Participation
IAP NAS of Ukraine
in understanding of vacuum breakdown phenomena

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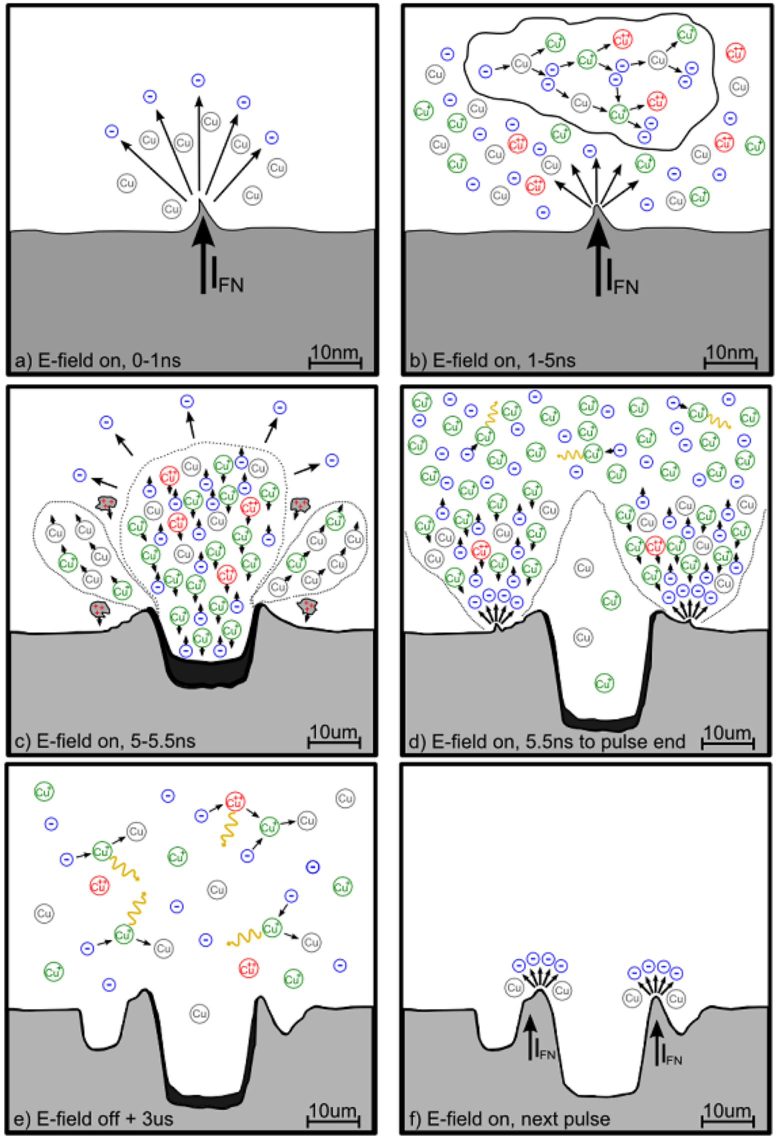
Outline

1. • Optical spectroscopy of breakdown
2. • New DC-spark system in IAP NAS of Ukraine
3. • Magnetic field effect studies
4. • Effect of ion implantation on work function

