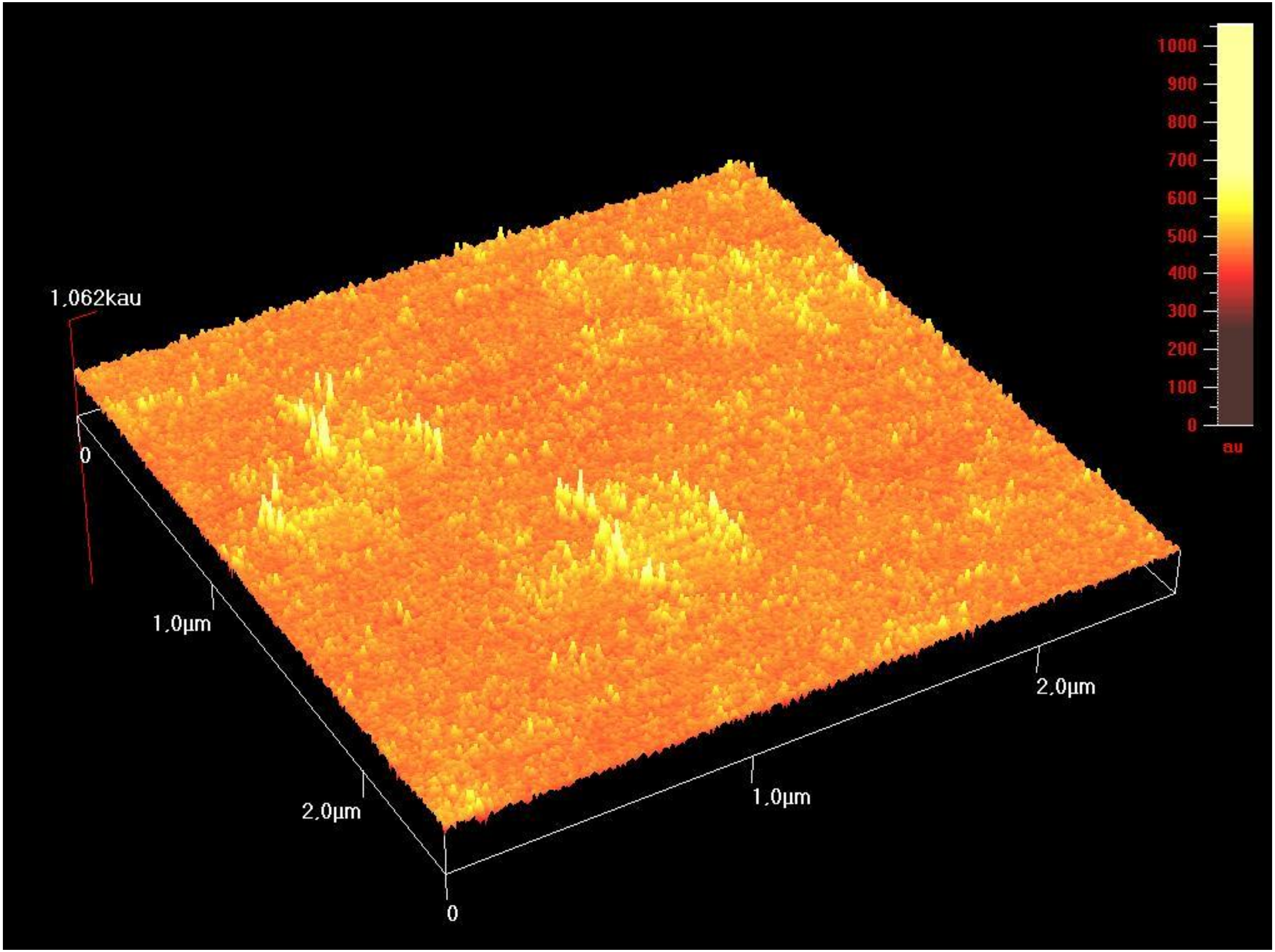
GMR films



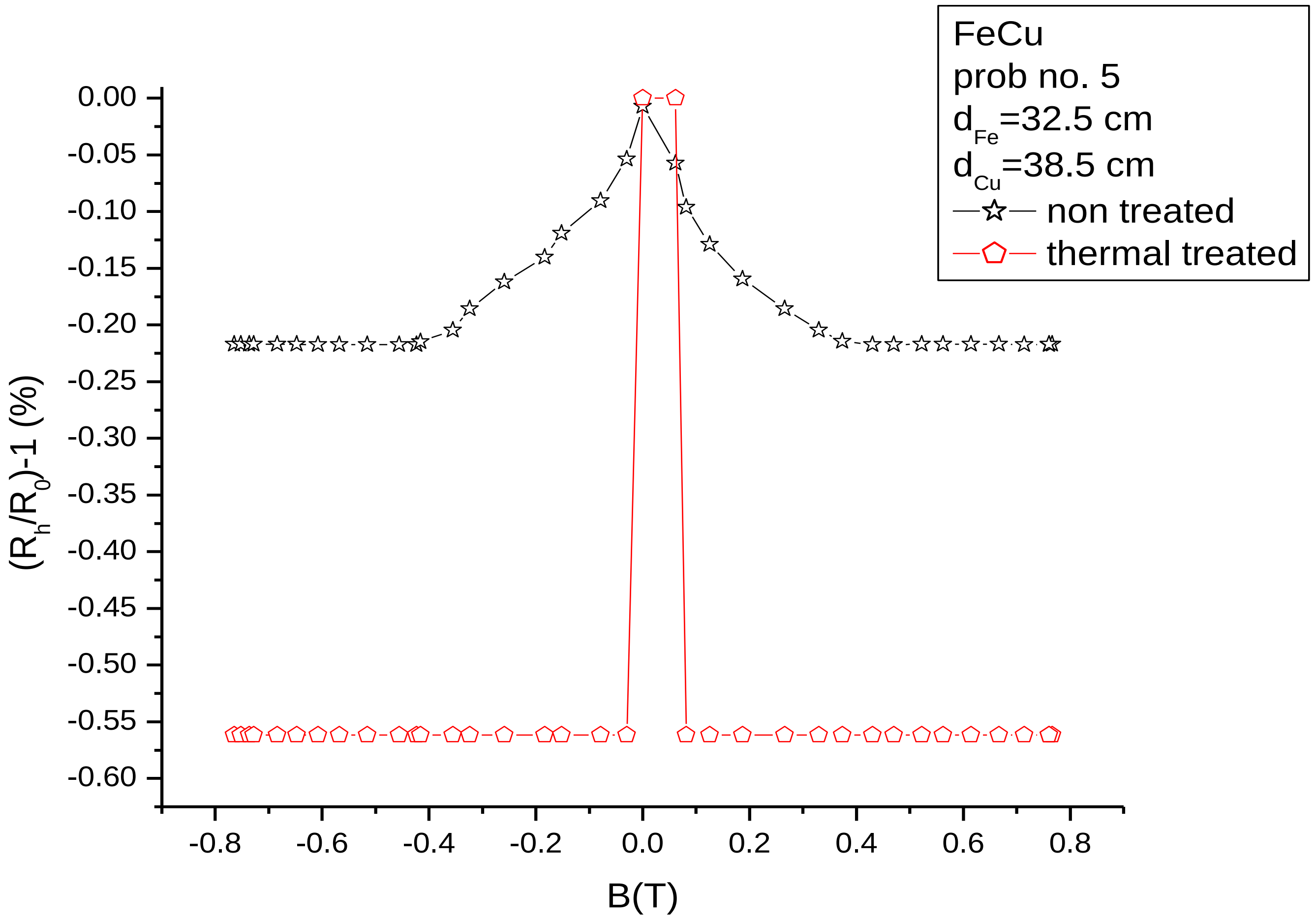




