ATTEMPT OF TARGET SLANTING ON FACING TARGETS SPUTTERING SYSTEM

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Abstract--- The facing targets sputtering system (FTS) can prepare the Co-Cr and Fe-Ni-Cr films with high performance for perpendicular magnetic recording media because of the many advantages depending on the unique layout of targets and substrates. In this study, the improvements of the deposition rate and the distribution of film thickness have been attempted by slanting the targets. Then, the discharge characteristics have been investigated. However, in the case of a targets-slanted type, only a little increase of discharge current was observed for increasing the target voltage. These results could be attributed to the loss of the high energy secondary electrons which are confined between two targets in FTS system of normal layout. It was confirmed that two targets must be parallel to each other to confine the discharge plasma effectively and to deposit on the substrate at plasma free.

INTRODUCTION

Recently, the technology for high density perpendicular magnetic recording system has advanced greatly. And it may depend on the preparation technique of thin films mainly. So, the trends required to these film deposition system are as follows: 1)plasma free process, 2)high deposition rate for magnetic materials, 3)low substrate temperature and low argon gas pressure during deposition, etc. Especially, the film depositing at plasma free is a very important factor to prepare high performance films such a magnetic recording media. In this regard, the facing targets sputtering (FTS) system is very useful and attractive technique because of the unique arrangement of targets and substrates[1 - 2]. With these advantages as background, more faster deposition rate and better surface flatness in the large area of substrate have become demanded for FTS system in resent years.

In this study, the target slanting to the side of a substrate has been attempted from above-mentioned background. Then, the discharge characteristics have been investigated. And the plasma characteristics for standard type of FTS system have been investigated. From these results, the discharge mechanism of FTS system has been discussed in detail.

EXPERIMENTAL

The fundamentals of standard FTS system is schematically shown in Fig.1. A magnetic field of 180 gauss at center of two targets is applied normal to each target plane in order to confine the discharge plasma. For FTS system, the substrate can be set up the "plasma free" region. So, the films can deposit without the various damages from plasma such as the bombardment of high energy secondary electrons and recoiled argon atoms from the target on the growing film surface.

Fig.1 Schematic diagram of facing target sputtering(FTS) system.

Therefore, the raising of substrate temperature and the entering of impurity during deposition is negligible.

Figure 2 shows the schematic diagram of the FTS system used in this study. Fe, Co-Cr and SUS304(Fe-Ni-Cr-Mn) were used as sputtering targets. Target diameters was 100 mm. The distance between two targets was set at 150 mm for standard type of FTS. Target slanting was carried by exchanging the backing plates of standard type. The slanting angle was 30° as shown in Fig. 2, (b). The backing plates were cooled by water during sputtering. Pure argon of 99.99% purity was used by the discharge gas. The discharge plasma was generated and maintained by DC power supply with a maximum power of 5 kW.

The plasma characteristics such as electron density, electron temperature and floating potential were measured by using a langmuir probe.

Fig.2 Schematic diagram of standard type(a), and targets-slanted type(b) of FTS.

RESULTS AND DISCUSSION

1. Discharge characteristics

Figure 3 shows the discharge characteristics at the argon gas pressure P_{Ar} of 5 mTorr. For standard type of FTS, the discharge current increased abruptly at the proper target voltage which was decided by the kind of target materials and the argon gas pressure. This result may be caused by the effective confinement of the plasma due to the magnetic field between two targets. More detailed discussions for the confining mechanism will be described later.

On the other hand, in the case of a targets-slanted type, only a little increase of the discharge current was observed with increase of the target voltage as shown in Fig. 3. Such a discharge situation suggest that the plasma is not confine between two targets. However, when the shield covers were removed from this slanted target holders and the side of backing plates were exposed in discharge space, the stable discharge was generated, while the plasma spread in chamber and the substrate temperature raised over 100°C .

Fig.3 Discharge characteristics of standard type and targets-slanted type of FTS.

For the other variation of target slanting, only one of target holders were rotated for 180°. In this time, each target plane is facing parallel. For this arrangement of targets, the discharge characteristics were same as the standard type of FTS.

These results suggest the significant relationship between the confining of plasma and the slanting angle between two targets. So, the plasma characteristics were investigated for standard FTS.