Principle of Optical Emission Spectroscopy



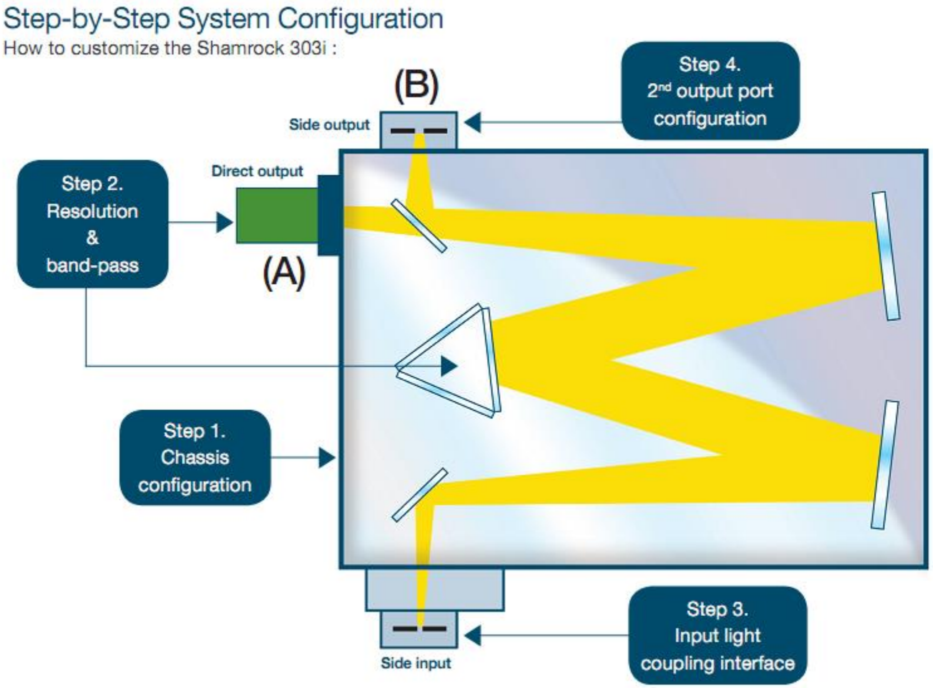


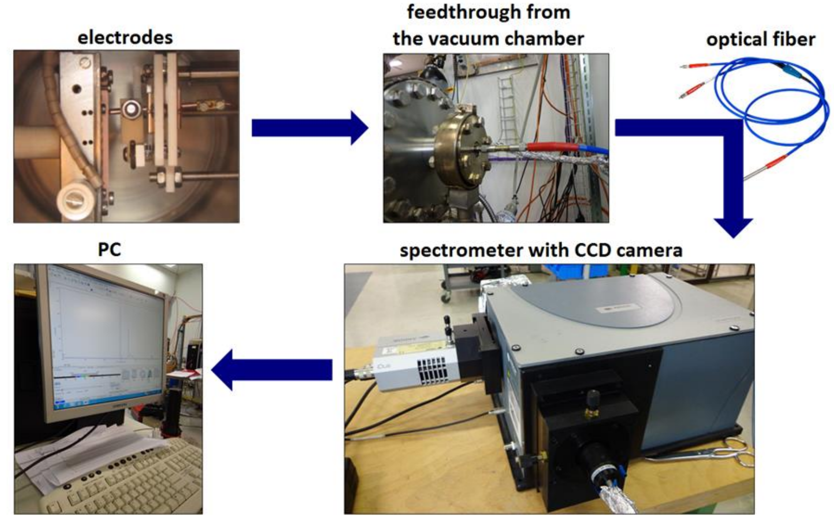
Fig. 3.2. Principle of spectrometer work.

Fig. 3.1. Breakdown stages in chronological order

Optical spectroscopy of breakdowns

Experimental setup

DC-spark system at CERN

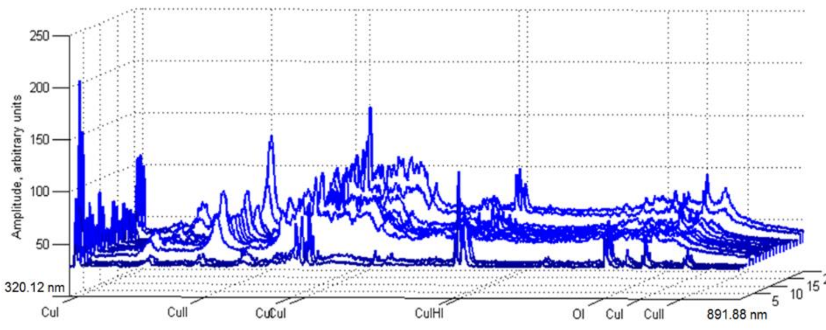


The scheme of setup for optical spectroscopy of breakdowns

Specifications for optical spectroscopy parts			
Optical fiber	bandpass, nm	400-2100	
CCD camera	active pixels	1024×255	
	pixel size, um	26×26	
Spectrometer	grating, l/mm	150	1200
	resolution, nm	0.88	0.1
	bandpass, nm	600	67

The basic results

1. The emission lines of CuI, CuII and CuIII were indentified.
2. The emission lines of some gas impurities were found (HI, OI).
3. The changes in the first and consecutive spectra were found.



A comparison of the optical spectra for 20 consecutive breakdowns

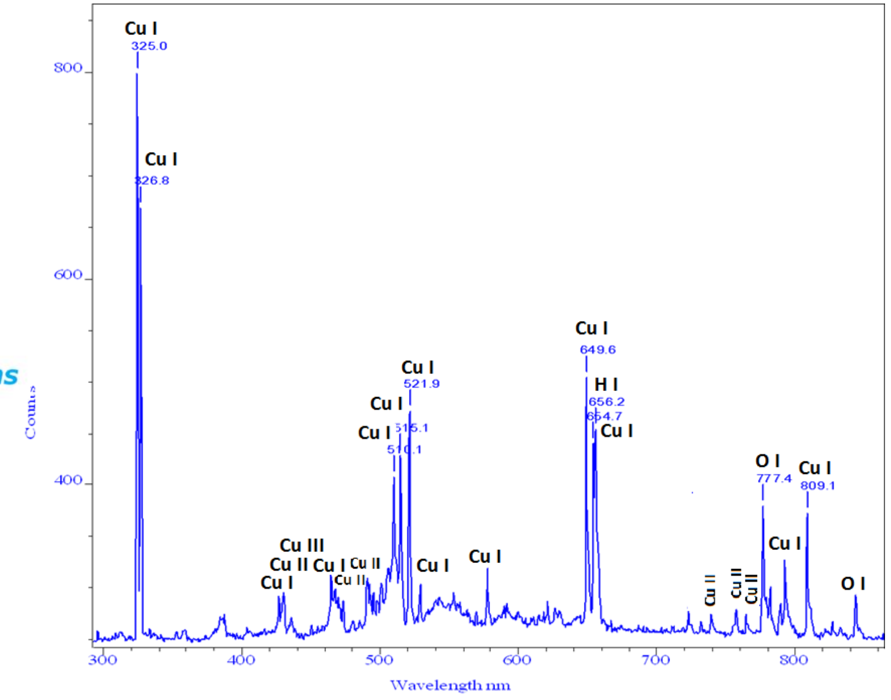


Fig. 5. The emission spectra of the first breakdown at the surface.