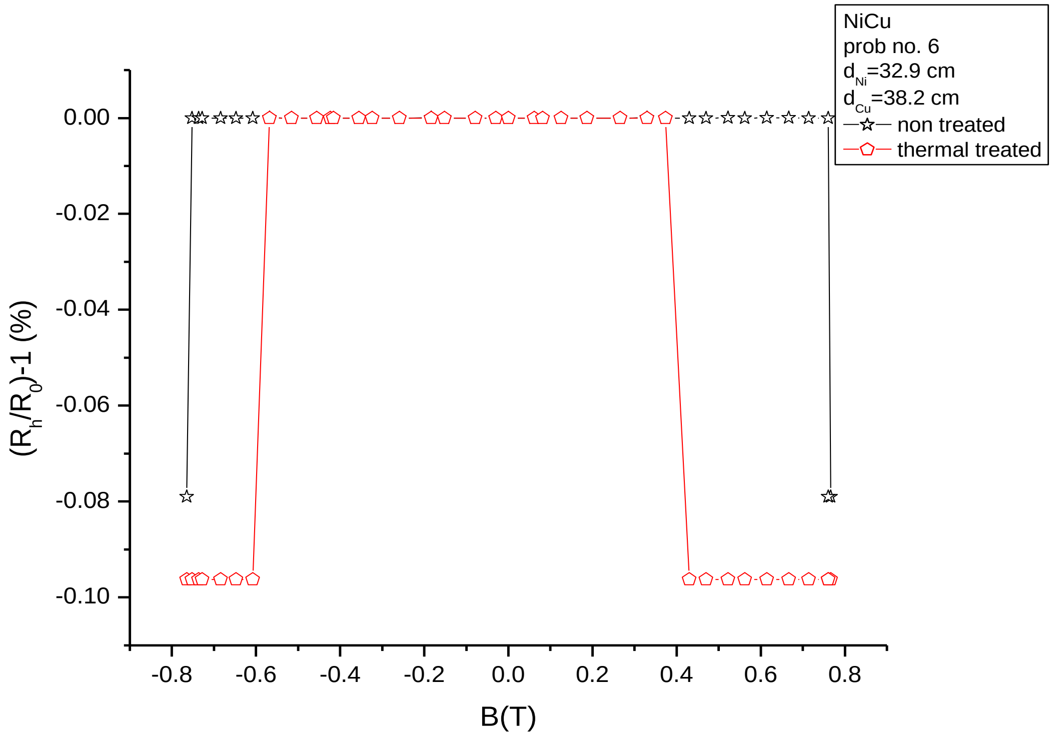
Topographic Magnetic Force Microscopy (MFM) image



