A DC POST-MAGNETRON CONFIGURATION FOR NIOBIUM SPUTTERING INTO 1.5 GHz COPPER MONOCELLS.

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Summary

We have built a DC post-magnetron for the Niobium sputtering of 1.5 GHz Copper monocells. The working principle is based on a plasma confinement that, by means of both magnetic and electrostatic mirrors follows the resonator profile. The idea was the search for a configuration having high deposition rates and sputtering from cathode simultaneously all over the substrate. By modulating the magnetic field shape and the field strength we can achieve in some areas a loose magnetic confinement that produces a sort of discharge unbalancing. We investigated the effect of plasma interaction with cavity walls on the RRR values of the Niobium coating.

Introduction

The achievement of higher accelerating fields at low rf losses accompanied by cost reduction in cavity manufacture, is compulsorily for the new generation of linear colliders as TESLA. If the sputtering technology will be proved to work successfully for TESLA-type ninecell resonators, cost reduction due to material saving will be not negligible. In such a framework our investigation of Niobium sputter-coated 1.5 GHz Copper monocell prototypes is a preliminary stage of a feasibility research on sputter-coating ninecells applicable in real accelerators.

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The DC post-magnetron

Since the cavity has a rather complex shape, the problem of uniform rate of sputtering could be solved in two different ways:
i) by Biased diode sputtering, properly shaping the Niobium target in order to have everywhere the same distance between cathode and anode. This could have been done by means of a collapsible target to insert into the resonator.
ii) by magnetron sputtering, keeping the form of target the most simple as possible, then properly shaping the magnetic field parallel to the substrate.

We chosen the latter approach to the problem. Hence we have built a DC post-magnetron with four coils external to the cavity as sketched in fig. 1. The two long coils are needed for the plasma confinement; the two shorter help the electrostatic mirror focusing the magnetic field on wings.

Plasma is strictly confined onto the target surface portion parallel to the cavity cut-off tubes. It is left unconfined at the equator level, where ionizing electrons are trapped by magnetic field lines. From the reflecting wings there is very little sputtering. The maximum of ionization instead takes place at the center of the magnetron. The distribution of sputtered particles from cathode is cosinusoidal, and at low pressure the sputtered particles have almost straight trajectories.

By this configuration we can dispose of high deposition rates and moreover we can sputter simultaneously all over the substrate. High deposition rates are beneficial for the film purity, since increasing the arrival rate of Niobium atoms to the substrate, it decreases the fraction of impurities trapped in the film.

In our sputtering configuration we have the possibility to change the gap between coils (i.e. the field shape) and the current supplied to them (i.e. the field strength). More than all the others the coils gap is the parameter that more influences the quality of the coating. It determines indeed the discharge penetration depth inside the resonator cell. Hence it influences the thickness distribution and simultaneously the effect of discharge unbalancing. Figure 2 shows that opening the gap the sputtering rate inside the resonator gets more uniform.

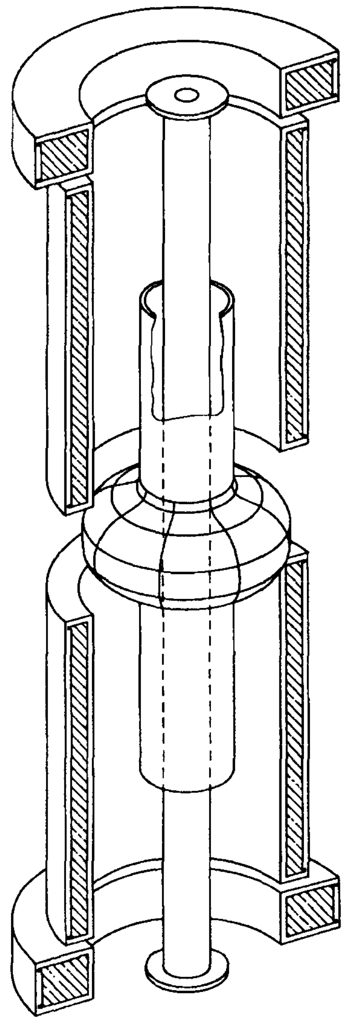

Fig. 1. - Cathode, cavity and coils arrangement in our DC post-magnetron sputtering configuration:

The effectiveness of magnetic confinement is understandable by the I-V characteristics. Discharges operating in the magnetron mode obey a relationship of the form $I \propto V^n$, where **n** is index of confinement efficiency, and in some respects expresses the quality of the magnetron. In literature for cylindrical magnetrons **n** is typically between 5 and 12. Fig. 3a and 3b show the Volt-Ampere characteristics respectively versus the magnetic field at the cavity equator at fixed pressure and versus Argon pressure at fixed magnetic field.

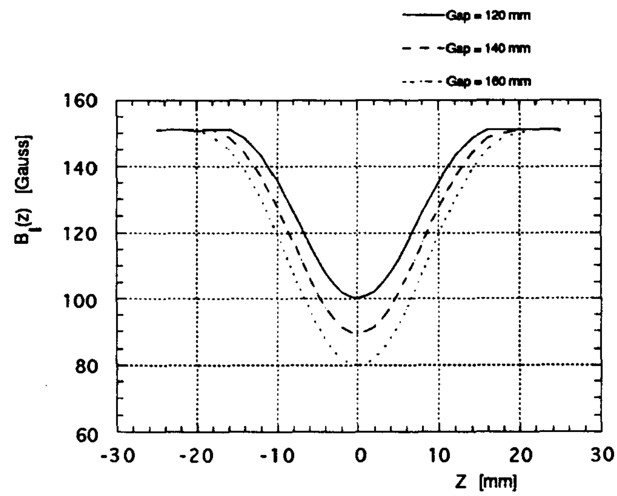

Fig. 2 Magnetic field component parallel to the target B||(z) versus distance from the equator along the cavity axis, at different values of the coils gap. The current across coils is kept constant.