Table 5.Experimental conditions.

Parameter	Value
Gap distance	20 μm
Voltage	8 kV
Pressure	9×10^{-9} mbar

Possible development of OS of breakdown

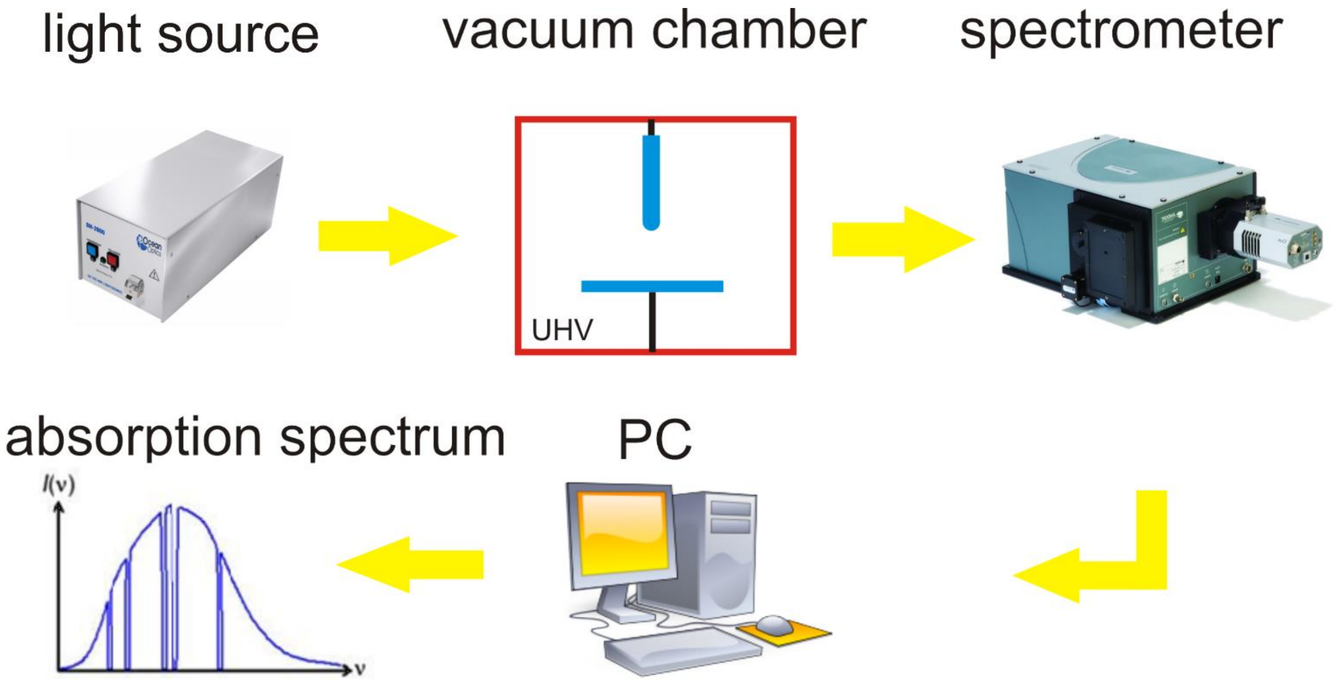


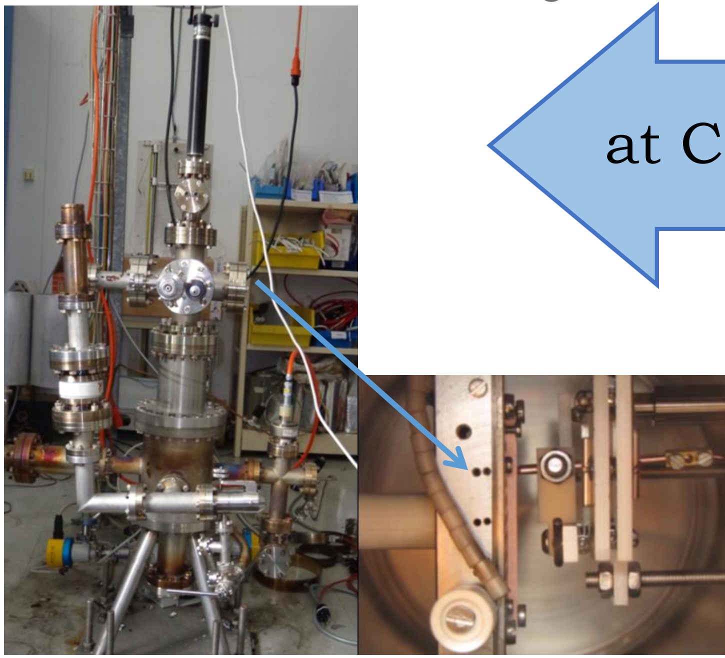
Fig. 6. The possible experimental scheme for absorption spectrum studying at DC-spark system.

