PRELIMINARY RESULTS ON NIOBIUM SPUTTERED FILMS INSIDE TESLA TYPE CAVITIES

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Abstract

In the framework of the ARES project and as a possible application for TESLA [1] we realized a test set-up to study the deposition of Nb films inside a single-cell TESLA type cavity. The plasma confinement was obtained with two external coils centered on the cavity axis in a magnetic bottle configuration. The system is operational and optimization of the discharge parameters is in progress: samples are been produced to test the film quality.

This paper covers a brief description of the test set- up and preliminary results on samples (thickness, RRR, and XRD measurements).

Introduction

The Nb coated copper cavities provide higher stability against quench respect to cavities traditionally made of Nb sheet. This is a very important characteristics for high acceleration field application, because quenching is still a field limitation above 10MV/m for high frequency cavities [2].

Sputtering is a well known [3] and useful technique for coating copper RF cavities with superconducting thin films [4], [5].

Magnetron sputtering to coat accelerating cavities with superconducting film was developed at CERN for 500 MHz cavities, and is at present used in industry to coat 350 MHz copper cavities for LEP with Nb films [6]: the magnetic field is produced by a coil placed inside the cylindrical cathode and displaced in steps along the cavity axis to achieve a uniform coating.

Because our setup is designed to coat 1.3 GHz cavities for TESLA that are 3 times smaller than the CERN ones, external coils placed on the outside of the cavity cut-off pipes (see Fig.1) and producing a magnetic mirror field configuration have been adopted, so as to preserve full control over the field shape and intensity.

The two coils are contained in a soft iron shield (low carbon contents) 4 mm thick realized so as to be taken down completely and changed according to needs. This configuration has the aim to obtain a magnetic field concentrated along the axis of cavity with a minimum at center of about 200 Gauss and a mirror ratio ($B_{min.}/B_{max.}$) of about 2.

The field simulation has been obtained with Poisson-Superfish program, on which is based the whole coil design.

The Sputtering System

The sputtering system is schematically shown in Fig.1; we have different stainless steel TESLA type cavities [7] in the inner walls of which, along all cavity profile, we can place small copper and sapphire (Al_2O_3) samples that allow us to make a complete film diagnostic. We can characterize the Nb film through RRR (Residual Resistivity Ratio), T_c thickness and XRD (X Ray Diffraction) measurements.

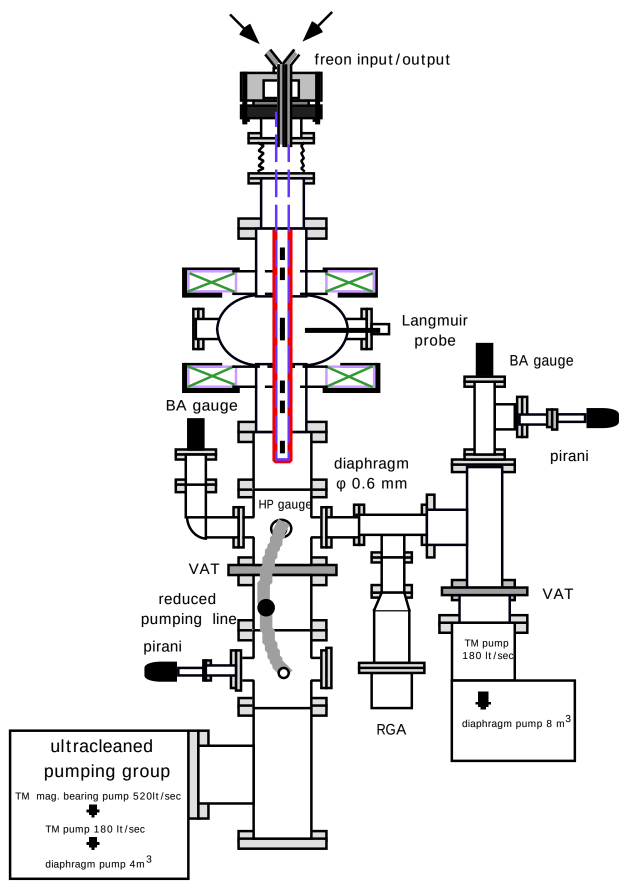

Fig.1 Sputtering system scheme

The vacuum on the system is performed by an ultracleaned pumping group consisting in a 4 m^3/h diaphragm pump for the primary vacuum and two on fall turbo molecular pumps (nominal pumping speed respectively 180 l/sec and 300 l/sec) one of which is provided with magnetic bearing, in this way we have a very good compression ratio for hydrogen besides a good ultimate pressure (~10^{-10} mbar) and total absence of hydrocarbons.

The system is provided of a residual gas analyzer (RGA) which besides finding the ultimate pressure gas composition, permits to check, during sputtering process, the percentage of gas produced, as for instance hydrogen, that damages the film structure if it is over a certain threshold. To use the RGA during sputtering process, due to relatively high operating pressure (~10^{-3} mbar), we need a differential pumping, i.e. the RGA communicates with cavity through a diaphragm of .6 mm and it is provided with another pumping system in such way as to decrease the pressure of 3 order of magnitude respect to the pressure of the cavity vacuum chamber.

The cathode consists of a vacuum tight stainless steel tube (17 mm inner diameter) surrounded by a niobium liner (20/24 mm inner/outer diameters). The liner is an high purity Nb tube (RRR value better than 150) without welding. The stainless steel tube is provided of an inner support that holds and centers 7 SamCo permanent magnets (small cylinders 8 mm diameter 16 mm long) along all the cavity length that will be cooled through a liquid freon circuit to take away about 2 KW of power. We have performed the preliminary tests to optimize discharge parameters; in those preliminary tests we used magnetic bottle configuration without permanent magnets inside cathode.