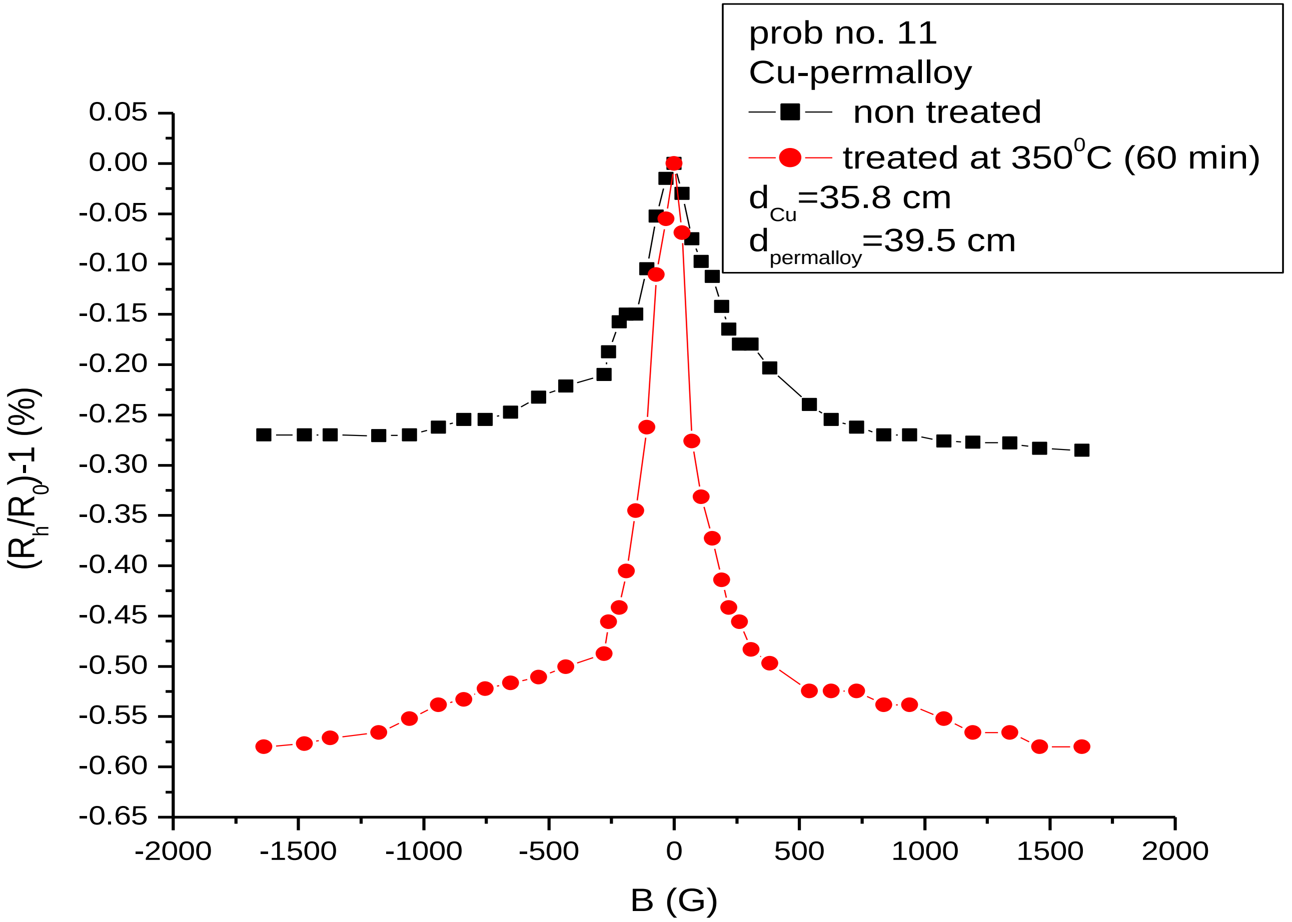
Magnetic domains distribution of a Fe-Cu film



GMR in Fe-Cu at RT and thermally treated: (uniform dimensional distribution of formed domains)