Comparison of DC spark systems

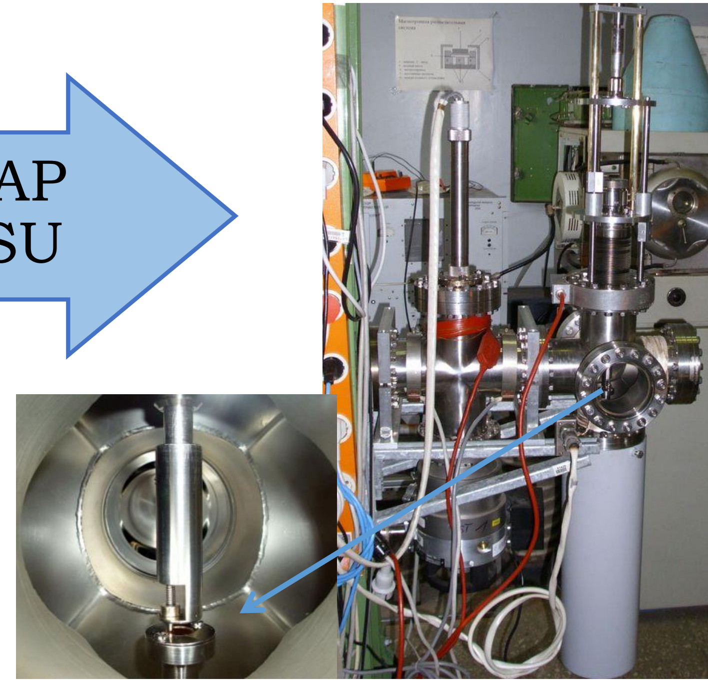
New DC-spark system

at CERN

at IAP NASU



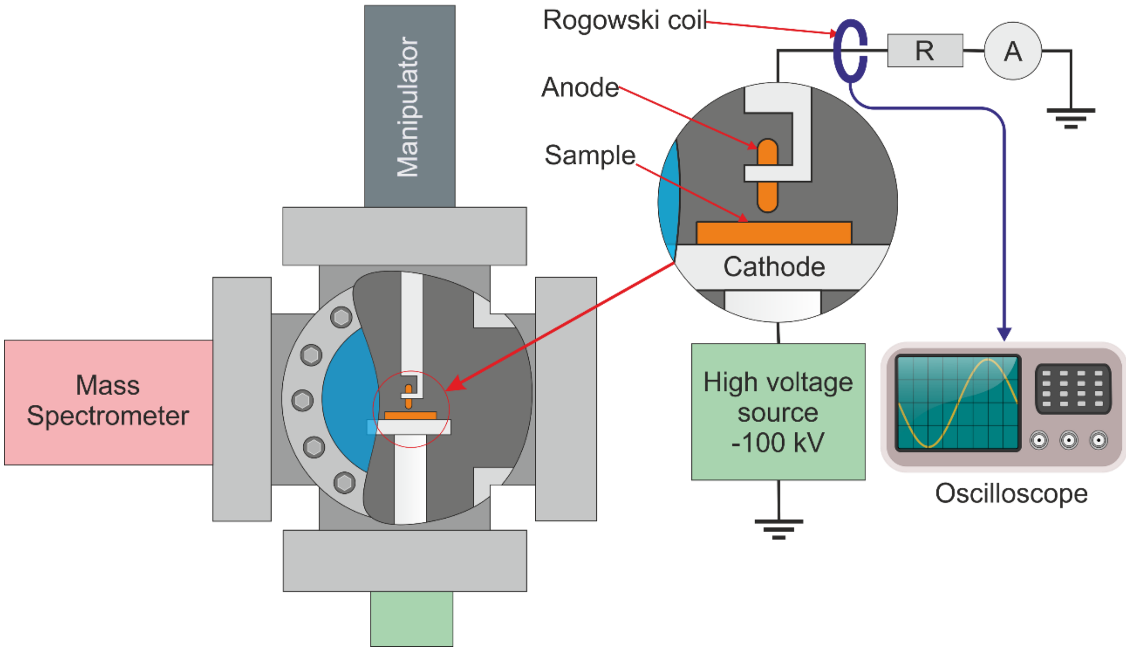
Vacuum chambers with electrodes



The main aim: testing the breakdown field strength of different kinds of materials in order to speed up the validation of different materials for rf structures. **Vacuum level:** 10^{-10} mbar **Max voltage:** 12 kV **Usual gap distance:** 20 μm	**The main aim:** testing the breakdown field strength of samples after plasma and ion treatment. **Vacuum level:** 10^{-7} mbar **Max voltage:** 50 kV **Usual gap distance:** 100 μm

