New Possibilities in the Preparation of Heavy-Ion Targets by Sputtering Deposition

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Introduction: Sputtering is a ballistic process which allows to deposit layers of very different materials: low melting metals as well as refractory materials, elements and compounds, and with an rf-sputter source even dielectrics and insulators can be sputtered. Additionally it is possible to sputter in presence of an reactive gas or a gas mixture so that for example oxides can be created directly during the deposition. At large sputtered layers have a higher adhesive strength on a substrate than evaporated layers. All these properties make sputtering deposition a powerful tool in preparation of heavy-ion targets.

Sputtering in the target laboratory: Until recently we used the sputtering technique solely with a focused ion beam sputtering apparatus from Danfysik [1]. There, a beam of Ar-ions is extracted from a duoplasmatron ion source and is focused to a diameter of about 2 mm on a sputter cathode made of the wanted target material. This method has a very high efficiency so that one can work with extremely small amounts of material. This is essential especially for rare and expensive isotopes. But because of the limited power (10 keV, 1 mA) and the close set up only small-size targets can be produced in a justifiable time and with a reasonable homogeneity.

In the end of 2000 the target laboratory purchased a new sputter coater from BOC Edwards which is equipped with two 1" and one 3" magnetron sputtering sources like the one depicted in principle in figure 1. They can be operated in the DC as well in the RF mode. After the installation of the machine and a rather short running-in period we began in 2001 with the test and the first production of targets with this equipment.

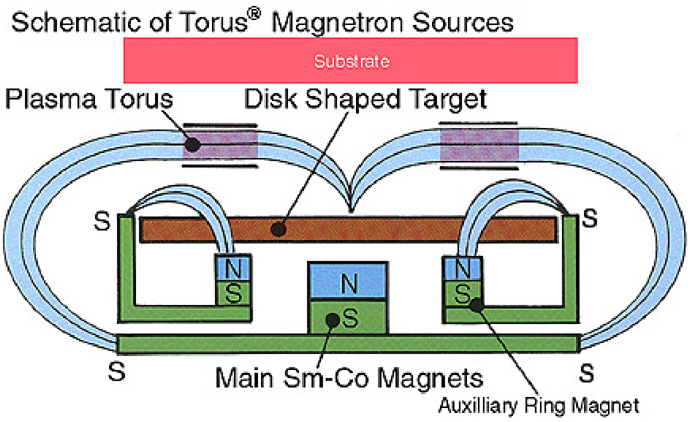
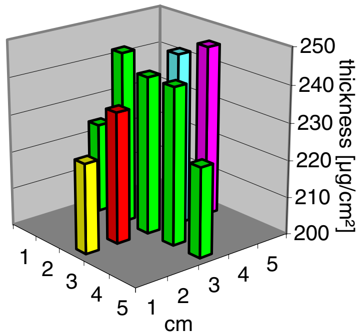


Figure 1: Principle of a Magnetron Source [2]. The magnetic fields depicted above in combination with a vertical **E**-field confine the low-pressure plasma to a torus above the target.

Gold is a material that sputters well. We deposited Au-layers in a wide thickness range on glass substrates coated with betain-saccharose and detached them easily. By depositing Au directly on glass plates one gets durable mirror layers. We also deposited Au-layers on thin Cr-layer on diamond substrates for the detector laboratory.

We made some tests of producing free standing C-layers with DC sputtering as well as with RF-sputtering but the sputtering rate of C is rather poor and the results are not convincing until now.

We also had the task to produce layers of cobalt, of chromium, of nickel, and of niobium on tantalum plates respectively which had to have an high adhesive strength. In the case of Cr and Nb the sputtering was rather easily and straight forward and the homogeneity of the layers is satisfactory as you can see in figure 2. But for the magnetic materials of Co and Ni we ran into problems. The inner magnetic field of Co respectively Ni interfered with the magnetic field of the Sm-Co magnets situated below the sputtering target (see figure 1). They are meant to confine the plasma to a stable a toroidal zone burning right above the sputtering target. With standard sputtering targets out of Cr or Ni of thickness between 3 mm to 5 mm it was not possible to ignite a stable plasma. We finally succeeded with those layers anyhow in stacking several thin foils of a thickness not higher than 250 to 300 µm and replacing the upper one after some time.



average 237 µg/cm²
deviation ± 9.94 µg/cm²
± 4.19 %

Figure 2: Distribution of the weight per area of a sputtered Ni-layer and the corresponding tolerances.

For the heavy-element program at SHIP we produced large-area targets of tantalum on a C-backing. Ta is a refractory material so that thermal evaporation - which is the standard method for the SHIP-wheels - was not possible in this case. Ta could only be evaporated with an electron beam gun but for the banana-shaped SHIP-targets with an active target area of about 18.5 cm² one would need a very large distance between the crucible and the target to get at least a tolerable homogeneity of the layer. This was no real alternative. Since ^{181}Ta has a natural abundance of 99,988 % it was possible to make a first try for the production of SHIP-targets because one could use a pure standard plate of Ta as sputtering target. In other cases this would possibly be not so easy since for experiments with low reaction cross-sections it is necessary to use highly enriched material. To get highly enriched isotopes in the form of a metal sheet of 1 inch in diameter and a sufficient thickness will be a difficult task for some isotopes. But nevertheless this new method opens up a new perspective for heavy-ion targets out of materials categorized until now as impossible.

References:

[1] H. Folger, J. Klemm, and M. Müller, IEEE, Vol. NS-30, No.2 April 1983.

[2] http://www.lesker.com