GMR in Ni-Cu composite layer

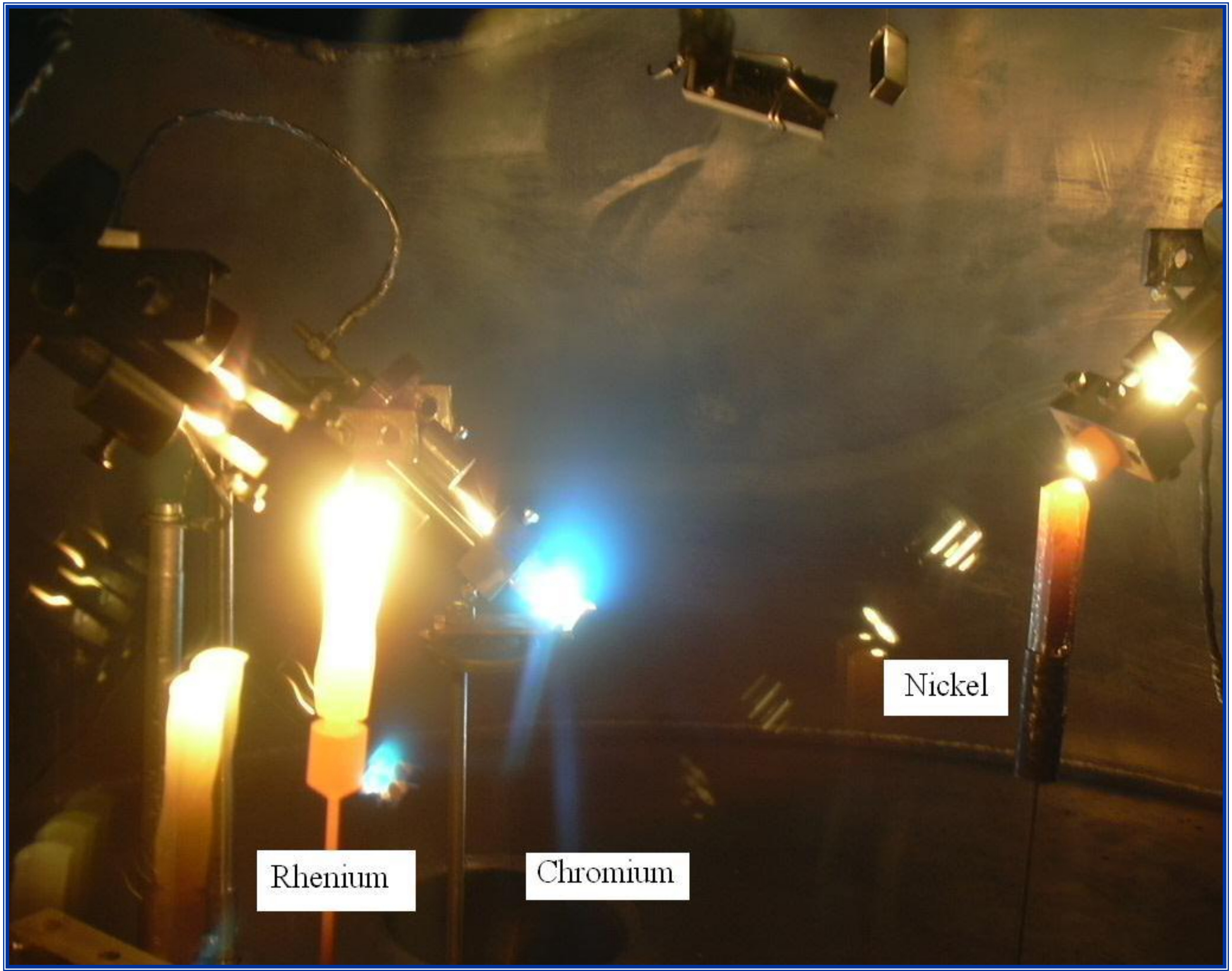


GMR in Cu-permalloy

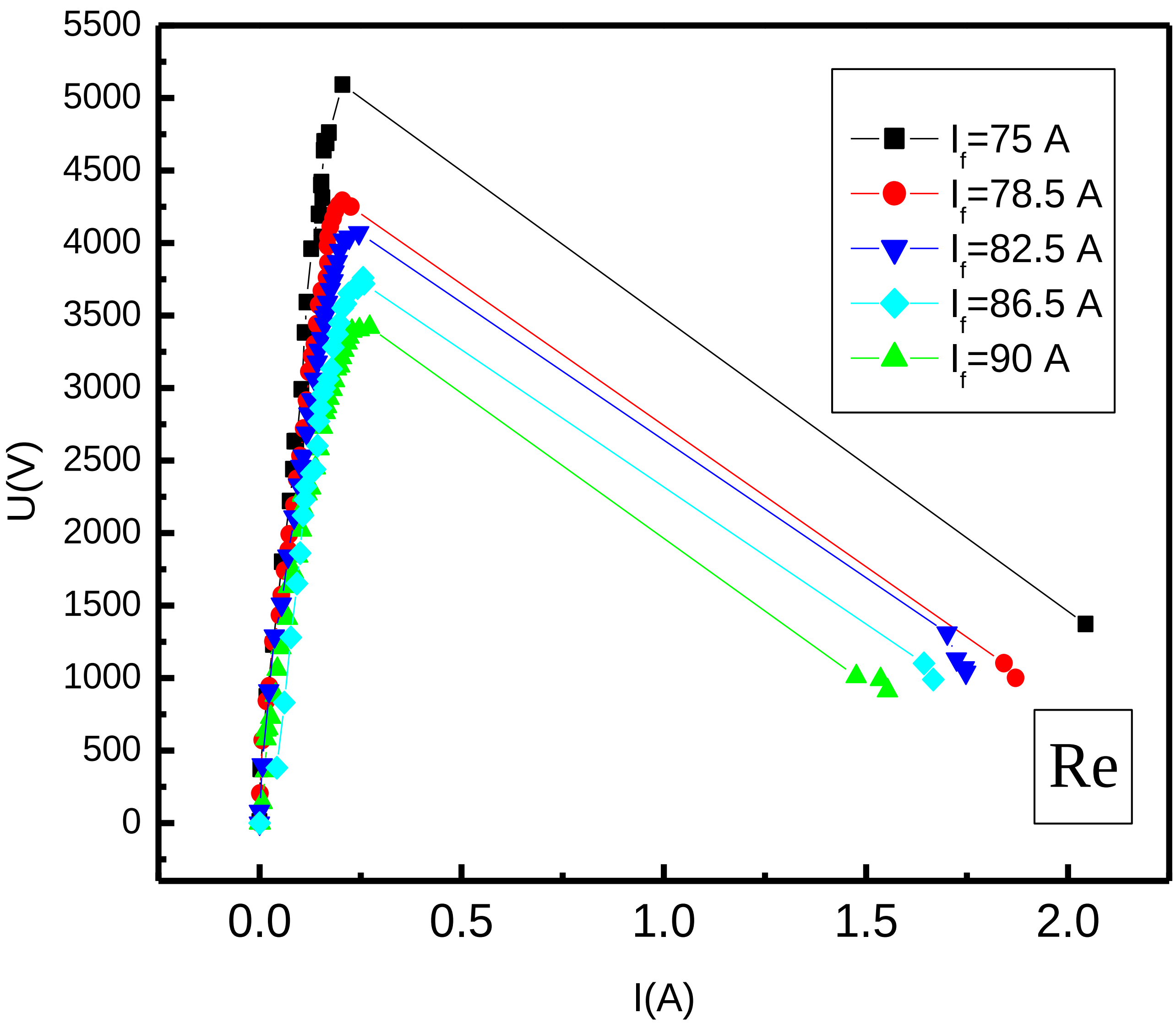
High temperature oxidation resistant composites:

