Sputter Deposition of Conductive Metal Oxides Using RF Ion Beam Sources

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Introduction

Veeco's RF Ion Beam Sources provide the advantages of low maintenance, filamentless operation in processes that require oxygen. They were designed primarily for reactive sputter deposition and ion beam assisted deposition of dielectric metal oxides such as quartz, tantalum pentoxide, titanium dioxide, and aluminum oxide. These materials are typically used for optical coatings and as high performance dielectric gap layers in thin film heads. However, there are some other applications involving reactive ion beam sputter deposition of conductive metal oxides where the low maintenance, filamentless characteristics of RF Ion Beam Sources are also of interest.

Spinel like materials are of interest for thin film resistors, lithium batteries, and temperature sensor applications. Nickel oxide is of interest as a material for the Giant Magneto Resistive (GMR) structures proposed for the next generation of thin film heads used in data storage applications. Because these oxides are somewhat conductive, it was postulated that sputter depositing them using RF Ion Beam Sources might increase the ion source maintenance requirements. This issue arises due to the fact that the Veeco RF Ion Source design utilizes an RF coil to inductively couple RF power into the source discharge through a quartz discharge chamber. Coating of the electrically insulating quartz discharge chamber with back sputtered conductive material from the deposition process can reduce source performance and increase maintenance requirements.

Described are the results of tests which were run to determine if the back sputtered material which coats the inside of the quartz discharge chamber during deposition would be conductive enough to increase ion source maintenance requirements.

A related issue affecting both equipment costs and maintenance requirements is the effect of back sputtered material on the accelerator grid. If the material that coats the accelerator grid is *not sufficiently* conductive, the grids have a tendency to arc and operate unstably. For deposition of dielectric materials, this has been addressed by the use of an additional (third) grounded grid called a decelerator grid which mounts in front of the accelerator grid. However, the third grid adds to the cost and complexity of the system, and has some performance trade-offs as well. An additional goal of the tests described here was to determine if a decelerator grid would be required for deposition of the conductive metal oxides described above.

Accelerated sputter deposition tests were conducted for both a spinel compound and for nickel oxide. Due to the availability of equipment at the time of the test, two different size ion sources and slightly different test setups were used for the two materials. The tests and corresponding results for each material are described below.

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Spinel Deposition Test

This test was conducted in a Veeco VPS-200 baseplate vacuum system with a 10" (25 cm) CTI cryo-pump and a 20" (50 cm) diameter vertical bell jar. The ion source was mounted on a top plate with the beam directed vertically down on to a horizontally mounted spinel target. In order to accelerate the test, the grid to target spacing was kept very short, 6" (15 cm), and the beam was at normal incidence to the target. This configuration resulted in a high back sputter rate and a shorter required test.

Deposition conditions including pumping speed, total pressure and oxygen partial pressure were comparable to those used in a Veeco HDG-200 automated deposition system to produce high quality films for an infrared detector application. The ion source used for the test was a 12 cm RF source with a two grid, convergent dished molybdenum grid assembly. Oxygen was supplied into the vacuum chamber as a background gas at a flow rate of 30 SCCM resulting in an oxygen partial pressure of approximately 2×10^{-4} Torr. The source was operated for 117 hours at a 150 mA/ 1500 V beam condition.

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Nickel Oxide Deposition Test

This test was conducted in a Veeco SDG-100 Dual Ion Beam Deposition System. This system has a 30" H x 28" W (76 cm H x 71 cm W) box chamber with a Balzers TPH 2200 (10"/ 25 cm) turbo pump. The 6 cm RF source used for deposition was mounted on the chamber door with its beam directed horizontally against a nickel target mounted in a vertical plane. In order to accelerate the test, the grid to target spacing was kept very short, 4" (10 cm), and the beam was at normal incidence to the target. This configuration resulted in a high back sputter rate and a shorter test than would have been required for the normal target distance, 10" (25 cm), used in this system.

The 6 cm RF source used for the test had a two grid, convergent dished molybdenum grid assembly. It was operated for 100 hours at a 100 mA/ 1000 V beam condition. The RF Ion Source and Plasma Bridge Neutralizer were operated on argon. Oxygen was supplied into the vacuum chamber as a background gas at a flow rate of 10.5 SCCM resulting in an oxygen partial pressure of approximately 1×10^{-4} Torr.

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Results

The results of the spinel and nickel oxide deposition tests were qualitatively similar.

In both cases, the quartz discharge chamber and accelerator grid were both heavily coated with back sputtered material. The resistance of the spinel material coating the inside of the 12 cm RF discharge chamber ranged from 0.7 to 3.0 MΩ depending on the location of the measurement. The resistance of the spinel material coating the downstream side of the 12 cm grids was 100 -150 kΩ. The resistance of the nickel oxide material coating the inside of the 6 cm RF discharge chamber ranged from 13 to 18 MΩ depending on the location of the measurement. The nickel oxide material coating the downstream side of the 6 cm accelerator grid ranged in resistance from a few hundred kilohms to a few megohms and was approximately 0.005" (0.13 mm) thick.

The 12 cm RF ion source showed no apparent degradation in discharge performance and no tendency for grid arcing during the spinel deposition test. RF power requirements at a given beam current are a good measure of discharge efficiency. The RF power increased by only 4% over the course of the spinel test and most of that change occurred during the first couple of hours. This is a good indication that the back sputtered spinel material did not impede the coupling of RF power into the discharge.

In the case of the nickel oxide test, the RF power gradually increased by about 25% over the 100 hour test. However, this increase in power was not due to a reduction in RF coupling efficiency from the nickel oxide coating of the discharge chamber. Rather, it was due to a reduction in the physical open area of the grid holes due to the large volume of back sputtered material. At the completion of the 100 hour test, the back sputtered material was removed by abrasive bead blasting and the 6 cm RF discharge power returned to the same value as at the beginning of the test. Recall that by the end of this test the coating on the downstream side of the accelerator was 0.005" thick. This relatively rapid build up of back sputtered material was due to the very close coupled geometry used for this accelerated test. For typical deposition system geometries, this build up of material on the grids would take place over a much longer time period. [Note that the target distance for the nickel oxide test 4" (10 cm) was significantly shorter even than that used for the spinel test 10" (25 cm). Also the 6 cm grids used for the nickel oxide test are relatively more sensitive to coating of the grid holes since they have smaller screen grid holes than the 12 cm grids; 0.038"(0.97 mm) verses 0.081" (2.06 mm).]

As with the 12 cm grids used for the spinel test, the 6 cm two grid accelerator system used in the nickel oxide test showed no tendency to arc even though the back sputtered nickel oxide material was found to be relatively insulating.

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Conclusions

The results of this test clearly demonstrate that Veeco RF Ion Beam Sources with two grid accelerator systems are a good match for deposition of conductive metal oxides such as the spinel and nickel oxide materials used in these tests. It is fortunate, although not totally unexpected, that the material which coated the inside of the discharge chambers was sufficiently insulating as to not cause discharge performance degradation while the material which coated the accelerator grid was sufficiently conductive as to not cause any grid arcing problems.

The tests did show that the material which coats the grids tends to be highly stressed and readily flakes off when the system is vented to atmosphere. This suggests that the ion source should be oriented such that the grid planes are vertical (i.e., with the beam horizontal) in order to minimize the tendency for grid flakes to fall between the grids and cause shorts. Such a source orientation is a standard design configuration for most ion beam deposition systems but would be particularly important for a system designed to deposit these conductive metal oxides.

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