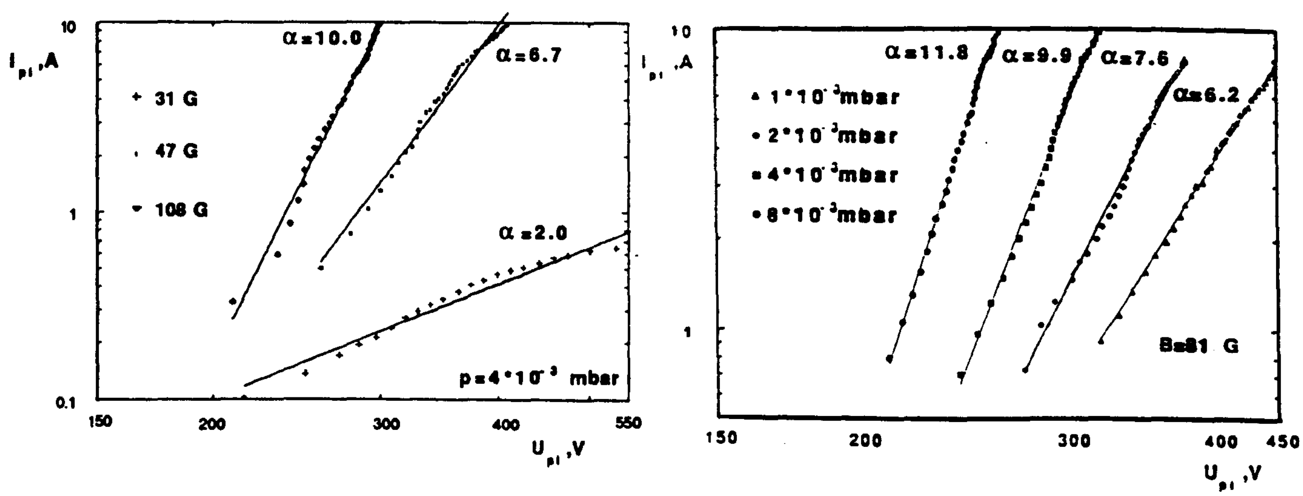

Fig. 3 I-V Characteristics: a), for different values of the magnetic field at the equator; b) for diffrent values of pressure.. The coils gap is kept constant while it varies the coil current

In fig. 4 is reported the curve of stability of our cylindrical magnetron. It is possible to see that a threshold magnetic field must be exceeded to start discharge. On the other side increasing field up to 60 G, the limit pressure get lower even of an order of magnitude.

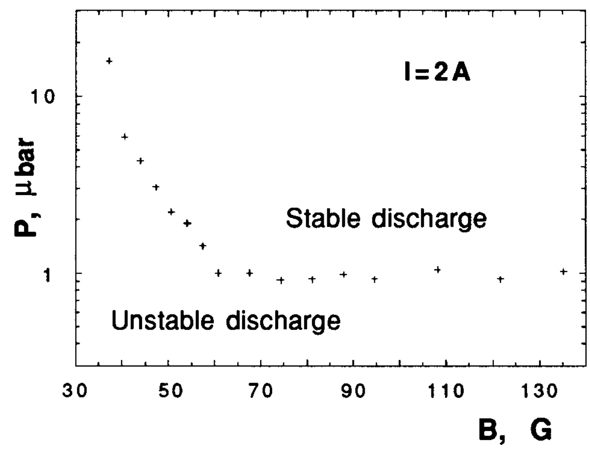

Fig. 4 Conditions of pressure and magnetic field strength for stable operation of the magnetron (at a discharge current of 2 A).

Usually increasing the power, the deposition rate increases too, and RRR values improve. Unfortunately in our experiments higher power gave no significant improvement. In fact passing from 2.5 KW to 4 KW, RRR at the equator increases from 22 to 24. Plasma-substrate interaction has a stronger influence of the film growing process. We found out that steerring the plasma by varying the coils gap from 95 to 115 mm, the RRR value at the equator increased from 22 to 30. Increasing the coils gap, the film quality decreases. Further Investigation lead RRR values from a minimum of 22 at the equator to a maximum of 52 at the iris.

The first sputtering test on a real cavity was performed onto a fully spun seamless monocell cavity. The cavity was electropolished in a orthophosphoric acid and n-butanol solution, then chemically polished and passivated. After a 24 hours baking at 200°C a vacuum in low 10^{-9} mbar range was reached. The sputtering parameters were: Voltage = 570 V, Current = 5.3 A; Temperature = 200°C Deposition time = 30 minutes. The cavity showed a strong residual during the RF cold test. The Q-factor at 4.2 K was only 2×10^8, and at 2 K it was around 1×10^9.

Acknowledgments

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