Re, Re-Ni-Cr, Ni-Al multilayer

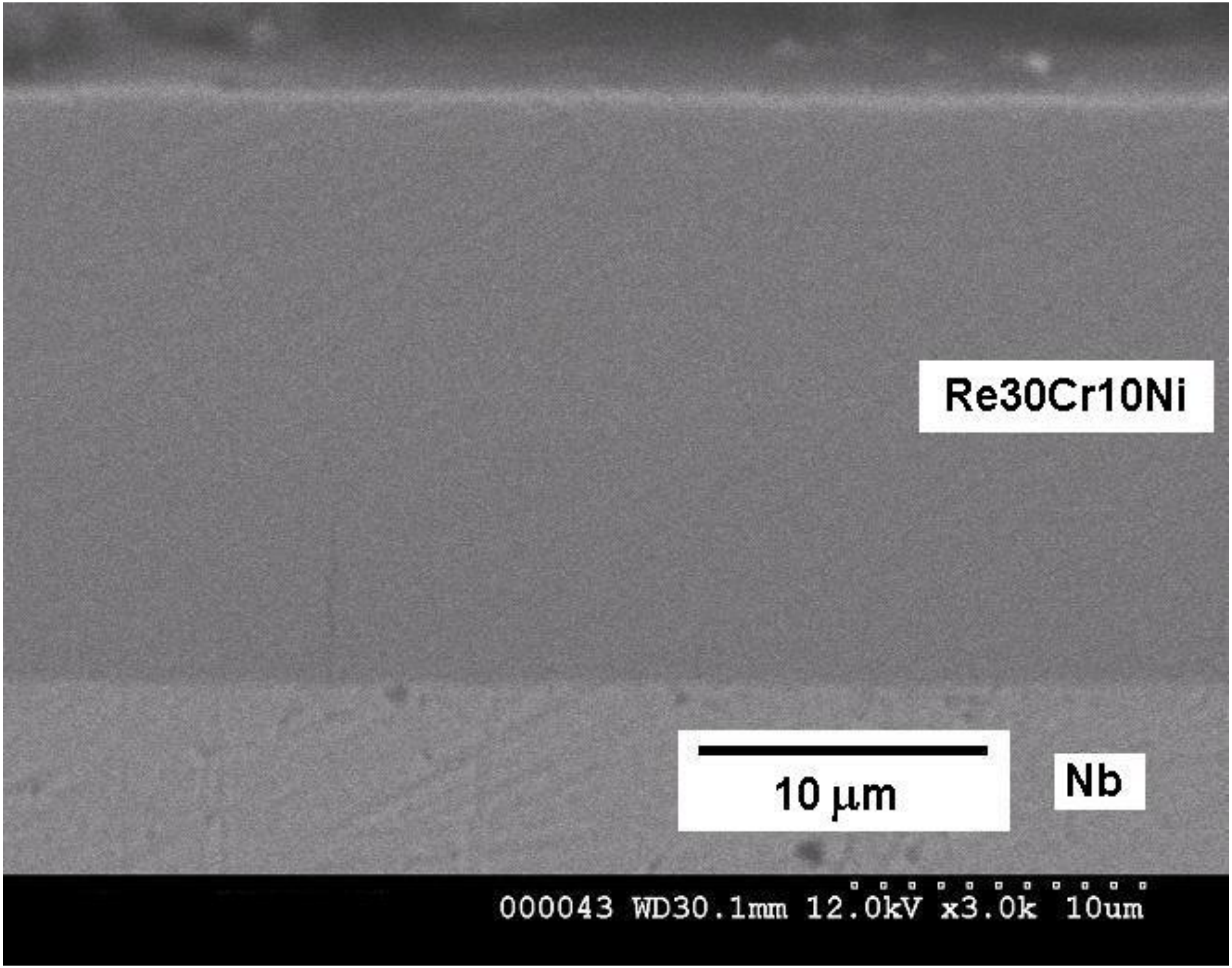
- Plasma ignition in pure Re vapours: thoriated tungsten filament heated by a 90-100 A a.c. current.
- The emitted electrons: were focused on the Re anode by a Mo Whenelt cylinder.
- The anode: Re rod of 8-10 mm in diameter and supported by a Mo flange.
- The distance between the thermoemissive filament and the Re anode: 3-4 mm
- The angle between the electron beam and the vertical line: 60^0.



