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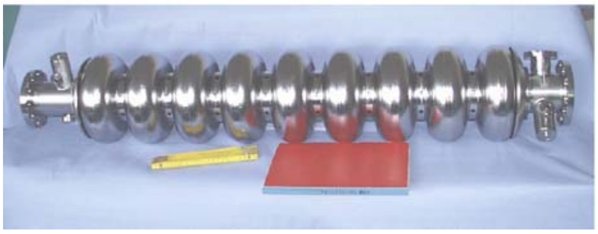

WP4.1 – Thin film cavity production

Deliverable 4.1.2.2
First multicell coating with linear arc cathode

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Abstract

Superconducting cavities can be produced from Niobium sheet material. An alternative fabrication method is to coat copper cavities with a thin Niobium film. At low frequencies cavities are large so that considerable cost can be saved with the reduced amount of expensive Niobium. The sputter coating technology has been developed by CERN. At moderate gradient Niobium coated copper cavities showed low loss, i.e. high quality factor. But with increasing gradient the quality factor drops down. Vacuum arc coating is a well known alternative coating method but was never tried out with RF cavities. There is a hope that the high impact energy of arc produced ions might create a "better" Niobium film without reduced Q-drop. In this R&D activity cavities have been coated by vacuum arc technology. The Niobium films show reasonable superconducting properties. But sever adhesion problems of the coating could not be solved within the time frame of the project.

Acknowledgements

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CARE Final Report on JRA1/WP4.1

JRA1 - Research and Development on Superconducting Radio-Frequency Technology for Accelerator Application

JRA 1 coordinator – Prof. D. Proch (DESY, Hamburg, Germany)

Work Package 4 - Thin film cavity production

Work package leader - Prof. M.J. Sadowski (IPJ, Swierk, Poland)

Task WP4.1 – Linear-cathode arc coating

Task leader* – Dr R. Nietubyc (IPJ, Swierk, Poland)

* A leader of this task was initially Dr J. Langner, who passed away on August 28, 2006. His duties were overtaken by M.Sc. P. Strzyzewski, but he resigned on August 24, 2007, and since that date the WP4.1 task leader has been Dr R. Nietubyc.

January 2009

1. Introduction

The main aim of WP4 was to develop a new method of thin-film coating by means of arc discharges under ultra-high vacuum (UHV) conditions. Instead of RF cavities made of bulk Nb one could then apply Cu-cavities coated inside with a thin Nb-layer. The cathode-arc technique was known and employed in different countries, e.g. in USA and Russia, but it has been applied at relatively high operational gas pressures. Our approach was based on the idea to use cathode-arc discharges under the UHV conditions to achieve very high purity films.

The main institutions engaged in the Work Package 4 (Thin Film Cavity Production) were the Andrzej Soltan Institute for Nuclear Studies (IPJ), Poland, responsible for task WP4.1 task (Linear-Arc Cathode Coating) and the INFN-Roma2, Italy, responsible for WP4.2 task (Planar-Arc Cathode Coating). Those tasks used different experimental facilities, but they explored the same principle and identical measuring techniques. Therefore, the both tasks were realized in a frame of the scientific collaboration with some support from: CERN, Cornell University (USA), DESY (Germany), INFM Naples (Italy), INFN-LNF (Italy), INFN Milano (Italy), and HCEI in Tomsk (Russia).

2. WP4.1 – Linear cathode coating

This report presents the most important results of the realization of the WP4.1 task in the period from Jan. 2004 until December 2008.

2.1. Design of a prototype facility for single cells coating

Task WP4.1 was focused on the development of an UHV cathode-arc system with the linear (cylindrical) configuration, as shown in Fig. 1.

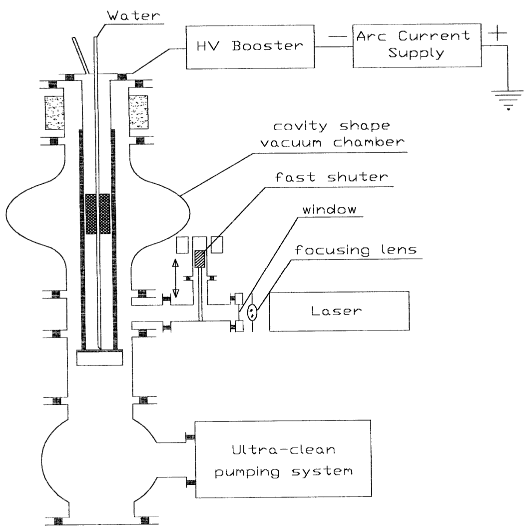


Fig.1. Scheme of an UHV facility designed for the linear-arc cathode coating.

Since a crucial role during the formation of thin superconducting niobium layers plays a cleanliness of the deposition process, to achieve good superconducting film properties the pumping system must be totally oil-free and all parts of the deposition system must be designed and built in accordance with UHV technology requirements.

Preliminary efforts to achieve the required UHV conditions in Swierk, Poland, were undertaken before starting the CARE project. A prototype set-up with a linear (cylindrical) cathode, designed especially for the deposition of niobium films, was constructed and put into operation in the mid of 2003. The ultimate pressure in that system was equal to $2\cdot10^{-8}$ mbar, but it was 1-2 orders of magnitude higher than the value required. Therefore, appropriate modifications of that prototype were needed.

2.2. Modification of prototype facility for single cells coating

The modernization of the prototype set-up was planned in a frame of CARE project, according to a scheme shown in Fig.2.

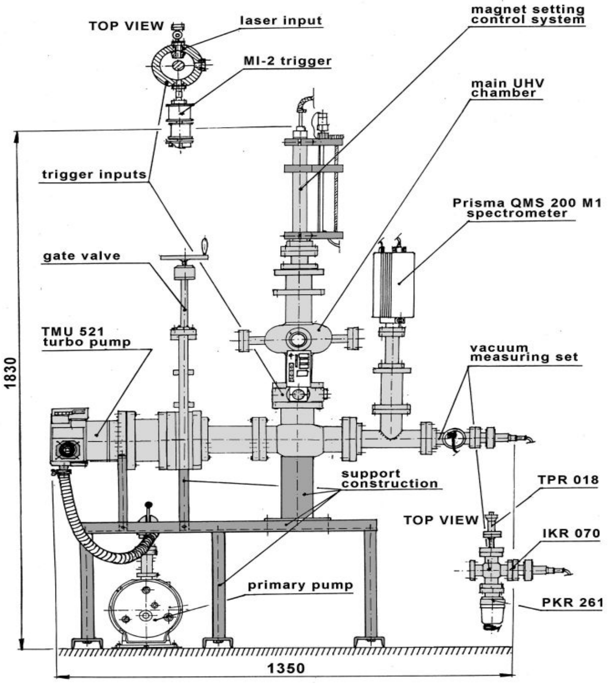


Fig.2. Scheme of the modified UHV stand equipped with the linear-cathode arc system.

In spite of a delay in the CARE funds transfer to Poland in 2004, the most important modifications of the whole pumping system were performed. There were installed: a new turbo-molecular pump of the TMU 521 type, a new dry-piston pump of the Xtradry 150-2 type, new UHV gauges and a modern gas analyzer of the QMS 200 Prisma type. Improvements in the control unit were also made and a new baking system was installed. It made possible to improve the ultimate vacuum and to reduce the final pressure to about 10^{-10} mbar. A typical mass spectrum of residual gasses in the chamber is shown in Fig. 3.

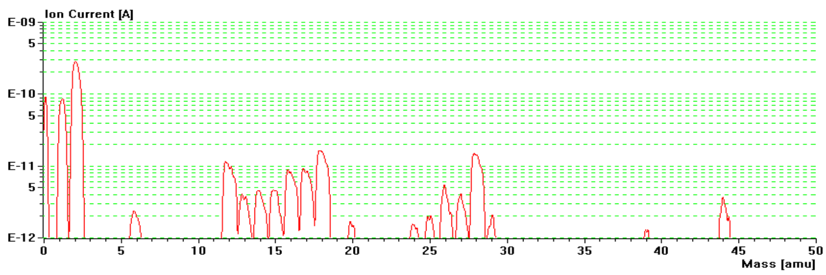


Fig.3. Mass-spectrum of residual gases, recorded at the final pressure $p = 1.5x10^{-10}$ mbar, as achieved after 180-hour pumping and 30-hour backing at $T_b = 150^oC$.

2.3. Optimization of a triggering system

Since the triggering of arc discharges creates many problems, particularly at the UHV conditions, various ignition techniques were tested from the point of view of their operational reliability and purity. On the basis of those tests three triggering systems were chosen and applied in the modified set-up described above. They applied a Nd:YAG laser of energy 100 mJ, emitting 10 ns pulses at the repetition rate up to 20 Hz; a modified mechanical trigger with a movable high-voltage electrode; and a ruby laser of energy of 0.7 J, producing 50 ns pulses at the repetition of 1 shot/min. Those triggering systems were compared and it was decided to base on the most reliable Nd:YAG laser.