Experimental setup in Ukraine

New DC-spark system



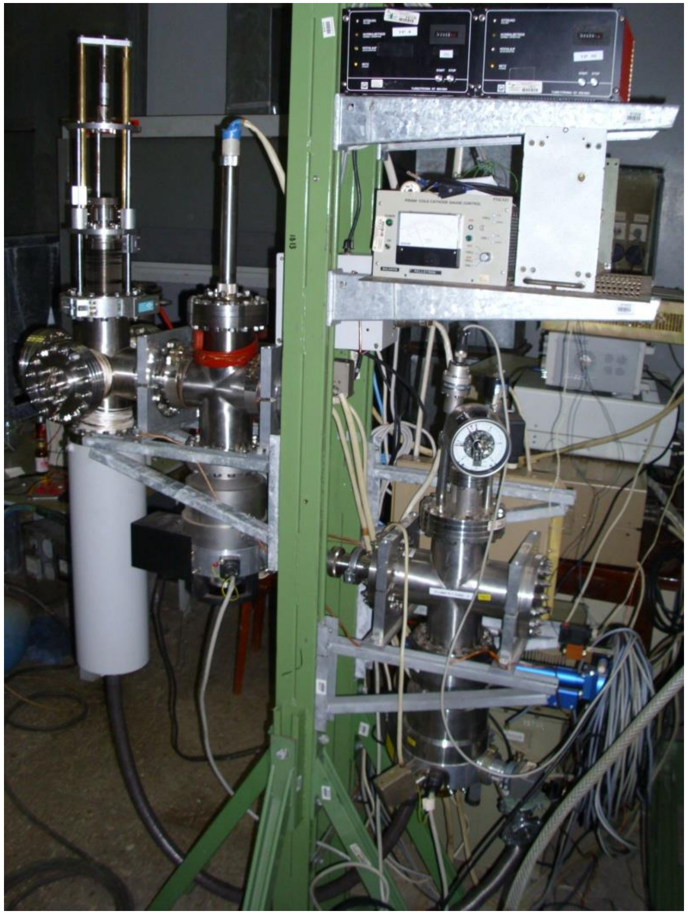


Fig. 8. The New DC-spark setup with continuous applied voltage:
a) the schematic drawing of the system; b) the photo of the system.

New DC-spark system

The primary results

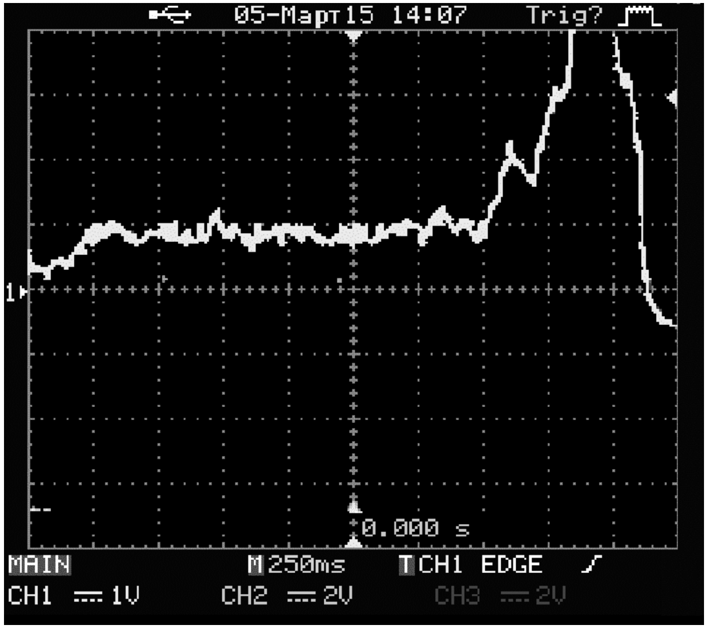


Fig. 9.1. The image of pre-breakdown and breakdown currents from the oscilloscope.

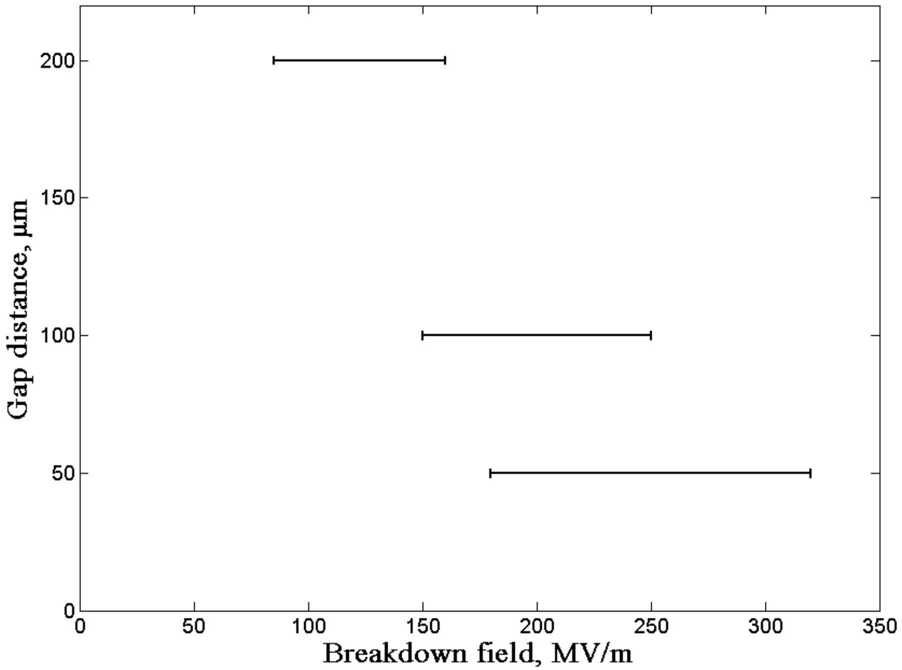


Fig. 9.2. The electrical breakdown field dependence on the distance between the electrodes (W anode and Cu cathode are used).

