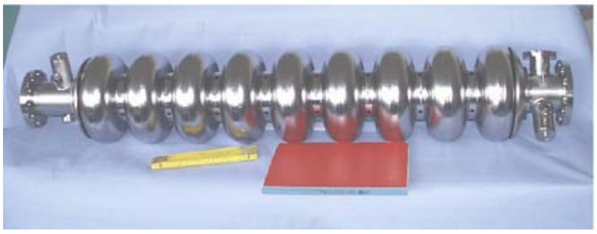
SRF



Deposition of Thin Superconducting Coatings by Means of Ultra-High Vacuum Arc Facilities

M.J. Sadowski[1], P. Strzyzewski[1] and S. Tazzari[2]

[1] The Andrzej Soltan Institute for Nuclear Studies (IPJ), Warsaw, Poland
[2] Tor Vergata University – INFN Roma 2, Rome, Italy

Abstract

This paper presents systems used for deposition of thin coatings by means of arc discharges performed under ultra-high vacuum (UHV) conditions. It also reports on progress achieved in the UHV arc technology.

Contribution to the "16th Symposium on Application of Plasma Processes SAPP XVI", Podbanske (Slovakia), 20-25 January 2007

Work supported by the European Community-Research Infrastructure Activity under the FP6 "Structuring the European Research Area" programme (CARE, contract number RII3-CT-2003-506395)

IL12

Deposition of Thin Superconducting Coatings by Means of Ultra-High Vacuum Arc Facilities

M.J. Sadowski[1], P. Strzyzewski[1] and S. Tazzari[2]

[1] The Andrzej Soltan Institute for Nuclear Studies (IPJ), 05-400 Otwock-Swierk n. Warsaw, Poland
[2] Tor Vergata University – INFN Roma 2, Rome, Italy
e-mail: msadowski@ipj.gov.pl

Abstract

This paper presents systems used for deposition of thin coatings by means of arc discharges performed under ultra-high vacuum (UHV) conditions. It also reports on progress achieved in the UHV arc technology.

Introduction

The deposition of thin layers upon surfaces of various materials is of great importance for the material science and engineering. Such a process can be performed by means of different techniques, e.g. plasma vacuum deposition (PVD), magnetron sputtering, etc. [1]. In modern technology, e.g. in the construction of RF-type accelerators, there appears interest in the use of superconducting materials. Since pure niobium (Nb) is expensive, the application of Cu-cavities coated with a thin Nb-layer may reduce costs considerably. For this purpose, the use was made of the magnetron sputtering technique [2], but quality of the deposited Nb-layers has not been the best one. To improve adhesion and to reduce amount of impurities, a new technique based on arc discharges under UHV conditions was proposed several years ago [3].

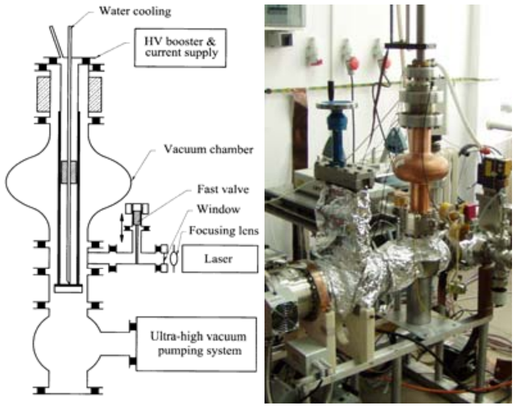


Fig.1. Scheme and view of UHV cylindrical-arc facility constructed at IPJ in Swierk.

Experimental facilities and results

The Polish-Italian team developed UHV arc devices of two different configurations: so-called UHV linear-arc facilities equipped with a cylindrical cathode (see Fig.1) and UHV planar-arc devices equipped with a planar cathode. Several UHV linear-arc facilities were constructed and modified step by step [4]. To optimize the operational conditions, samples (made of sapphire or Cu) were coated within a chamber of dimensions similar to the TESLA-type cavity. The samples coated by UHV linear-arc discharges showed that the deposited Nb-layers have good characteristics: a relatively high RRR (the record was 48) and the good composition, but the main problem constitute micro-droplets.

The structure of the deposited Nb-layers was investigated by means of a scattering electron microscope (SEM) and scattered ion mass spectroscopy (SIMS) techniques. The SIMS profiles showed that the deposited layer contains mainly pure Nb, but SEM pictures demonstrated micro-droplets of different sizes. It was observed that such micro-droplets are immersed into the Nb-layer or deposited upon its surface (Fig.2). To reduce the number of micro-droplets, there were designed special cylindrical filters. The first filter was a concentric system of the Venetian blinds cooled at the end, while the second one consisted of many thin Cu-tubes carrying magnetizing currents and cooling-water flow simultaneously (Fig.3). Test of these filters have already been performed and characterization of the coated samples is realized [4].

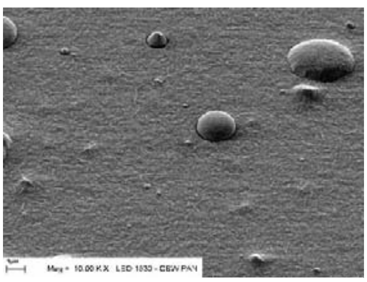


Fig.2. SEM image of the Nb-layer with micro-droplets.