2.4. UHV linear arc prototype facility ready

According to the WP4.1 time-schedule, after the described modifications and optimization of a triggering system, the modified UHV linear-arc system was ready and tested before the end of 2004, as shown in Fig.4.

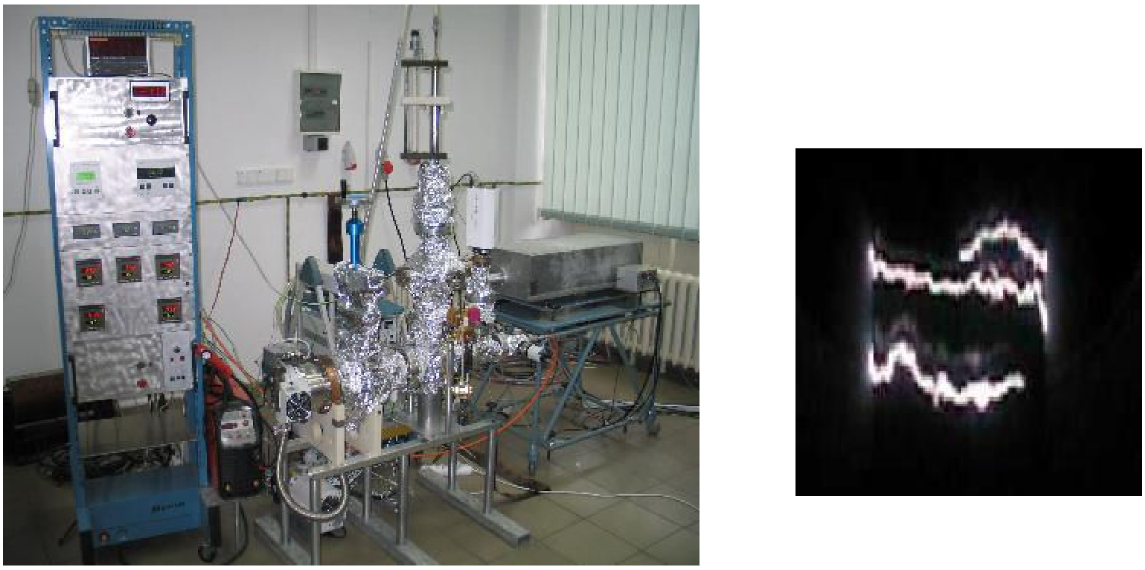


Fig.4. General view of the modified UHV linear-arc system (left) and a picture of a stable arc discharge (right), as observed on the cylindrical cathode at the base pressure of $4x10^{-10}$ mTr, arc current of 40 A, during the discharge lasting 1 minute.

The results obtained during the realization of the CARE program in 2004 were summarized in 5 papers presented at different international conferences or workshops and in a paper published in Czech. J. Phys. **54** (2004), Suppl. C (see the list of WP4 publications).

2.5. Study of arc current reduction and stabilization

After the commissioning of a high-current pulse generator in 2004, there was initiated research on the arc current reduction and stabilization. In 2005 studies of the arc-current optimization were performed with the use of a stainless-steel chamber of the shape and dimensions similar to an original single TESLA RF-cell. That chamber was equipped with two output flanges (used for the connection with the UHV pumping stand at the bottom) and a magnet driving system at the top) and 4 side-on (radial) diagnostic ports distributed symmetrically in the central symmetry plane of the applied cell.

Since the cleanliness of deposition processes plays a crucial role during the formation of thin superconducting niobium layers, in order to achieve high-quality superconducting films particular attention was paid to the initial vacuum conditions. The residual gas pressure, and particularly partial pressures of impurities (as water, nitrogen, oxygen, CO_2, hydro-carbides etc.) were reduced by the operation of the linear-arc facility according to requirements of the UHV technology. Due to the long backing it was possible to achieve the final pressure of $1.5\cdot10^{-10}$ mbar, and to reduce the amount of impurities considerably, as shown in Fig. 5.

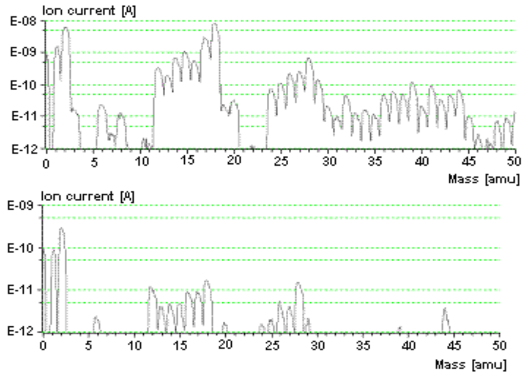


Fig.5. Typical RGA mass-spectra recorded within the linear-arc facility, as recorded before and after 24-hour baking at 150 ^{0}C.

Studies of the arc current stabilization were performed by means of a new power supply and a special solid-magnet system, which was placed inside the cathode tube in order to drive the arc along the cathode surface. Those studies were completed in February 2005, and stable discharges were achieved at arc currents reduced to about 70 A. Measurements performed with the ion-current collector, placed at a distance corresponding to the cell wall, showed that at the investigated operational conditions the ion-current density amounted to 50-80 mA/cm^2.

2.6. Optimization of powering system

The optimization of the powering system was performed in the first quarter of 2005. A general view of a new DC/pulse supply unit is shown in Fig. 6.

Fig.6. New DC/pulse power-supply for the UHV linear-arc facility.

The operational parameters of that power-supply were as follows: the maximum discharge current I_{max} = 350 A, booster voltage V_b = 200 V, PC control, and DC- or pulsed-operation.

2.7. Coating apparatus operational

In order to make the UHV linear-arc facility operational for the single-cavity coating, two TESLA-type cavities made of pure copper have been prepared by means of the EB welding.

They have been equipped with standard flanges and installed at the modified UHV linear-arc facility, as shown in Fig.7.

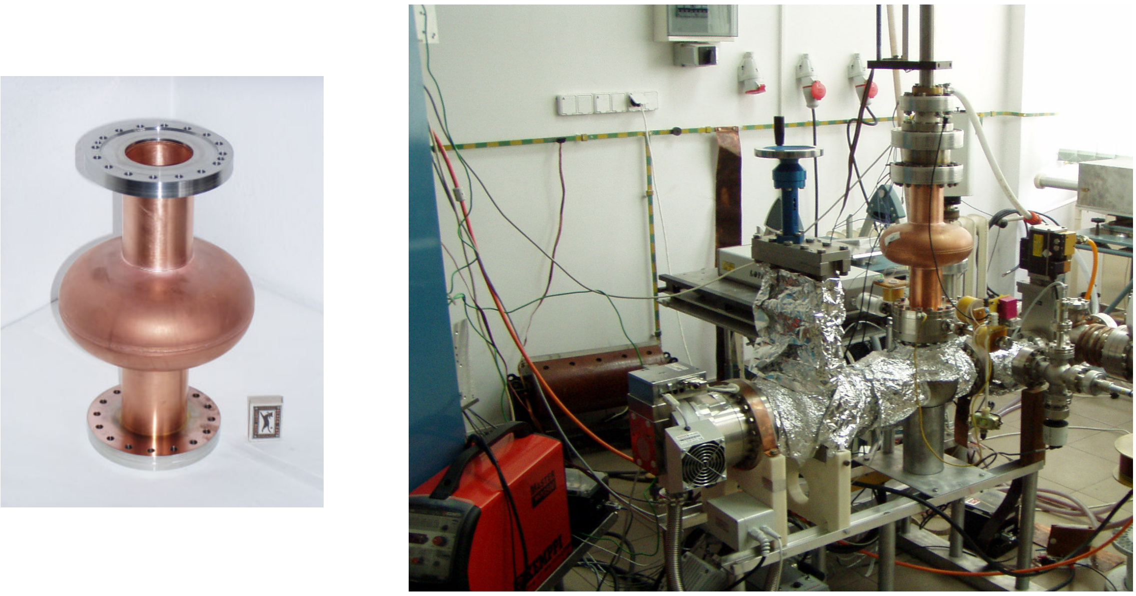


Fig.7. Single copper-cavity with end flanges (left) and the modified UHV linear-arc system during laboratory tests of the single-cavity coating (right).

Temporal behavior of the discharge current in the UHV linear-arc facility without magnetic filtering was studied. The maximum arc current amounted to about 100 A, and the period of the cathode-spot motion (around the cylindrical cathode) was found to be 20 ms. Waveforms of the arc current were recorded, as shown in Fig.8.

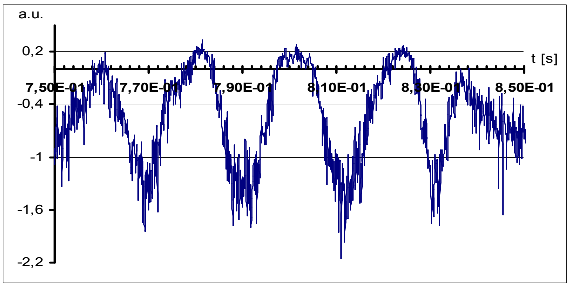


Fig.8. Waveforms of the discharge current, as recorded during laboratory tests of the UHV linear-arc facility.