Average breakdown field

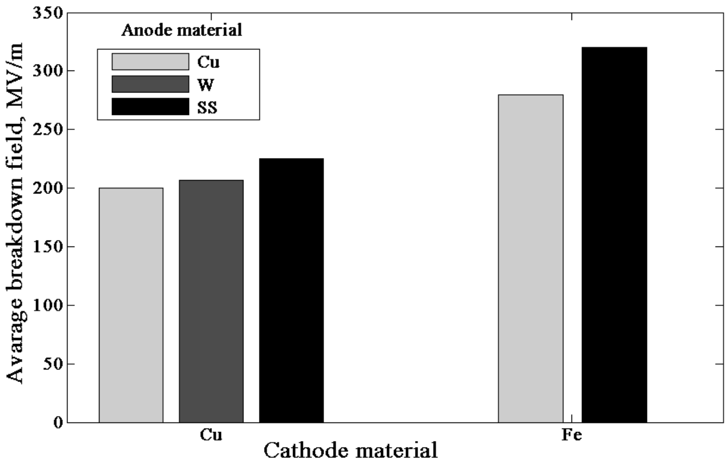


Fig. 10.1. The average breakdowns field reached between electrodes from different materials for 100 μm gap distance.

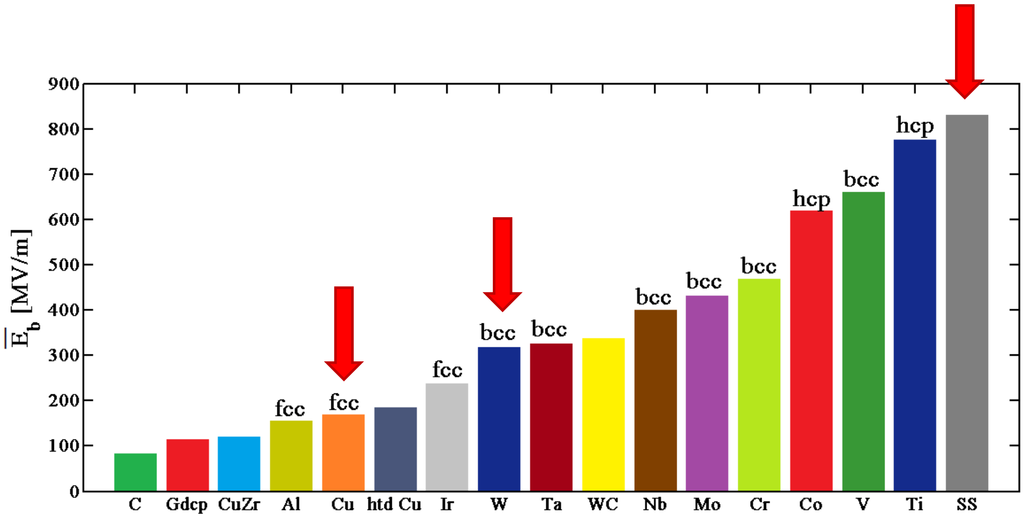


Fig. 10.2. Average breakdown fields after conditioning of the materials previously tested at DC-spark system at CERN. For pure metals, their crystal structures are indicated (fcc = face-centred cubic, bcc = body-centred cubic, hcp = hexagonal closest packing) on the top.

Experimental studies at CERN

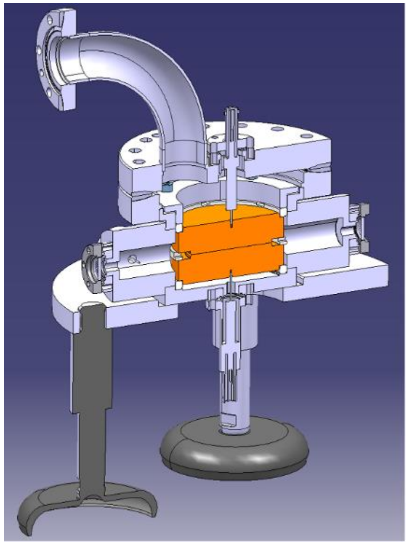


Fig. 11.1. The schematic view of the used system.

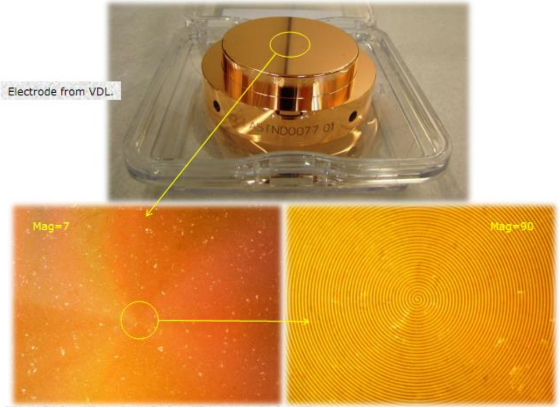


Fig. 11.2. The image of one from electrodes and its surface. The diameter of disks is 80 mm.