Discharge parameters optimization

To characterize our system we produced I versus V curves for different pressures, typical curves are shown in Fig. 2.

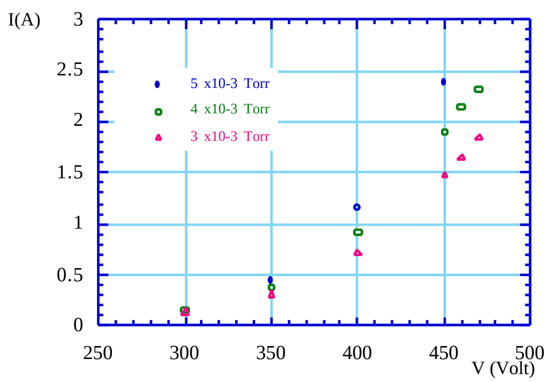

Fig.2. Discharge characteristics at different pressures

The current in our coils was 80 A and the distance between the coils 17.5cm. After a coil shields optimization and coils distance reduction (10.8cm) to increase plasma confinement, we could work at lower pressure ($3x10^{-3}$ Torr) and higher current (1.5 A) with same voltage; we obtained the I versus V curves showed on Fig. 3.

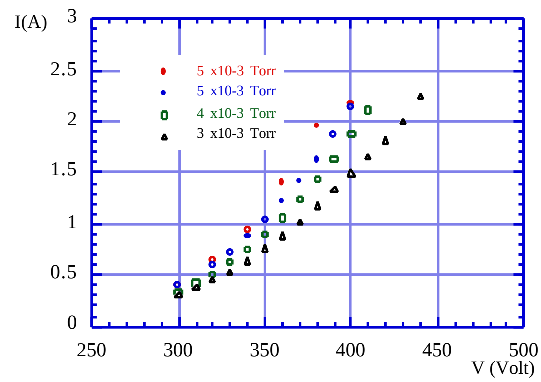

Fig.3. Discharge characteristics at different pressures with new magnetic shields configuration

We produced 4 samples, the discharge parameters for each sample are listed on table 1. The sample 4* is produced with new magnetic shield configuration.

Sample	Current [A]	Power [W]	Pressure [mTorr]	t
1	1.0	400	4.5	60'
2	1.0	400	4.5	60'
3	1.2	480	5.1	60'
4*	1.5	600	3.0	50'

Table 1
Discharge parameters

As one can observe the discharge current for last sample was increased at lower pressure due to a better plasma confinement with new magnetic field configuration.

Measurements on samples

The crystalline quality of the samples has been investigated by means of x-ray diffraction in the θ-2θ mode using Cu Kα_1 radiation. Diffraction data from sample 4* are shown in Fig 4.

Indexing of the lines allowed the identification of three different orientations, namely (110), (211), (321), the latter being barely discernible as a bump in the experimental data. The lattice constant d_o has been estimated by careful extrapolation in order to minimize systematic errors (see Tab.2), a comparison can be made with the value d_o =3.30 Å quoted for bulk Nb crystals. The samples have thus the same lattice parameter within the experimental uncertainties (± 0.006 Å).

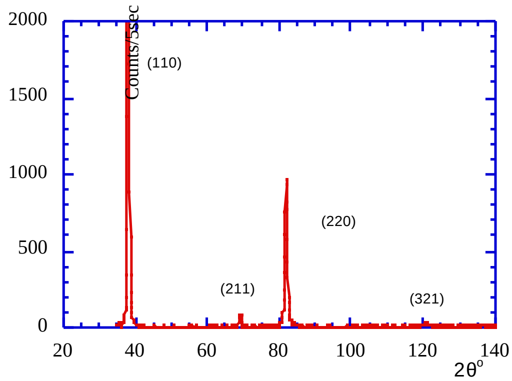

Fig.4 Diffraction data for sample 4*

Other conclusions can be drawn from an analysis of the relative intensities of the diffraction peaks from the (110), (211) orientations. For a polycrystalline sample the ratio of the intensities can be calculated using standard crystallography packages (including temperature factor corrections), yielding the value $I_{211}/I_{110} = 0.305$. The same ratio has been estimated from the experimental data (see Tab.2). From these results it is readily seen that the films have a tendency to grow along a preferred orientation, in this case the (110). The effect is particularly evident in samples 3 and 4*, where the intensity from the (211) orientation is depressed by a factor of 30 compared to the predicted intensity from a polycrystal.

Sample	Depos.rate [Å/sec]	d_o [Å]	I_{211}/I_{110}	Thickness [μm]	RRR
1	4.4			1.6	9
2	4.4	3.312	9.2×10^{-2}	1.6	10.5
3	6.1	3.314	9.7×10^{-3}	2.2	12.5
4*	8.7	3.316	1.1×10^{-2}	2.6	16

Table 2
Results on samples measurements

An analysis of RRR shows that the values increase with the deposition rate and with the thikness; for sample 4* a lower deposition pressure works together producing a further increase.

Conclusions

We need more statistics, but preliminary results on RRR measurements show that this new magnetron sputtering configuration is competitive with the CERN one [8].

In the near future we plan to optimize the magnetic field in order to further improve the discharge confinement.

Surface resistance measurements are also foreseen to obtain a more complete diagnostic picture of film quality.

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