Deposit Insulators with Dual Cathode ICM Cylindrical Magnetron

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Introduction

Cylindrical magnetrons are the perfect way to completely coat three-dimensional objects at high rates. The target is the inside surface of a cylinder and sputtered material arrives simultaneously from all radial directions. Many applications, such as ceramic layers on biomedical devices, barrier coatings on fibers and wires, and optical films on complex parts require electrically insulating coatings such as aluminum oxide.

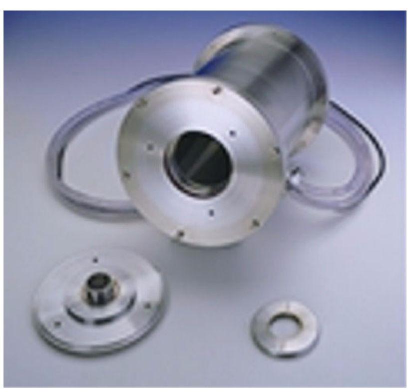

Figure 1 ICM 516

Reactive sputtering of insulator is a challenge because non-conducting regions form on the targets and lead to arcing. Futhermore, anodes can become coated and cease to function. An inverted cylindrical magnetron, that consists of two co-axial targets in a common magnetic field, eliminates both of these problems. This new design has been used in a CYCLONE™ system to reactively sputter aluminum nitride, aluminum oxide, and titanium oxide at high rates.

Discussion

An illustration of the dual cathode system is shown in the figure below. The two targets are driven by an AC power supply, so that they alternate as cathode and anode. Therefore, the buildup of positive charge that causes arcs in DC sputtering is dissipated on every cycle by the attraction of electrons. And since each electrode alternately sputters and serves as the anode, there is no insulating buildup and thus no "hidden anode" effect.

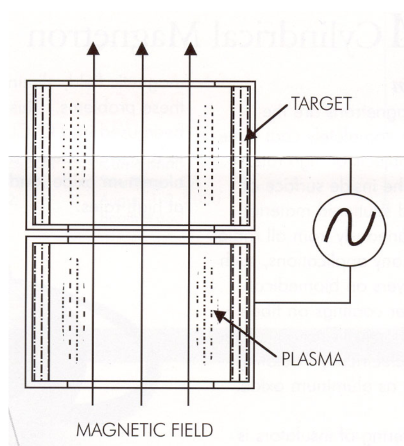

Figure 2 Dual Cathode System

In order to stabilize the process, a 1600 l/s turbomolecular pump was used on the CYCLONE system. In the case of aluminum nitride, which was formed by sputtering aluminum in mixtures of argon and nitrogen, we operated by simply controlling the gas flows alone. The high pumping speed eliminated the typical hysteresis seen in the relationship between the reactive gas flow and film properties.

The table below shows the deposition rates for pure aluminum and transparent aluminum nitride films made at several combinations of power and total pressure.

Power (kW)	Pressure (mTorr)	Al Rate (nm/min)	AlN Rate (nm/min)
1	4	82	27 (33%)
1	8	68	36 (53%)
2	4	147	69 (47%)
2	8	141	55 (39%)

Figure 3 ICM 522

Sputtering aluminum in argon and oxygen mixtures, on the other hand, required the use of feedback control to achieve the highest deposition rates for aluminum oxide.

The following table shows these rates for the same power and pressure conditions and compares them to the rate for aluminum oxide deposited in the "poisoned" mode. Poisoning refers to the condition in which the target is completely covered by aluminum oxide. While the poisoned mode has the obvious disadvantage of low rates, it is extremely stable and requires no feedback control of the oxygen gas. Once more, the rates compared to aluminum metal are shown in parentheses.

Power (kW)	Pressure (mTorr)	Poisoned (nm/min)	Feedback (nm/min)
1	4	4.8	25 (30%)
1	8	5.4	32 (47%)
2	4	7.8	38 (26%)
2	8	9.0	54 (39%)

Ellipsometry measurements showed that we were able to make aluminum oxide films with an index of refraction of 1.63. That is very close to the value reported for aluminum oxide sputtered with ion beam assist. [1]

Figure 4 ICM 1921

1 R.B. Sargent, T.H. Allen and K.Takano, "*Metal Mode Reactive Sputtered Metal-Dielectric Coatings*," 36th Annual Technical Conference Proceedings of the Society of Vacuum Coaters, 68 (1993).

Finally, titanium oxide was also deposited in both the poisoned mode and in feedback control and the deposition rates are compared to the pure metal rate below.

Power (kW)	Pressure (mTorr)	Ti Rate (nm/min)	Poisoned (nm/min)	Feedback (nm/min)
2	4	70	7.2	22 (31%)

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Conclusions

We have successfully coated aluminum nitride, aluminum oxide, and titanium oxide at high rates with a new Dual Cathode ICM Cylindrical Magnetron. Operation was completely free of arcing and films could be made at high rates using the same feedback control methods commonly used in reactive sputtering. With this new design, for the first time, it is possible to deposit insulating materials with all of the advantages that cylindrical magnetrons offer.

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Ask THE WIZARD

Q. Can multi-layer optical films be deposited with the dual cathode cylindrical magnetron?

A. Absolutely. Multi-layer optical films are deposited to form anti-reflective, high-reflective or filter coatings. This is done by making a stack of thin films that alternate between a high refractive index material and a low refractive index material. This can be done in the cylindrical magnetron by choosing materials with different indexes that can be formed using the same target material and different reactive gases. For example, aluminum oxide can be chosen as the low index material and aluminum nitride can be chosen as the high index material. Both of these are produced using an aluminum target and just varying the reactive gas from oxygen to nitrogen. Other materials like silicon oxide and silicon nitride and also be chosen. The advantage of using the cylindrical magnetron to make these coatings is that three-dimensional parts can be coated without rotation or translation.

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