2.8. Coating of single cells

To perform coating of single RF-cells the IPJ team designed and manufactured a special arc-driving system, equipped with miniature permanent magnets placed inside the Nb-cathode tube. A magnetic field, as produced by those permanent magnets, could stabilize the arc discharge and focus it on the cathode surface near the magnet position. The described construction facilitated to control the arc motion along the z-axis and to improve uniformity of the Nb-layer deposition upon the inner surface of a RF-cavity.

It was well known that the main disadvantage of all arc-techniques is the production of micro-droplets of the cathode material emitted from arc spots. To overcome this difficulty special measures were needed. Therefore, the first tests of the single cell coating were started according to the CARE time-schedule (in March 2005) without micro-droplet filtering.

2.8.1. Coating of single cell without micro-droplet filter – Phase I

The first coating of TESLA-type single cells were performed using the modernized UHV linear arc facility described above and single copper-cavities taken from a TESLA test-bed, which were earlier manufactured at IPJ. Two single cells were coated during subsequent tests without micro-droplet filtering. After the coating those cavities were cut along the symmetry axis to perform an analysis of the deposited Nb layers, as shown in Fig.9.

Fig.9. Two parts of the coated single-cell, which show the Nb layer on the inner surfaces.

Several samples were cut out the Nb-coated surface and an analysis of their surfaces was performed by means of SEM, as shown in Fig. 10.

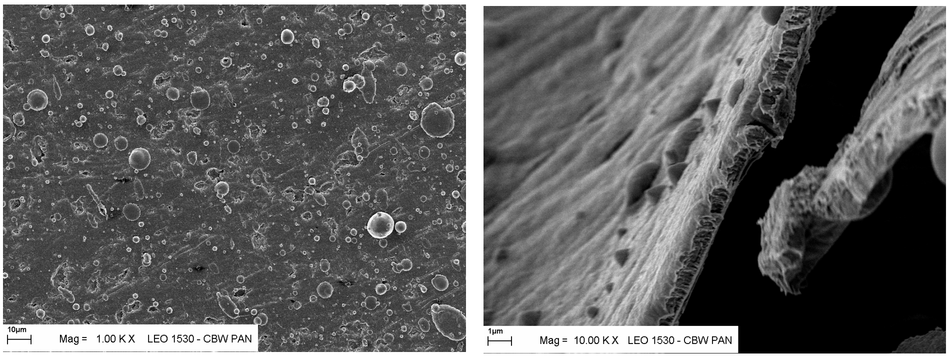


Fig.10. SEM pictures showing a relatively large population of the deposited micro-droplets (left), and the edge and thickness of the deposited Nb-layer (right, larger magnification).

For a comparison, several samples of pure sapphire were also coated within the UHV linear-arc facility under similar experimental conditions. They were analyzed with the same SEM, as shown in Fig. 11.

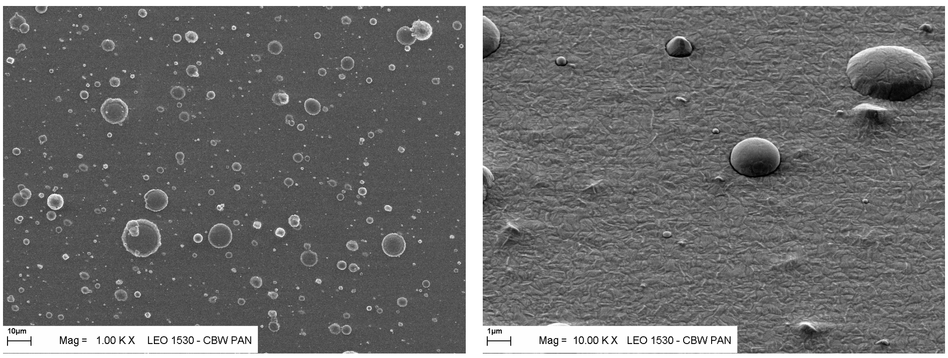


Fig.11. SEM pictures showing the population of the deposited micro-droplets (left), as well as the structure of the Nb-layer and shapes of micro-droplets (right, larger magnification).

An analysis of the micro-droplets deposited upon the sapphire samples was performed within the frame of the IPJ-Tor Vergata Uni collaboration. Some exemplary results are presented in Fig.12.

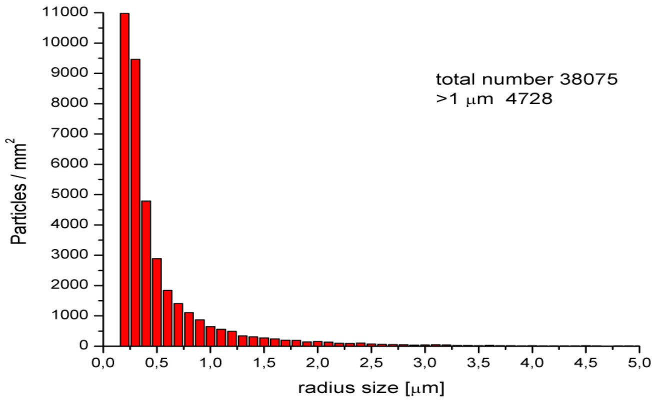


Fig.12. Histograms of the micro-droplet population, as measured upon the sapphire sample coated within the UHV linear-arc facility.

2.8.2. Design and construction of a micro-droplet filter

To reduce a number of the micro-droplets within the UHV linear-arc facility, it was necessary to design and construct special filters. The first version was a cylindrical Venetian-blind filter, consisting of copper blades distributed symmetrically around the periphery. Its construction was simple one, but its disadvantage was strong reduction of the deposition efficiency, because Nb ions could hardly penetrate through narrow slits between the Venetian blades. Therefore, there was designed a special magnetic filter, which consisted of a set of thin copper tubes distributed in two cylindrical layers and joint at the ends by special connectors, which enabled an appropriate magnetizing-current and cooling-water flows to be realized. The cylindrical magnetic filter was a new concept and it required extensive theoretical modeling and experimental tests. Computations of the magnetic field distribution were performed for different configurations, i.e. various numbers and dimensions of tubes carrying the magnetizing current. An example of such a modeling is presented in Fig. 13.

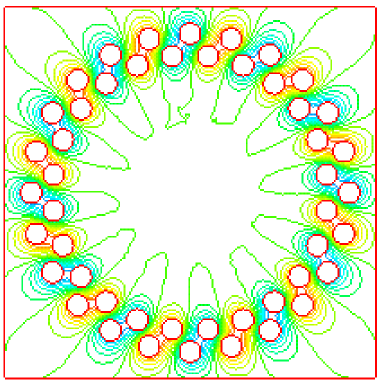


Fig.13. Distribution of magnetic field lines in the horizontal cross-section of the cylindrical magnetic filter, which consisted of 24 pairs of current-carrying tubes.

2.8.3. Micro-droplet filter ready

In order to perform experimental tests of the micro-droplet filters there were manufactured two cylindrical filters: the Venetian-blind filter and the magnetic (multi-tube) filter. The

Venetian-blind filter was partly destroyed during the first exploitation tests because of high thermal loads. The construction of the second magnetic filter enabled an appropriate magnetizing-current and cooling-water flows through a system of copper tubes to be assured. A general view of that filter is shown in Fig. 14.

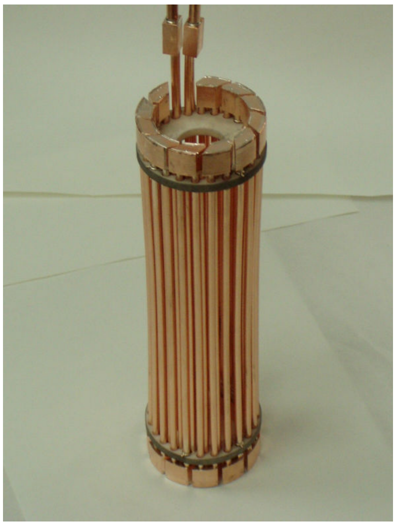


Fig.14. General view of the cylindrical magnetic filter with connections for magnetizing current and cooling water flows.

Preliminary tests of that cylindrical magnetic filter were performed within an auxiliary experimental stand, which is shown in Fig. 15.

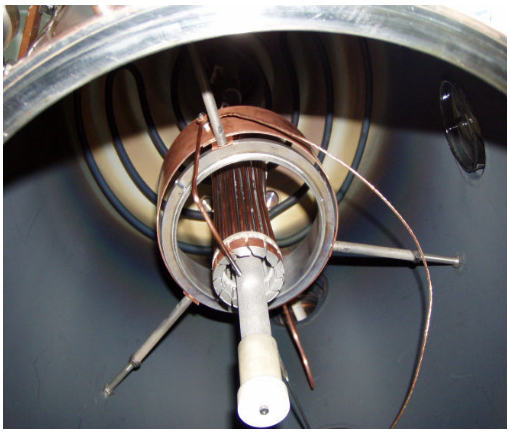


Fig.15. Picture of the cylindrical magnetic filter and an additional anode after the exploitation tests.