Fig. 11.3. The view of the full experimental system: Electromagnet (up to 0.54 Tesla), Fixed-gap system, electronics and etc. The pressure in the chamber is $3x10^{-9}$mbar.

Experimental results at CERN

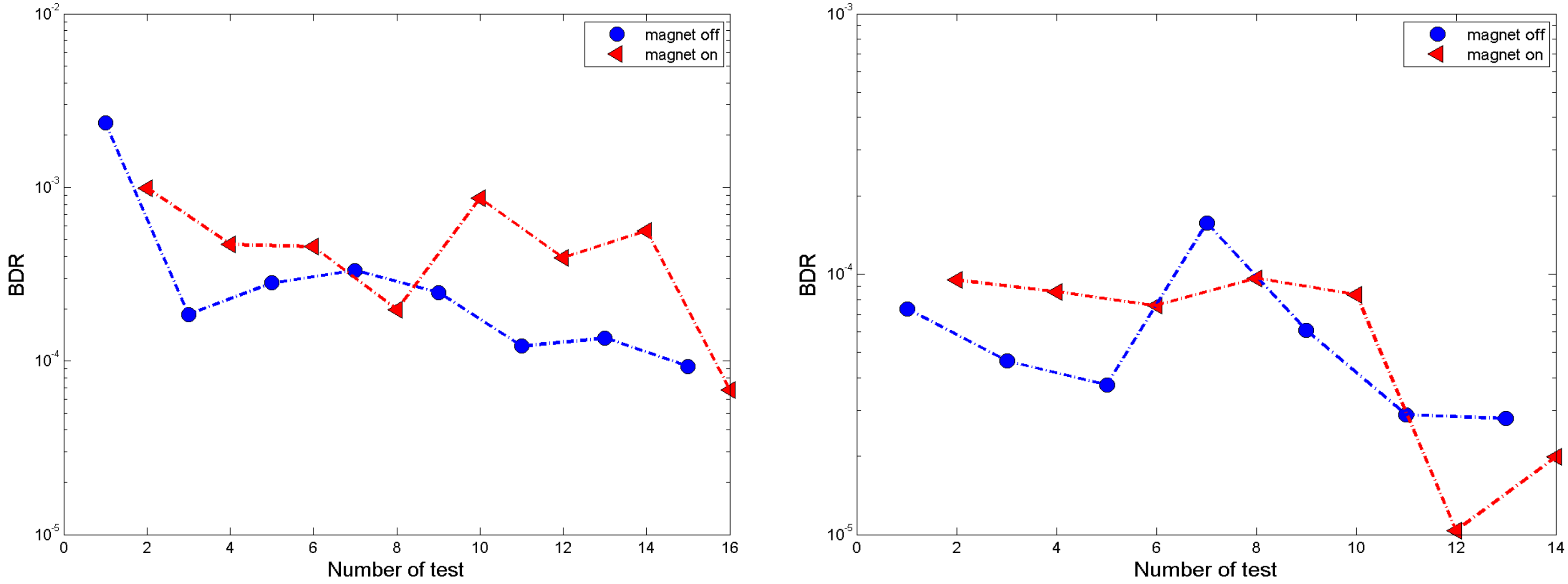
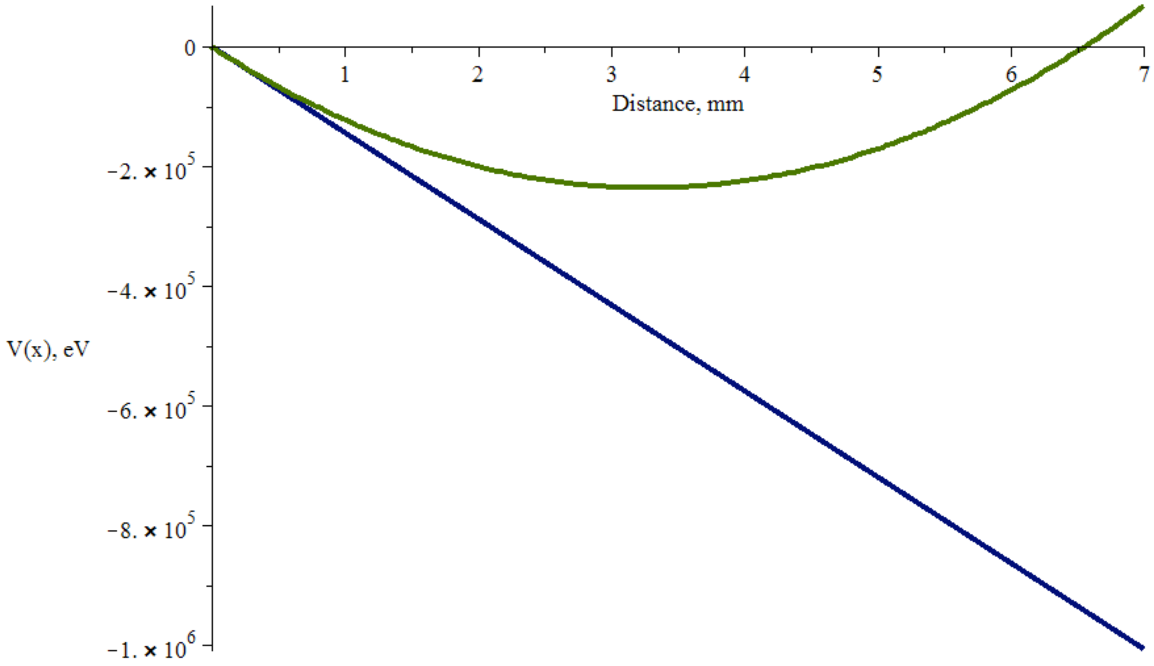