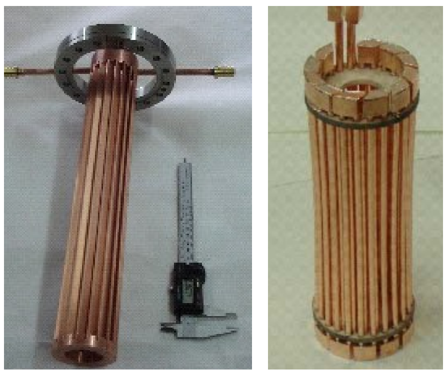


Fig.3. Venetian-type filter (left) and a new one (right) consisted of many thin current-carrying tubes.

During recent years there were also constructed several UHV planar-arc facilities [4]. In fact they were equipped with Nb cathodes of the truncated-cone shape (see Fig.4). Similar to the linear-arc systems, the arcs within the UHV planar-arc devices were also initiated with a laser beam focused on the cathode surface. In order to investigate the Nb deposition, the samples made of sapphire and copper were placed inside the vacuum chamber upon a special holder, which enabled the application of polarization voltage. Using different coating times and different values of the substrate bias, the Tor Vergata team produced Nb-layers of 1 µm to 3.5 µm in thickness, with the RRR values ranging from 26 to 50 for the bias above - 40 V. Recently, attention was paid a dependence of the of an Nb-layer quality on an angle of the exposition to the arc discharge, as shown in Fig.5. The main problem appeared also to be micro-droplets.

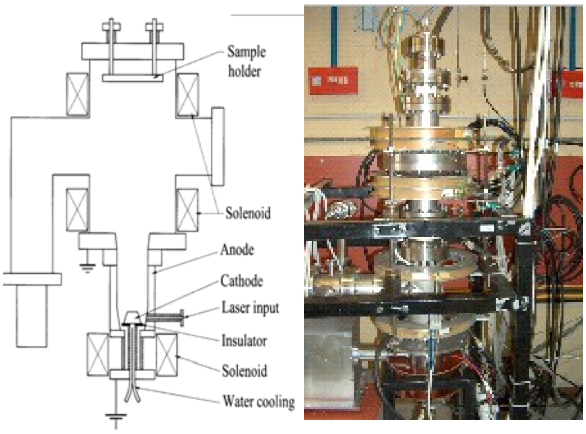


Fig.4. Scheme and view of UHV planar-arc device at Tor Vergata University in Rome.

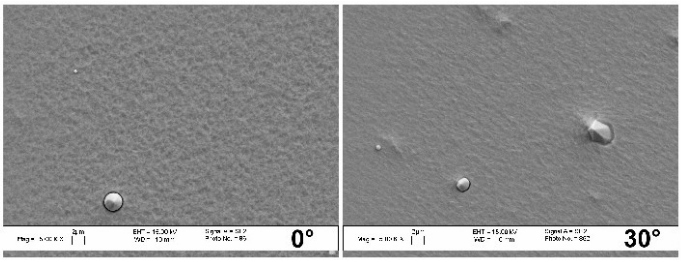


Fig.5. SEM pictures of Nb-layers deposited at different angles within an UHV planar-arc device without filtering.

To reduce the number of the micro-droplets, the IPJ and Tor Vergata teams designed and constructed special magnetic filters. The idea was to deflect the arc column and to allow the heavy micro-droplets (moving along almost straight lines) to be deposited upon walls of a special channel.

Theoretical modeling of such magnetic filters (see Fig.6) and laboratory tests enabled the optimum configuration to be found [5]. In 2006 a new UHV planar-arc device with a T-type filter was put into operation and optimized. Characterization of Nb-layers deposited upon Cu samples was performed by means of FEG-SEM and XRD techniques. It was shown that the deposited layers have smooth surfaces and lattice parameters very similar to those of bulk Nb [6].

It should also be added that the UHV planar-arc device with a magnetic filter has recently been applied also for the deposition of pure lead (Pb) layers which can be used as photo-cathodes in modern electron injectors [7].

Fig.6. Distribution of B-field lines in a T-type filter.

Conclusions

In conclusions it can be stated that the UHV planar- and linear-arc facilities with laser triggering systems, as described above, provide very clean conditions for thin-film deposition processes. Such facilities have already been used for the deposition of superconducting Nb-films, which showed properties similar to the bulk Nb. In general, the UHV cathodic-arc devices are powerful tools for the deposition of pure metallic and super-conducting films, but efficiency of the micro-droplet filtering must still be improved.

Acknowledgement: We acknowledge a support of the EC - Research Infrastructure Activity under the FP6 “Structuring the European Research Area” program (CARE, contract number RII3-CT-2003-506395).

References

[1] R.L. Boxman, et al., *Handbook of vacuum arc science and technology*, Noyes, Park Ridge, NJ, 1995.
[2] C. Benvenuti, et al., *Physica* **C 351** (2001) 421-425.
[3] J.Langner, et al., *Czech. J. Phys.* **52**, Suppl. D (2002) D829-D835.
[4] M.J. Sadowski, et al., *Proc. Workshop on Thin Films*, INFN-Legnaro, Italy, Sept. 2006, p. 51.
[5] P. Strzyzewski, et al., *Physica Scripta* **T123** (2006) 135-139.
[6] R. Russo, et al., *Proc. Workshop on Thin Films*, INFN-Legnaro, Italy, Sept. 2006, p. 52.
[7] P. Strzyzewski, et al., *Proc. EPAC 2006*, Edinburgh, Scotland, June 2006, pp. 3205-3205.