In particular, there were investigated the vacuum tightness, cooling efficiency and resistance of the filter to arc discharges. Simultaneously, there was installed an additional anode which made possible to apply higher acceleration voltage to Nb ions penetrating through the filter. The ion current density, as measured by means of the ion collector placed at a distance of 7.4 cm from the filter surface, amounted to10 mA/cm^2 only, but it was demonstrated that the prototype cylindrical magnetic filter can be used under the required experimental conditions. After those tests the micro-droplet filter became ready for the routine exploitation. Some constructional improvements (in the design, selection of materials and manufacturing technique) might be still needed, but it would require other tests within the

UHV linear-arc facility equipped with copper RF-cavities of the TESLA type. Unfortunately, at that time such cavities were not available (neither from INFN-Legnaro nor DESY).

The results obtained during the realization of the CARE program in 2005 were summarized in 5 papers presented at different international conferences or workshops and in 6 papers published in Supercond. Sci. Technol. **18** (2005), Elektronika **XLVI** (2005), Proc. SPIE Vol. **5948** (2005), Advances Appl. Plasma Sci. **5** (2005), etc. (see the list of WP4 publications).

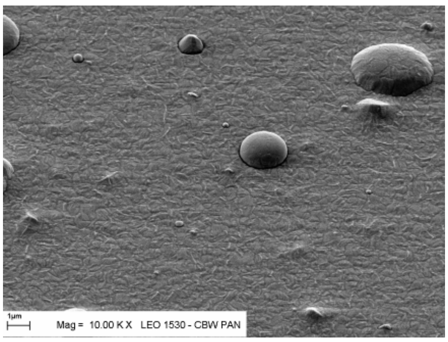
2.8.4. Coating of single cell with micro-droplet filtering

In 2006 studies of the arc-current reduction and stabilization were continued with the use of a stainless-steel chamber of the shape and dimensions similar to the single TESLA RF-cell. To perform some modification of the UHV linear-arc facility two new pure-Nb tubes of 24 mm in diameter (with walls of 3 mm in thickness) were ordered. The first tube (of about 50 cm in length) was used as a cathode for coating a single RF cavity, while the second one (of about 120 cm in length) was designed for future experiments with a multi-cell structure.

In order to facilitate biasing of samples used for coating tests, the IPJ team designed and constructed a so-called keying module. It could transform a DC input signal into pulsed output signals of amplitude varied from -800 V to 0, with a frequency set within the range of 0-100 kHz. Such a module was also delivered to the Tor Vergata laboratory to perform tests within a UHV planar-arc facility.

Tests on the coating of original TESLA single cells within the UHV linear-arc facility was delayed because the collaborating laboratories (INFN-Legnaro and DESY) were not able to deliver the TESLA-type copper cavities during the whole 2006. At the CARE Annual Meeting 2006, it was declared that the original TESLA-type copper cavities should be delivered in the first quarter of 2007. Therefore, it has been proposed to extend the coating of single-cell without a micro-droplet filter at least until mid 2007.

In order to investigate characteristics of thin Nb-films deposited by means of the UHV linear-arc facility, the use was made of several sapphire samples, which were placed in the horizontal diagnostic port. The deposition processes were performed under very clean and controlled vacuum conditions, without any micro-droplet filter. Since the samples were mounted on the grounded support, no additional bias was applied. The Nb-coated sapphire samples were investigated in other laboratories in order to get SEM images, micro-droplets populations, RRR values and SIMS profiles. The SEM pictures of the Nb layers deposited without any micro-droplet filter showed a relatively large population of micro-droplets, as shown in Fig. 16.



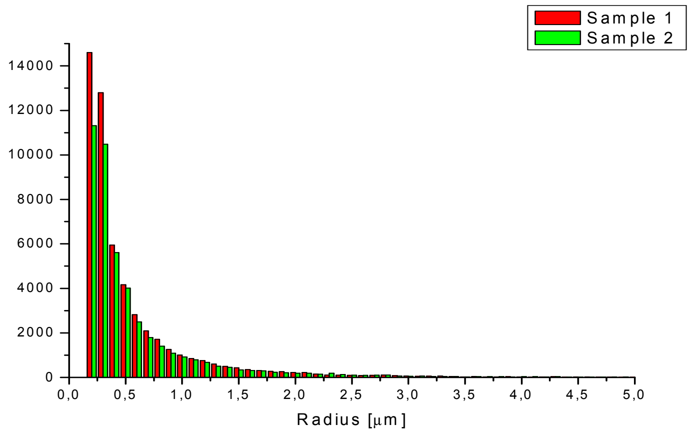


Fig.16. SEM picture of an unfiltered sample and numbers of the deposited micro-droplets.

Measurements performed at the Tor Vergata laboratory showed that the unfiltered Nb layers had low RRR values (below 25), what was explained by an influence of numerous micro-droplets. Better results (RRR up to 48) were obtained for the biased (-70 V) samples, but this procedure could not for the whole TESLA-type cavities. Therefore, the application of a cylindrical micro-droplet filter appeared to be necessary.

To study chemical composition of the deposited layers the use was made of the SIMS technique. Preliminary measurements were performed with an O_2+ ion-gun and time-of-flight (ToF) mass analyzer, but the O_2+ ions caused the formation of an additional NbO admixture. Therefore, next SIMS measurements were carried out with non-reactive gas (Ar) ions. As a result, the oxygen contamination was considerably reduced, as shown in Fig. 17.

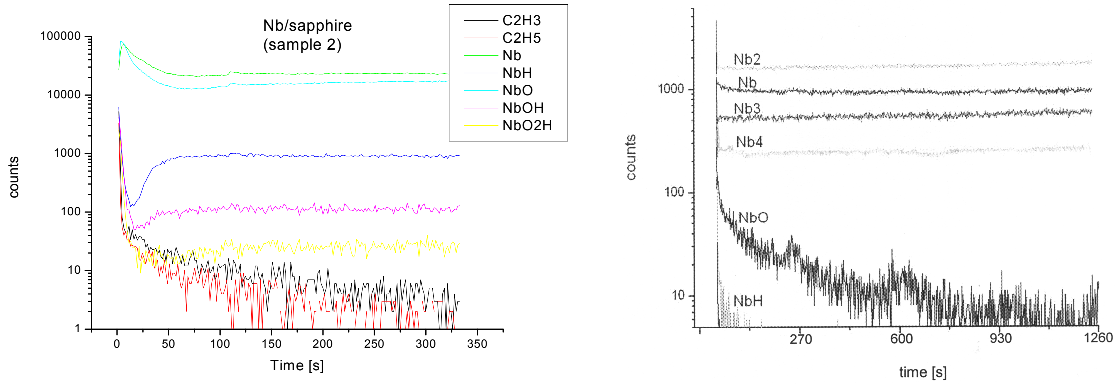


Fig.17. SIMS profiles of the Nb films deposited without any micro-droplet filter, which were recorded with the use of the oxygen ions (left) and argon ions (right).

In order to prepare for coating of single cell with micro-droplet filtering some sapphire substrates were placed in the UHV linear-arc facility equipped with the second version of the Venetian-filter (see 2.8.3). Those samples were coated at the arc current equal to 55 A during 25 minutes. The deposited Nb-film thickness was about 1.5 µm. The obtained Nb-layers were characterized by measurements of the micro-droplets distribution, as shown in Fig. 18.

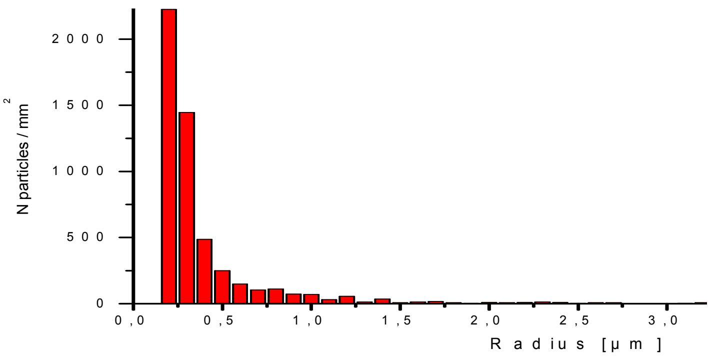


Fig.18. Population of micro-droplets upon the filtered Nb-layer.

The amount of the deposited micro-droplets was strongly reduced in a comparison to the layer deposited without filtering (see Fig.16), and about 90% of the micro-droplets had diameters below 0.5 µm, which might be admissible in some cases.

The results obtained during the realization of the CARE program in 2006 were summarized in 7 papers presented at different international conferences or workshops and in 4 publications in Physica Scripta **T123** (2006), AIP CP **812** (2006), Vacuum **80** (2006) and Physica **C441** (2006) - (see the list of WP4 publications).