Fig. 12. Experimental results of BDR (15 um gap distance, the applied voltage 2160 V, the electrical field is 144 MV/m, the magnetic field is 0.5 Tesla):

a) magnetic field parallel to electrical field;
b) magnetic field perpendicular to electrical field

Theoretical studies at IAP NASU



The equation for the wave function component that describes the electron motion:

$$\frac{d^2\psi}{dx^2}-\frac{2m}{\hbar^2}\left[\frac{\omega_B{}^2x^2m}{2}-eE_0x-\frac{e^2}{16\pi\varepsilon_0x}-\varepsilon\right]\psi=0,$$

The effective potential energy *V(x)* of an electron near a metal surface is described as follows

$$V(x)=\frac{\omega_B{}^2x^2m}{2}-eE_0x-\frac{e^2}{16\pi\varepsilon_0x}$$

Fig.2. Effective potential energy V(x) of an electron near a metal surface, as given by eq. (5) for data from experiments at CERN. The blue line is the case of E = 144 MV/m, B = 0.5 T. The case E = 144 MV/m, B = 0 is shown in green. Courtesy of S.Lebedynskyi.

Future plan of experiments at IAP NASU

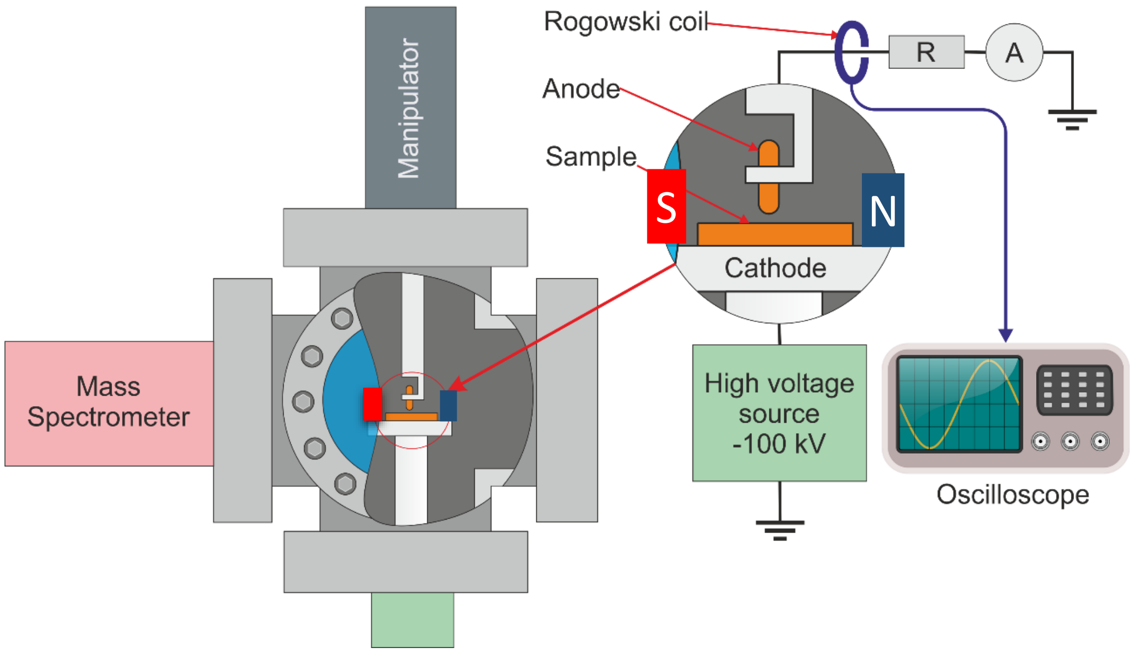


Fig. 14. The schematic drawing of the system.

Magnetic field:
~1 - 1.5 Tesla

The aim: to study effect of magnetic field to pre-breakdown current

Effect of ion implantation on work function

The main idea: to make the layer (less than skin layer) with higher work function using ion implantation.

To use plasma treatment for sample surface.

The implantation facility at IAP NAS of Ukraine could implant the ion of different particles (H^+, He^+, C^+, N^+, O^+, Ar^+, Zr^+ and etc). The ion energy: from 20 keV to 500 keV.

Thank you!