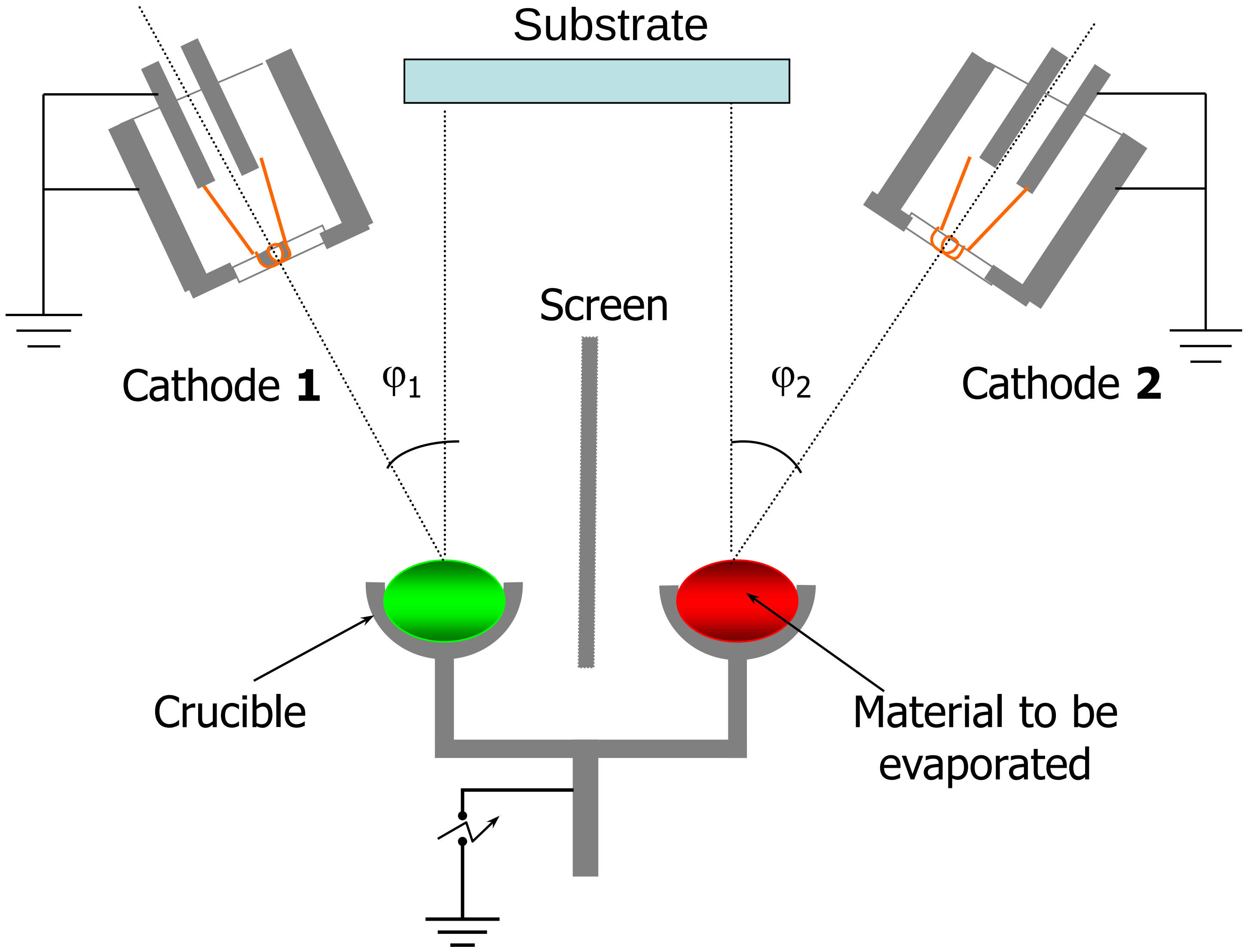
Experimental set-up used for simultaneously depositions of Re, Ni and Cr