It should be noted that in addition to the planned tasks, the IPJ team had also performed several depositions of pure Pb-layers, which were investigated as potential photo-cathodes for new electron injectors. The preliminary results were presented in 3 papers at EPAC-2006 in Edinbourgh (June 2006), the international conference in Alushta (Sept. 2006) and the international workshop in Legnaro (Oct. 2006).

2.8.5. Coating of single cell without micro-droplet filter – Phase II

In 2007 the WP4.1 activities were concentrated on the final preparation of the UHV linear arc facility. To ensure the elimination of micro-droplets an improved model of the cylindrical Venetian-type filter with cooling flanges at the both ends was designed and ordered at an external manufacturer. Due to very strong requirements as regards the quality of the applied materials (OFHC) the manufacturing met some difficulties and the new filter was available in November 2007. The second version of the magnetic filter, which was designed as the cylindrical two-layer set of cooled copper tubes (distributed symmetrically around peripheries) was also manufactured before the end of 2007.

In order to reduce an amount of impurities, which might be introduced into an open vacuum chamber or the tests RF-cell, a prototype laminar-flow chamber was designed and completed, as shown in Fig. 19.

Fig.19. Removable laminar flow chamber equipped with operation al gloves.

Waiting for a delivery of original 1.3-MHz copper cavities from INFN-Legnaro and DESY the WP4.1 team concentrated on analyses of different samples deposited within the UHV linear-arc facility. Some examples of such analyses are shown in Fig. 20.

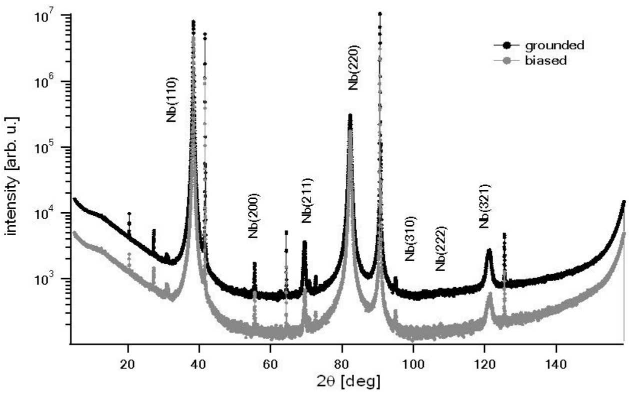


Fig. 20. X-ray diffraction patterns from Nb layers deposited upon the biased- and grounded-samples.

The X-ray diffraction lines from a sapphire substrate and the deposited Nb-film were identified. The lines from the substrate were stronger and narrower than those from the Nb layer. Estimates of the Nb lattice constant gave values very close to that observed for the bulk Nb crystal. Simultaneously with the described tests we carried various tests of the samples deposited during previous operational runs. Since the film oxidation may be an important reason for the deterioration of the superconductive properties, the oxidation of $Nb/Al_2O_3(0001)$ samples was studied in order to identify niobium oxides formed during the thermal annealing (up to 600 ºC) in the atmosphere, characterized by the partial pressure of oxygen equal to 10^{-4} mbar. Grazing-incidence scans and $\theta - 2\theta$ diffraction patterns were measured with the Cu $K_{\alpha 1,2}$ radiation for the films before and after their oxidation. The results showed that the deposited Nb layer was converted into a new crystalline phase. A detailed analysis of this phase should be continued because it might be of importance for future deposition processes. X-ray diffraction measurements were also performed for the Nb/Al_2O_3 samples, using a W1 beam-line at the DORIS in DESY. The enhanced 110 reflection at 38.45 ° indicated that the preferable orientation of the 110-plane was parallel to the sample surface. In the θ–2θ pattern such a reflection showed two broadened components, while only one was observed in the grazing incidence pattern. The broaden component was interpreted as a result of a thin (a few nanometers) epitaxial-layer formed on the sapphire substrate directly.

In spite of previous promises, in 2007 the original TESLA-type copper cavities were not delivered by CERN and DESY labs. Due to courtesy of Dr Bernard Visentin team, the first original copper cavity was delivered from CEA-Saclay in April 2007, but it was broken during its transport to Poland. After the inspection of that cavity by Dr B. Visentin and Miss M. Bruchon during their visit at IPJ in May 2007, it was sent back to CEA-Saclay. The second cavity, which was equipped with an improved external supports, was delivered from CEA-Saclay in June 2007. That cavity was installed within the UHV linear-arc facility and its internal walls were coated with the Nb-layer. The coated cavity was sent to CEA-Saclay to perform cleaning and RF tests. Unfortunately, it appeared that adhesion of the deposited Nb-layer was too low to withstand the high-pressure water rinsing. Therefore, the next cleaned-up cavity was delivered from CEA-Saclay to IPJ in July 2007. To improve the adhesion of the deposited Nb-layers, the IPJ team applied an additional biasing of the cavity by means of an auxiliary anode. After the preliminary ion cleaning, the described cavity was Nb-coated at the polarization of -200 V. Tests performed later on at CEA-Saclay showed that the water cleaning at 10 bars removed some potions of the deposited Nb-layer, as shown in Fig. 21.

Fig. 21. End-on picture of the second cavity from CEA-Saclay, as taken after its coating (left), and a picture taken after the cleaning process at CEA-Saclay, which shows some destruction of the Nb-layer by high-pressure water rinsing.

A reason of a too low adhesion of the Nb-coating might be an improper preparation (EP and chemistry) of the original copper cavities as well as too many micro-droplets (since the described coating test was performed without any micro-droplet filter). To solve the problem further coating tests should be performed with new copper cavities expected from DESY.

2.9. Coating multi-cell

The WP4.1 milestone concerning the first multi-cell coating within the UHV linear-arc device was delayed until tests of the coated single-cavities give satisfactory results. Another reason of a delay was a lack of appropriate cavities, because the collaborating labs (INFN-Legnaro, CERN and DESY) did not deliver copper multi-cells in proper time.

2.9.1. Design and commissioning of facility for coating of multi-cells

In spite of problems with a delivery of the copper multi-cells, a considerable progress in preparations for Nb coating of multi-cells was achieved. The IPJ team manufactured a longer Nb-cathode and the appropriate auxiliary anode. Those parts were installed within the UHV linear-arc facility together with a model triple-cell cavity manufactured at the IPJ previously. A general view of the UHV linear-arc facility prepared for coating of a triple-cell cavity is shown in Fig. 22.

Fig. 22. UHV linear arc facility before commissioning for the first coating of a test triple-cell.

2.9.2. First multi-cell coating

Before the first Nb coating of the model triple-cell cavity (described above) particular attention was paid to chemical preparation of the cavity surface. To improve the surface cleanliness there was elaborated a citric acid preparation procedure. The test deposition was performed within a triple-cavity structure, which before the deposition process was filled with a 15% citric-acid solution and kept at 60 ºC to avoid the precipitation. After that the structure was flushed carefully with de-ionized water and propanol. The deposition was performed under routine operational conditions, but without any micro-droplet filtering. The base pressure was of about 10^{-9} mbar, and it rose up 10^{-6} mbar during the arc discharge. A Nb layer was deposited during 25 minutes and the temperature of the outer cavity surface was below 190 ºC. A general view of the coated structure is shown in Fig. 23.

Fig.23. End–on picture of the model triple-cell cavity coated with Nb layer.

In order to test the adhesion of the deposited film the high-pressure water rinsing (HPWR) was applied. That procedure showed that the deposited Nb-layer could well withstand a soft rinsing (up to 10-15 bars), but a higher water pressure could destroy the deposited layer partially. Therefore, it was necessary to undertake some special measures in order to improve the adhesion of the deposited Nb layers. Unfortunately, in 2007 the IPJ team did not receive the original TESLA-type multi-cell cavities made of high-purity copper.

The results obtained during the realization of the CARE program in 2007 were summarized in 9 papers presented at different international conferences or workshops and in 4 publications in Meas. Sci. Technol. **18** (2007), Probl. Atom. Sci. & Techn. Vol. **1** (2007), IEEE Trans. Plasma Sci. **35** (2007) and Proc. SPIE Vol. **6937** (2007). It should be added that in addition to the described studies, the IPJ team performed also UHV-arc depositions of pure Pb-layers, which were designed as photo-cathodes for new electron injectors. Preliminary results of those additional studies were published in PAST Vol. **1** (2007) and reported elsewhere by J. Sekutowicz et al. (see the list of WP4 publications).

It should also be noted that a financial support for the IPJ team from CARE program was finished in 2007, and it made the realization of further technological studies very difficult.

2.9.3. Research on improvements of adhesion of deposited Nb layers

The first TESLA-type copper single-cavity was delivered from DESY to IPJ at the very beginning of 2008. Unfortunately, that cavity was partly destroyed during its transportation. Nevertheless, using domestic funds to cover costs of the operation of the UHV linear-arc facility, that cavity was coated within the operating machine and sent back to DESY.

