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# Optimization of the RF magnetron sputtering parameters of Mo films with low oxygen contamination for application to high-gradient RF breakdown accelerator


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## Abstract

In the framework of the collaboration with SLAC, KEK and Frascati Laboratory, we started an intense activity on dedicated materials coating for high-gradient RF breakdown accelerator. At this goal Molybdenum is an attractive material for accelerator components and a stimulating option for RF linear accelerating structure characterized by low breakdowns at high RF power. The aim of the present paper is to investigate the electrical and chemical properties of Molybdenum thin and thick films deposited by sputtering technique after the Mo sputtering process parameters have been optimized in order to reduce the oxygen contamination in the Mo films.


## Introduction

A bulk molybdenum brazed RF cavity has been realized and tested at high power at SLAC [1]. It is known that the molybdenum is very difficult to be machined with a good roughness ( not less than 350 nm has been obtained ) and could trap residual gas by limiting the sections performances in terms of breakdown effects, as it was observed at SLAC during the high power tests on brazed three cells section. For this reason, we are investigating the possibility to make the cavity resonators in copper with an excellent roughness and then to cover it by a Molybdenum film to be deposited by sputtering technique in order to reduce the breakdown phenomena. In this paper we explore the possibility of reducing the oxygen contamination on dedicated samples which could affect the deposition quality. Then, additional investigations will be carried in order to get the global chemical composition of the deposition.

## Sputtering technique at CNR

The Mo thin films were grown by rf magnetron sputtering technique on different insulating substrates, such as Corning glass 7059, $Al_2O_3$ (0001) and $Al_2O_3$(11-20), starting from a high purity (99.995%) Mo target. The sputtering process was performed in ultrapure Ar gas atmosphere and the substrates were positioned on a cold sample holder. Figure 1 shows the sputtering apparatus from Ionvac Process srl.

Figure 1: the RF magnetron sputtering apparatus from IONVAC PROCESS srl.

The Mo film optimized sputtering parameters are the following:

| | |
|---|---|
| Background Pressure | ~$2 \cdot 10^{-7}$ torr |
| Presputtering pressure<br>Gas<br>Power<br>time<br>Pressure during the sputtering process | 4mTorr<br>ultra pure Argon (23 sccm)<br>60 watt<br>30 min<br>4 mTorr |
| Substrate Temperature | 20°C |
| sputtering pressure | 4 mTorr |
| gas | ultra pure Argon (23 sccm) |
| Power | 60 w (150w) |
| substrate | Corning glass ; sapphire (0001) and (11-20); silicon (001) |
| Film thickness | 3000 Å; 6000 Å; 9000 Å. |

The sputtering process was preceded by a pre-sputtering performed on the shutter for about 30 minutes in order to clean the Mo target. The glass and sapphire substrates were carefully cleaned before being put inside the chamber.

The Mo films were simultaneously sputtered on the glass or sapphire substrates and on a reference sample to be used to measure the film thickness and previously prepared for the lift off process. The reference sample, prepared at IDASC-CNR, shows an interdigitated electrode configuration (see figure 2) that was photolithographically defined on a AZ positive resist film, previously deposited by spinning technique on its surface. After the Mo film sputtering, the reference sample was dipped in acetone to remove the film parts grown onto the resist so to leave the metal defined geometry. Finally, at IDASC-CNR the thickness of the Mo film grown on the reference sample was measured by a mechanical profilometer from Taylor-Obson (see figures 2 and 3).

Figure 2: interdigitated Mo electrode geometry obtained by lift off process

Figure 3: The mechanical profilometer used to measure the thickness of the thin Mo films grown on the reference samples (courtesy of IDASC-CNR).

Two different sputtering RF power values, 60 and 150 Watt, were applied, corresponding to two different deposition rate (and obviously deposition time): the Mo films grown on glass were sputtered at 60 Watt, while the Mo films grown on $Al_2O_3$(11-20) and $Al_2O_3$ (0001) were sputtered at 150 Watt. At the present, preliminary investigations on the Mo films grown on glass reveal that the film has a lower Oxigen content and a better resistivity with respect of the previous one [2]. Figure 4 shows, as an example, the RBS (Rutherford Back Scattering) measurements performed on a Mo film sputtered on glass. The acquired spectrum is in black, the red is a simulation of a pure Mo film 300 nm thickness without glass. In the acquired spectrum of the deposited film Mo the signal is overlapped to the signal of the glass, for this reason it is higher than the simulation. It looks there is no oxygen (or very low concentration) on the surface (no signal in correspondence of O surface channel indicated by the label).

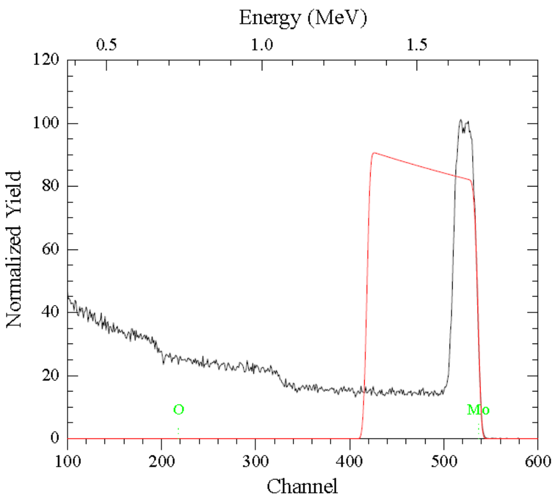


Figure 4 : RBS measurements performed on a Mo (300 nm thickness) film sputtered on glass

## Conclusions

Further analysis are in progress on the chemical composition of the Mo films deposited on sapphire substrates. The chemical composition of the Mo films sputtered on different substrates and with different rates will be investigated in order to verify if the substrate and deposition time can influence the oxygen contamination in the Mo films. Measurements of the RF resistivity are also in progress for all the Mo samples. Technological solutions are being studied in order to achieve a further reduction of the oxygen contamination in the molybdenum: in particular it is intended to work on the possible contamination of the film from the residual gases due to outgassing of the walls of the growth chamber. Detailed RF resistivity measurements are in progress for the all samples, too [3].

## References

[1] B. Spataro et al." Technological issues and high gradient test results on X Band Molybdenum accelerating structures, NIM-A-**657** (2011) 114-121;
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