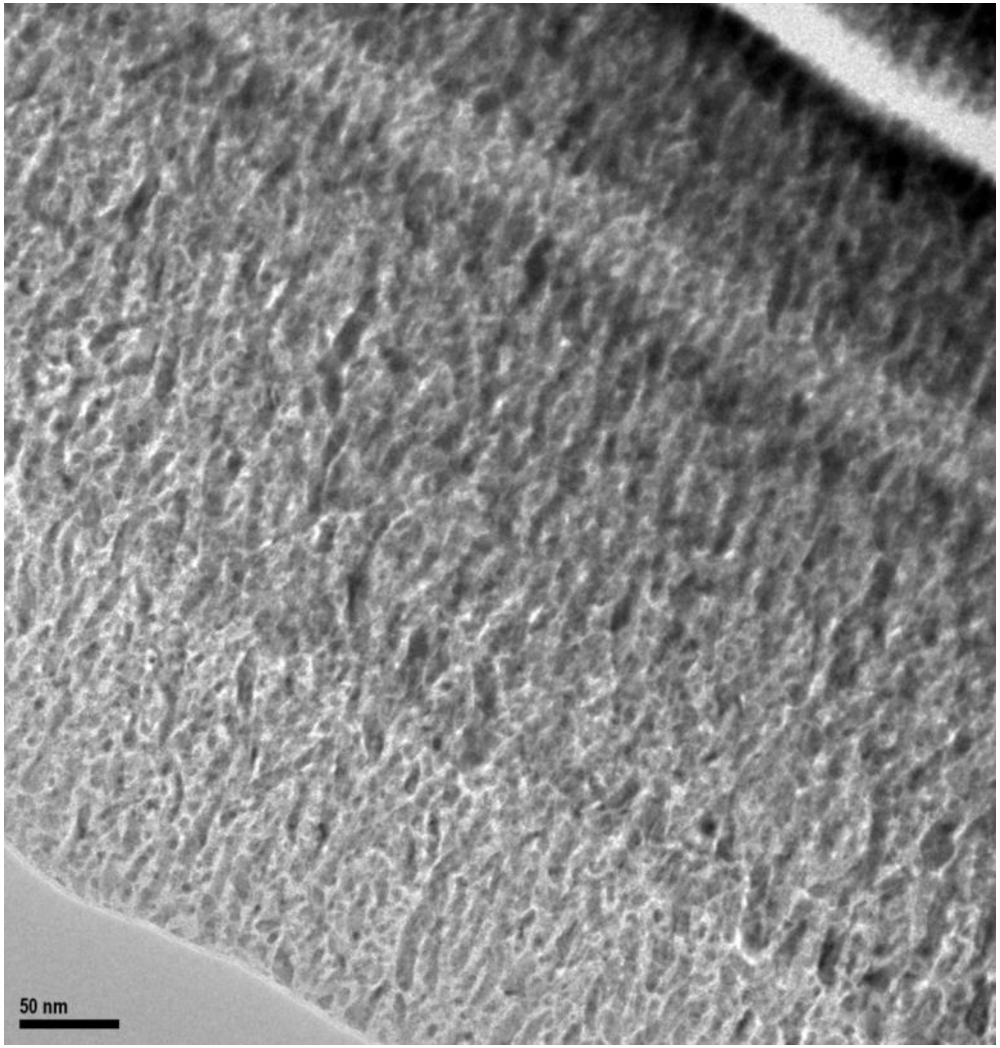
I-V charateristics of Re plasma as function of the filament current