Subsequently, other tests were undertaken to improve adhesion of the deposited Nb layers. For that purpose several small copper samples were prepared and coated within the same UHV linear-arc facility under various conditions. The first test was performed with an electro-polished copper sample, which was additionally treated with the citric-acid solution. The test after its Nb-coating showed that it could withstand up to 80 bar HPWR without peeling, as shown in Fig. 24.

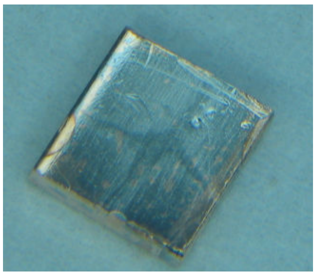


Fig.24. Surface of the prepared Cu-sample after its Nb-coating and HPWR at 80 bars

Other copper samples (after their coating) were also put to trial of the HPWR, and it was demonstrated that some of them withstand the HPWR up to 100 bars, as shown in Fig. 25.

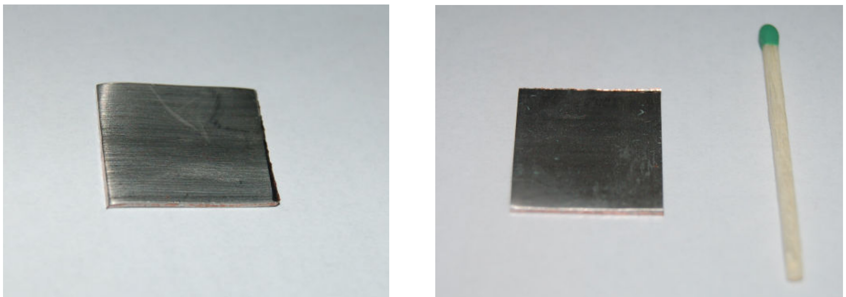


Fig.25. Nb-coated Cu-sample (left) and the same sample after the HPWR at 100 bars (right).

The described tests demonstrated that under appropriate conditions it is possible to deposit Nb-layer with adhesion good enough to withstand the HPWR up to 100 bars, although it is not sure whether such high pressure will really be required for future TESLA-type structures.

It was found that the adhesion depends on both: chemical and mechanical treatment of the surface before the deposition. For a smoothly polished samples, an appropriate cleaning enables to obtain an Nb-film resistant to HPWR at 120-bars, as shown in Fig. 26. It was, however, observed that a small roughness results in stronger adhesion too.

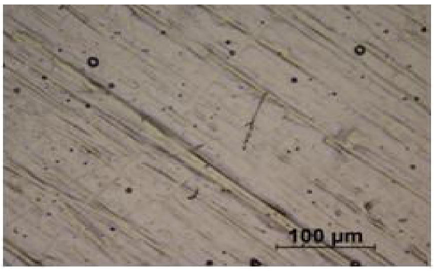


Fig.26. *Surface of the Nb-layer deposited upon a polycrystalline copper sample, as observed after HPWR at 120 bars.*

In order to study the crystalline structure of Nb films, a series of samples were prepared. Films of thickness in the range 50-150 nm were deposited onto a single sapphire crystal and electro-polished copper substrates. For the copper substrates it was found that the film structure is different the that of bulk Nb, since it was affected by the thermal behavior of the film and substrate. The investigated films contained a thick epitaxial layer built in the interface region, as shown in Fig. 27.

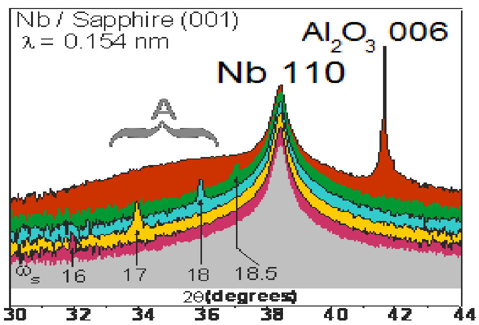


Fig.27. Nb-110 reflection measured for the Nb/sapphire film. The upper pattern represents results of the symmetric ω-2θ scan, where two components of peak profile are clearly seen. The other patterns were measured in a detector scan at the fixed incidence angle ω_s.

The described effect occurred independently on energy of incoming ions. Polycrystalline part of films was tetragonally distorted to the degree dependent on ions energy, and it showed the preferred orientation. Results obtained for the Nb deposited on sapphire indicated the presence of two distinguished niobium phases in the film. Further studies should be dedicated to the structure of the phase formed during early stages of the deposition process.

The results obtained during the realization of the CARE program in 2008 were summarized in 4 papers presented at different international conferences or workshops and in 4 papers published in AIP CP Vol. **993** (2008), Mat. Sci. – Poland Vol. **26** (2008) and Elektronika (2008) in print.

4. Summary and conclusions

The most important results achieved by the IPJ realizing the WP4.1 task can be summarized as follows:

1. The UHV linear-arc facility for coating of single-cell cavities was put into the operation at IPJ according to the CARE time-schedule, and the first model single-cell cavities were coated. The adhesion of the deposited Nb-layers appeared to be too low to withstand HPWR at 100 bars, but later tests performed with many copper samples showed that appropriate polishing and cleaning of copper surfaces enables to produce Nb-layers resistant to HPWR up to 120 bars.
2. The UHV linear-arc facility was also adopted for coating longer (triple-cell) structures, and almost all milestones of WP4.1 task were achieved, except for 100% coatings of the original TESLA-type structures. Those high-risk aims were not achieved because of a lack of the original structures (to be delivered in proper time) and a lack of CARE funding (particularly in 2008).
3. The performed series of tests showed that films can be deposited upon the inner wall of a 70-cm-long structure as a routine procedure, and basing on the gain experience a similar system can be assembled and put into industrial operation.
4. The applicability of the produced Nb coatings was limited by their too low adhesion to copper surfaces, but the described tests showed that it could be improved by a careful and clean preparatory treatment of substrates. The achieved adhesion of Nb layers upon the TESLA-type Cu-cells was not high-enough to withstand HPWR at 100-bars (typically applied in bulk Nb cavities), but such a treatment might not be necessary for the UHV-prepared high-purity coatings.
5. An important challenge in the UHV linear-arc deposition technology is a reduction of the population of micro-droplets deposited upon the coated surface. It should be noted that the elaborated magnetic filters enable the strong (even tenfold) reduction of that population and the considerable lowering of droplets dimensions.

The dissemination of the obtained results was realized through numerous papers presented at various international conferences and/or published in recognized scientific journals (see the attached tables).

As regards applications the elaborated UHV arc technique, after further improvements this technology might be used in application-oriented research and in manufacturing of Nb-coated copper RF-cavities for various linear accelerators.

The collaboration with different research labs and some industrial organizations might be very helpful in promoting the described technology. Intellectual property rights might be granted if new patents are obtained.

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3. WP4.1 & WP4.2 Joint Activities

Meetings/Workshops of JRA1/WP4

Date	Title/Subject	Location	Number of attendees	Website address
Jan. 21-23, 2004	Start-Up Meeting during the ZEUTHEN TESLA Meeting	Zeuthen, Germany	2	None
Feb. 12, 2004	ARCO Meeting	Rome, Italy	6	None
May 3-6, 2004	ELAN Meeting	Frascati, Italy	3	None
Sept. 9, 2004	JRA1 Meeting	Orsay, France	1	None
Nov. 2-6, 2004	Annual CARE Meeting	Hamburg, Germany	3	None
Nov. 21-24, 2004	WP4 Collaboration Meeting	Rome, Italy	8	None
Feb. 8-9, 2005	Approval of the final version of AR-2004, publication policy, modelling of new magnetic filters	Swierk, Poland	6	None
May 20-21, 2005	Problems of the arc current reduction and stabilization, design of new magnetic filters	Rome, Italy	6	None
Oct. 17-18, 2005	Problems of present UHV arc experiments, preparation of Annual Report CARE-JRA1- WP4, discussion of future plans (for 18 month period)	Rome, Italy	7	None
March 28-31, 2006	CARE-JRA1-WP4 (Thin film production) Collaboration Meeting 1-2006; Experimental problems, publication policy, modeling of new magnetic filters	Tor Vergata University - INFN Roma 2, Italy	8	None
Sept. 7-8, 2006	CARE-JRA1-WP4 (Thin film production) Collaboration Meeting 2-2006; Approval of the WP4-Quarter Report 2/2006, new papers and joint experiments	IPJ Swierk Poland	5	None
April 23-24, 2007	CARE-JRA1-WP4 (Thin film production) Working Meeting No. 1-2007;	Tor Vergata University	9	None

	Current experimental problems, publication policy, papers and presentations for topical conferences in 2007.	- INFN Roma 2 Italy		
May 23-24, 2007	CARE-JRA1-WP4 (Thin film production) Working Meeting No. 2-2007; Draft of the Midterm 2007 Report on WP4, proposals of new papers and joint experiments.	IPJ Swierk Poland	5	None

List of talks of JRA1/WP4 members

Subject	Speaker/Lab	Event	Date	Website
Super-conducting niobium films produced by means of UHV arc	J. Langner, IPJ, Swierk	21st Symposium on Plasma Physics and Technology, Prague, Czech Rep.	June 14-17, 2004.	None
Status of research on deposition of superconducting films for RF accelerating cavities	J. Langner, IPJ, Swierk	7th International Conference on Modification of Materials with Particle Beams and Plasma Flows, Tomsk, Russia.	July 25-30, 2004	None
UHV arc deposition of superconducting niobium films	J. Langner, IPJ, Swierk	10th International Conference and School on Plasma Physics and Controlled Fusion, Alushta (Crimea), Ukraine.	Sept. 13-18, 2004	None
Annual Report on CARE-JRA1-SRF Work Package 4 (Thin film cavity production)	M.J. Sadowski, IPJ. Swierk	CARE Annual Meeting, DESY, Hamburg, Germany.	Nov. 2-6, 2004.	None
Modelling of magnetic channels for micro-droplets filtering and tests of their efficiency in UHV arc-discharges	P. Strzyzewski IPJ, Swierk	The 5th International Workshop and Summer School "Towards Fusion Energy – Plasma Physics, Diagnostics, Spin-offs", Kudowa, Poland.	June 6-10, 2005.	None
High quality niobium films produced by Ultra High Vacuum	R. Russo INFN, Napoli	TFSRF 2005, Jefferson Lab, Newport News, USA.	July 17, 2005	http://www.jlab.org/intralab/calendar/archive05/

cathodic arc				TFSRF/program.html
Thin super-conducting niobium-coatings for RF accelerator cavities	P. Strzyzewski IPJ, Swierk	SPIE International Congress on Optics and Optoelectronics, Warsaw, Poland.	Aug. 28-Sept. 2, 2005,	http://spie.org/home.html
Research on the use of UHV arc discharges for deposition of superconducting layers	P. Strzyzewski IPJ, Swierk	Intern. Conference PLASMA-2005, Opole, Poland.	Sept. 6-9, 2005	http://draco.uni.opole.pl/plasma2005
WP4 - Thin film cavity production	M. Sadowski IPJ, Swierk	JRA1 Annual Meeting, IFNF-LNL Legnaro, Italy	Oct. 19-21, 2005	http://www.lnl.infn.it/-master/
UHV arc for high quality film deposition	R. Russo INFN-Na, Naple, Italy	ICMCTF06, San Diego, USA	June 2006	
Status of research on deposition of thin super-conducting films for RF accelerating cavities	S. Tazzari Tor Vergata Uni –INFN Roma-2, Rome, Italy	2nd Intern. Congress, Tomsk, Russia	Sept. 2006	
Ultra high vacuum cathodic arc for deposition of superconducting Pb photocathodes	P. Strzyzewski IPJ, Swierk, Poland	11th Int. Conf. PP&CF, Alushta, Ukraine	Sept. 2006	
Progress in use of ultra-highvacuum cathodic arcs for deposition of thin superconducting layers	M.J. Sadowski IPJ, Swierk, Poland	22nd ISDEIV, Matsue, Japan	Sept. 2006	
Progress in research on deposition of thin superconducting films by means of ultra-high vacuum arc discharges	M.J. Sadowski IPJ, Swierk, Poland	Intern. Workshop on Thin Films, Padua-Legnaro, Italy	Oct. 2006	
The UHV cathodic arc; The results on samples and the plasma transport for cavity coating	R. Russo INFN-Na, Naple, Italy	Intern. Workshop on Thin Films, Padua-Legnaro, Italy	Oct. 2006	

Deposition of pure lead photo-cathodes by means of UHV cathodic arc	P. Strzyzewski IPJ, Swierk, Poland	Intern. Workshop on Thin Films, IFNF Padua-Legnaro, Italy	Oct. 2006	
WP4 - Thin film cavity production	M.J. Sadowski IPJ, Swierk, Poland	JRA1 Annual Meeting, IFNF-Frascati, Italy	Oct. 14 2006	
Deposition of thin superconducting coatings by means of ultra-high vacuum arc facilities	M.J. Sadowski, IPJ, Swierk, Poland	16th Symp. on Application of Plasma Proc., Podbanske, Slovakia	Jan. 25, 2007	http://www.fmph.uniba.sk/sapp
Ultra pure metal coatings for superconducting applications using the arc in ultra-high vacuum technique	S. Tazzari, Tor Vergata Uni., INFN-Roma 2, Rome, Italy	IEEE Symp. on Photonics and Electronics, Wilga, Poland	May 24, 2007	http://wilga.ise.pw.edu.pl
Recent achievements in ultra-highvacuum arc deposition of superconducting Nb layers	J. Lorkiewicz, Tor Vergata Uni., INFN-Roma 2, Rome, Italy	IEEE Symp. on Photonics and Electronics, Wilga, Poland	May 24, 2007	http://wilga.ise.pw.edu.pl
Analysis of structure of superconducting Nb layers by means of X-ray techniques	R. Nietubyc, IPJ, Swierk, Poland	IEEE Symp. on Photonics and Electronics, Wilga, Poland	May 24, 2007	http://wilga.ise.pw.edu.pl
Ultra-highvacuum cathodic arc for deposition of superconducting lead photo-cathodes	P. Strzyzewski, IPJ, Swierk, Poland	IEEE Symp. on Photonics and Electronics, Wilga, Poland	May 24, 2007	http://wilga.ise.pw.edu.pl
Plasma technologies (in Polish)	P. Strzyzewski IPJ, Swierk, Poland	IPJ Symp. Warsaw, Poland	June 26, 2007	http://ipj.gov.pl
Deposition of thin metal films by means of arc discharges under ultra-high vacuum conditions	M.J. Sadowski, IPJ, Swierk, Poland	EUROCON 2007, Warsaw, Poland	Sept. 11, 2007	https://eurocon2007.isep.pw.edu.pl
Deposition and	R. Russo,	EUROCON 2007,	Sept. 11,	https://eurocon

characterization of niobium films for SRF cavity application	Instituto di Cibernetica, CNR and INFN-Na, Naple, Italy	Warsaw, Poland	2007	2007.isep.pw.edu.pl
Research and development of superconducting radio-frequency technology for accelerator application (WP4.1)	R. Nietubyc, IPJ, Swierk, Poland	CARE SRF Annual Meeting 2007, Warsaw, Poland	Sept. 18, 2007	https://indico.desy.de/contributionDisplay.py?contribld=1&confld=438
Recent development in deposition of niobium films by UHVCA in SRF cavity (WP4.2)	R. Russo, Instituto di Cibernetica, CNR and INFN-Na, Naple, Italy	CARE SRF Annual Meeting 2007, Warsaw, Poland	Sept. 18, 2007	https://indico.desy.de/contributionDisplay.py?contribld=1&confld=438
Deposition of superconducting niobium films inside RF-cavities of particle accelerators	R. Nietubyc, IPJ, Swierk, Poland	7th National Meeting on Synchrotron Radiation Users, Poznan, Poland	Sept. 26, 2007	http://www.fizyka.amu.pl/ksups
Deposition of superconducting layers on internal surfaces of resonance cavities and on photo-cathodes of electron guns by means of arc discharges at ultra-high vacuum conditions (in Polish)	R. Nietubyc, IPJ, Swierk, Poland	Workshop of FITAL Network, Cracow, Poland	Jan. 18, 2008	
X-ray diffraction studies of the structure of superconducting films deposited by ultra-high vacuum cathodic arc technique	R. Nietubyc, IPJ, Swierk, Poland	Symposium of SPIE, Wilga, Poland	June 1, 2008	

Publications of JRA1/WP4 teams

List of papers	Title	Authors	Journal/Conf.
CARE- Public.			
	Super-conducting niobium films produced by means of UHV arc	J. Langner, M.J. Sadowski, K. Czaus, R. Mirowski, J. Witkowski, L. Catani, A. Cianchi, R. Russo, F. Tazzioli, S. Tazzari, D. Proch, N.N. Koval, Y.H. Akhmadeev	Czech. J. Phys. **54**, Suppl. C (2004) C914-C921.
	High quality superconducting niobium films produced by ultra-high vacuum cathodic arc	R. Russo, L. Catani, A. Cianchi, J. Langner and S. Tazzari	Supercond. Sci. Technol. **18** (2005) L41–44.
	Research activities within a frame of the CARE-JRA1-WP4, thin film cavity production work-package	J. Langner, M.J. Sadowski and S. Tazzari	Elektronika Vol. **XLVI**, No. 2-3 (2005) 76-77.
	Research on deposition of thin superconducting films for RF accelerator cavities (in Polish)	J. Langner, R. Mirowski, M.J. Sadowski, P. Strzyżewski, J. Witkowski S. Tazzari, L. Catani, A. Cianchi, J. Lorkiewicz, R. Russo, F. Tazzioli and D. Proch	Elektronika Vol. **XLVI**, No. 7 (2005) 6-10.
	Thin superconducting niobium-coatings for RF accelerator cavities; progress in CARE-JRA1-WP4	J. Langner, L. Catani, A. Cianchi, R. Mirowski, J. Lorkiewicz, D. Proch, R. Russo, M.J. Sadowski, P. Strzyzewski, S. Tazzari and J. Witkowski	Proc. SPIE Int. Soc. Opt. Eng. **5948** (2005) 71-80.
	UHV arc deposition of superconducting niobium films for RF application	J. Langner, R. Mirowski, M.J. Sadowski, P. Strzyzewski, J. Witkowski, S. Tazzari, L. Catani, A. Cianchi, J. Lorkiewicz and R. Russo	Advances in Applied Plasma Science Vol. **5** (2005) 211-216.
	Modeling of distributions of magnetic fields used for guiding of plasma stream produced in arc discharges (in Polish)	P. Strzyzewski, J. Langner, R. Mirowski, M.J. Sadowski, S. Tazzari and J. Witkowski	Przegląd Elektrotechniczny **12** (2005) 35-37.