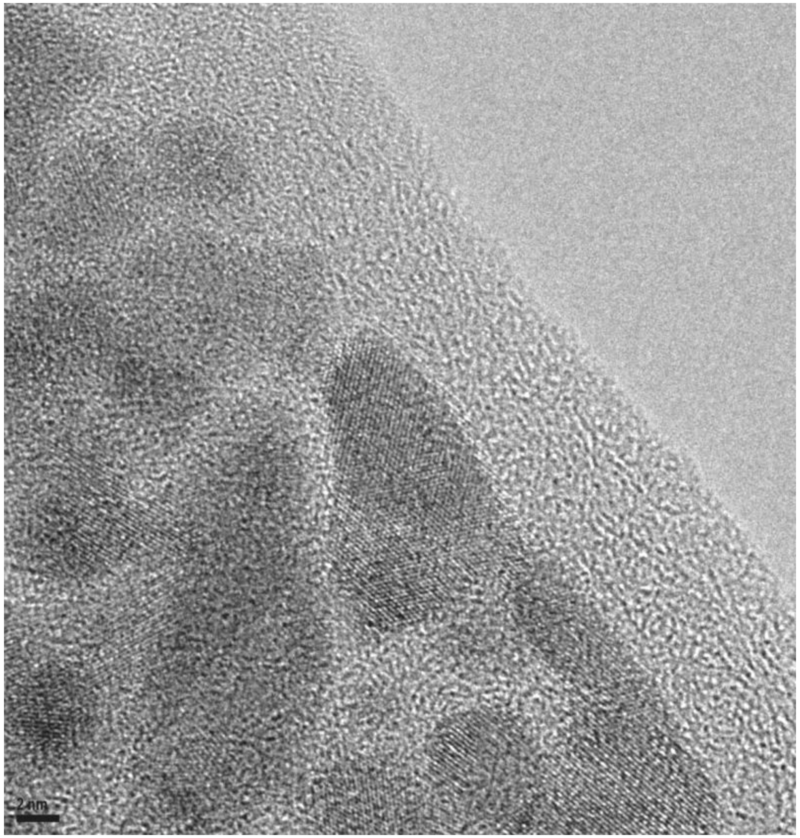

Re30Cr10Ni
10 μm
Nb
000043 WD30.1mm 12.0kV x3.0k 10um

Mixed layer formation –low friction composites



HRTEM of Ni-C layer



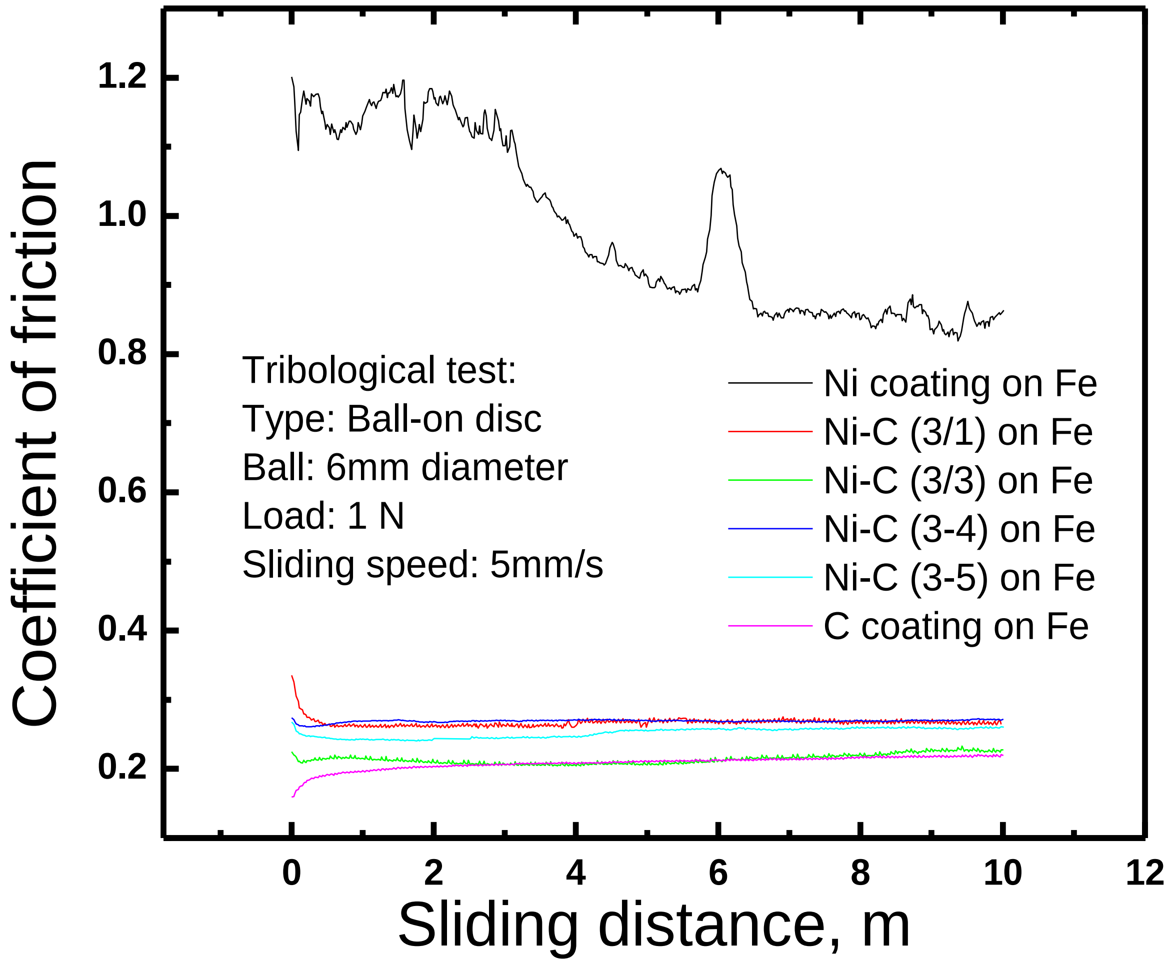


2 nm

Images of the structure of the upper layer: tubular features with about 10 nm width and 50-100 nm length appear together with small grains with a lateral size of about 5 nm.

The mentioned features are surrounded by a brighter carbon matrix.

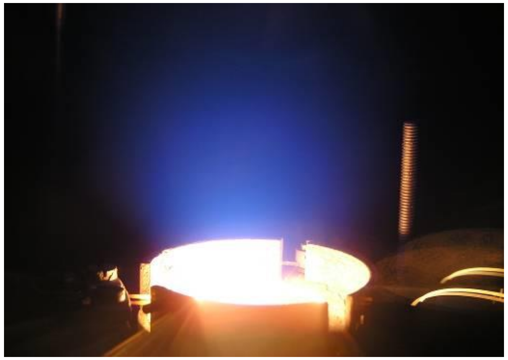
Coefficient of friction of C-Ni composite



Plain bearings for automotive applications

CIS Solar Cell Electrodes Deposition and Characterization

CuInSe2 (CIS) is an attractive material for high efficient, light-weight and cost effective flexible thin film solar cells.
A variety of flexible substrates: metallic foils, plastic materials, of thickness 0.02 mm are used to the CIS cell circuit.
The plastic materials are metallized by depositing a thin layer (approx. 0.5 μm) of Mo, Ni, Au, Ag, etc. by thermionic vacuum arc method for the back contact of the solar cell.
The metallized plastic materials are used as a cathode in an one-step electrodeposition process for growth of CIS thin film absorber material.



Plasma in Ni vapors

PREPARATION AND CHARACTERIZATION OF HARD ANTIREFLEXIVE DLC COATINGS

Preparation of the protective, antireflective coatings for optical components: windows, lenses

Wavelength range: (IR); 4-20 microns