	Magnetic Filters in UHV Arc-Discharges: Constructions, Field Modelling and Tests of Efficiency	P. Strzyżewski, J. Langner, R. Mirowski, M.J. Sadowski, S. Tazzari and J. Witkowski	Physica Scripta **T123** (2006) 135-139.
	Behaviour Of Gas Conditions During Vacuum Arc Discharges Used For Deposition Of Thin Films	P. Strzyzewski, L. Catani, A. Cianchi, J. Langner, J. Lorkiewicz, R. Mirowski, R. Russo, M.J. Sadowski, S. Tazzari and J. Witkowski	AIP CP **812** (2006) 485-488.
	Deposition of Superconducting Niobium Films for RF Cavities by Means of UHV Cathodic Arc	J. Langner, R. Mirowski, M.J. Sadowski, P. Strzyżewski, J. Witkowski, S.Tazzari, L. Catani, A. Cianchi, J. Lorkiewicz and R. Russo	Vacuum **80** (2006) 1288-1293.
	Cathodic Arc Grown Niobium Films for RF Superconducting Cavity Applications	L. Catani, A. Cianchi, J. Lorkiewicz, S. Tazzari, J. Langner, P. Strzyzewski, M.J. Sadowski, A. Andreone,G. Cifariello, E. Di Gennari, G. Lamura and R. Russo	Physica **C441** (2006) 130-133.
	Quality measurement of niobium thin films for Nb/Cu superconducting RF cavities	R. Russo	Meas. Sci. Technol. **18** (2007) 2299-2313.
	Ultra high vacuum cathodic arc for deposition of superconducting lead photo-cathodes	P. Strzyzewski, J. Langner, M.J. Sadowski, J. Witkowski, J. Sekutowicz	Probl. Atom. Sci. & Techn. Vol. **1,** Ser. Plasma Phys. No. **13** (2007) 185-187.
	Purity of Nb and Pb films deposited by an ultra-high vacuum cathodic arc	J. Langner, M.J. Sadowski, P. Strzyzewski, J.Witkowski, S. Tazzari, L. Catani, A. Cianchi, J. Lorkiewicz, R. Russo, J. Sekutowicz, T. Paryjczyk, J. Rogowski	IEEE Trans. Plasma Sci. Vol. **35**, No. **4** (2007) 1000-1003.
	Recent achievements in ultra-high vacuum arc deposition of superconducting Nb layers	L. Catani, A. Cianchi, D. Digiovanale, R. Polini, S. Tazzari, J. Lorkiewicz, M.J. Sadowski, P. Strzyzewski, B. Ruggiero, R. Russo	Proc. SPIE Vol. **6937** (2007) 69370R.
	Structure of Nb films deposited by means of ultra-high vacuum cathodic arc	R. Nietubyc, J. Pelka, M.J. Sadowski, P. Strzyzewski	AIP CP, **Vol. 993** (2008) 415-418.

	Fabrication of thin metallic films by means of arc discharges under ultra-high vacuum conditions	P. Strzyzewski, M.J. Sadowski, R. Nietubyc, K. Rogacki,W. Paszkowski, T. Paryjczak, J. Rogowski	Material Science – Poland, **Vol. 26** (2008) 213-220.
	Thin superconducting layers deposited by means of arc in ultra-high vacuum - (in Polish)	R. Nietubyc, M.J. Sadowski, M. Mirowski, J. Witkowski, J. Lorkiewicz	Elektronika (2008) – in print.
	Superconducting niobium layers reached by using vacuum arc technique in INFN-Roma Tor Vergata	J. Lorkiewicz, R. Nietubyc, M. J. Sadowski, D. Di Giovelane, L. Catani, A. Cianchi, S. Tazzari, R.Polini, R. Russo	Elektronika (2008) – in print.
CARE- Conf.			
	Super-conducting niobium films produced by means of UHV arc	J. Langner, M.J. Sadowski, K. Czaus, R. Mirowski, J. Witkowski, L. Catani, A. Cianchi, R. Russo, F. Tazzioli, S. Tazzari, D. Proch, N.N. Koval, Y.H. Akhmadeev	Proc. 21st Symp. on Plasma Phys. and Technology, Prague, Czech Rep., June 14-17, 2004, p.103.
	Status of research on deposition of superconducting films for RF accelerating cavities	J. Langner, M.J. Sadowski, K. Czaus, R. Mirowski, J. Witkowski, L. Catani, A.Cianchi, R. Russo, F.Tazzioli, S. Tazzari, D. Proch, N.N. Koval, Y.H.Akhmadeev	Proc 7th Intern. Conference on Modification of Materials with Particle Beams and Plasma Flows, Tomsk, Russia, July 25-30, 2004, pp. 399-403.
	Superconducting Nb film for RF applications	A. Cianchi, L. Catani, R. Russo, S. Tazzari, A. Andreone, E. Cifariello, E.Di Gennaro, G. Lamura, J. Langner, Yu. Akhmadeev	Proc. 9th European Particle Accelerator Conference, Lucerne, Switzerland, July 5-9, 2004, p.
	UHV arc deposition of superconducting niobium films	J. Langner, M.J. Sadowski, K. Czaus, R. Mirowski, J. Witkowski, L. Catani, A.Cianchi, R. Russo, F.Tazzioli and S. Tazzari, D. Proch, N.N. Koval, Y.H.Akhmadeev	Proc. 10th Intern. Conference and School on Plasma Physics and Controlled Fusion, Alushta (Crimea),Ukraine, Sept. 13-18, 2004.
	Annual Report on CARE-JRA1-SRF Work Package 4 (Thin film cavity production)	M.J. Sadowski, J. Langner, S. Tazzari	Proc. CARE Annual Meeting, DESY, Hamburg, Germany, Nov. 2-6, 2004.

	Modelling of magnetic channels for micro-droplets filtering and tests of their efficiency in UHV arc-discharges	P. Strzyżewski, J. Langner, R. Mirowski, M.J. Sadowski, S. Tazzari and J. Witkowski	Proc. 5th Intern. Workshop and Summer School Towards Fusion Energy – Plasma Physics, Diagnostics, Spin-offs, Kudowa, Poland, June 6-10, 2005.
	Cathodic arc grown niobium films for RF superconducting cavity applications	A. Cianchi, L. Catani, J. Lorkiewicz, S. Tazzari, J. Langner, R. Mirowski, M.J. Sadowski, P. Strzyżewski, J. Witkowski, A.Andreone, G.Cifariello,E. Di Gennaro, G. Lamura, R. Russo	Proc. SRF-2005 Intern. Workshop, Cornell,USA, July 10-15, 2005, P. TuP62.
	High quality niobium films produced by ultra-high vacuum cathodic arc	R. Russo	Proc. TFSRF-2005, July 17-18, 2005, Jefferson Lab, Newport News, USA, Ia-1.
	Modeling of the distribution of magnetic fields used for guiding plasma stream produced in vacuum arc discharges (in Polish)	P. Strzyzewski, J. Langner, R. Mirowski, M.J. Sadowski, S. Tazzari and J. Witkowski	Proc. XV General Symp. on Applications of Electromagnetism in Modern Techn. and Informatics, Ciechocinek, Poland, Sept. 1-3, 2005.
	Thin superconducting niobium-coatings for RF accelerator cavities	J. Langner, L. Catani, A. Cianchi, R. Mirowski, D. Proch, R. Russo, M.J. Sadowski, P. Strzyżewski, S. Tazzari and J. Witkowski	Proc. SPIE Intern. Congress on Optics and Optoelectronics, Warsaw, Poland, Aug. 28 – Sept. 2, 2005, P. 5948-8.
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	Behaviour of gas conditions during vacuum arc discharges used for deposition of thin films	P. Strzyzewski, L. Catani, A. Cianchi, J. Langner, J.Lorkiewicz, R. Mirowski, R. Russo, M.J. Sadowski, S. Tazzari and J. Witkowski	Proc. Inter. Conf. PLASMA-2005, Opole, Poland, Sept. 6-9, 2005, P-9.11.
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