2, Plasma analysis for standard FTS

The measurement of plasma characteristics such as floating potential, electron temperature and electron density was carried by sliding a langmuir probe parallel to the target plane. Figure 4 shows the measurement method schematically. In this figure, the L_s shows the distance between the sliding position of a probe and the target plane.

Figure 5 shows the space distribution of the floating potential for standard type of FTS. Two L_s of 15 mm and 75mm(center between two targets) was selected as the sliding position for the measurement of the floating potential. The argon gas pressure P_{Ar} was adjusted at 1 and 5mTorr. The discharge current was set up 0.5A. The "0" point of probe position in Fig. 5 means the center of a target with 100mm diameters. The SUS304(Fe-Ni-Cr-Mn) was used to targets in this time.

The floating potential had a tendency to increase toward the center of the target. And the degree of the increasing for P_{Ar} of 1mTorr was more remarkable than that of 5 mTorr. This difference of floating potential may be attributed to the difference of the mean-free-pass of secondary electrons extracted from the targets. Namely, as the argon gas pressure is high, the electrons is apt to loss the energy soon through the collision process for argon atoms. And from the results at L_s of 15 and 75mm, a little expansion of plasma was observed at the center between two targets ($L_s=75mm$). It could say for this FTS system that the substrate can be located to the plasma free space as the distance between the target center and the substrate set over 100mm.

Fig.4 Schematic diagram of measurement method of plasma characteristics.

Fig.5 The distribution of floating potential for standard FTS.

Figure 6 shows the space distribution of the electron temperature at the L_s of 15mm. The discharge current was set up 0.5A. The results of electron temperature showed the same tendency as the results of the floating potential. Namely, the electron temperature distributed as taking the maximum at the center of target. The

maximum values at target center showed 25000 and 15000 K at P_{Ar} of 1 and 5 mTorr, respectively. This difference of electron temperature due to the argon gas pressure could be attributed to that of mean-free-pass same as the floating potential.

Figure 7 shows the space distribution of the electron density in plasma at the L_s of 15 mm. The electron density was

Fig.6 The distribution of temperature of electrons for standard FTS.

Fig.7 The distribution of electron density for standard FTS.

also distributed as taking the maximum at the center of target. And the electron density at P_{Ar} of 5 mTorr showed larger values than that of 1 mTorr. This may show that the electron density depends on the density of neutral gas atoms. When the discharge current was raised to 1 A from 0.5A for P_{Ar} of 5 mTorr, the electron density increased more remarkably at the center of target rather than the edge of target.

These results seems to relate closely to the confining mechanism of plasma. And the confining of plasma may depend on the distribution of magnetic and electric field.

3. Plasma confining mechanism of FTS

The distribution of the magnetic field for standard FTS was measured by gaussmeter at the method showed in Fig.8. Namely, the probe (hole sensor) was slid parallel to the target plane at the L_s of 20mm and 75 mm(center between two targets). And the magnetic flux density of perpendicular direction to the target plane was measured at each probe position.

Fig.8 Schematic diagram of measurement method of magnetic flux density.

Figure 9 shows the results of the measurement. The target materials was SUS304(Fe-Ni-Cr-Mn). In the case of the magnetic targets, the distribution of magnetic field changed significantly.

Fig.9 The distribution of magnetic flux density for standard FTS.

For FTS system, two permanent magnets with ring shape were set up the rear of each target so as to link the magnetic line of force. So, the distribution of magnetic field between two targets seems to be decided by the shapes, arrangement and materials of the magnets. The result showed in Fig. 9 is a typical distribution for magnetic field for FTS system.

On the other hand, for the electric field, the voltage gradient in plasma is only 2 or 3 V. Target voltage is almost applied in the plasma sheath formed to several millimeter on target surface.

In such a magnetic and electric field, the discharge plasma could depend strongly on the movement of high energy secondary electrons extracted from target surface due to the sputtering process. These electrons are accelerated by the target voltage in the plasma sheath to the direction of perpendicular to the target plane. And also these electrons in plasma have a high mobility parallel to magnetic

line of force, while they can not diffuse to the direction of perpendicular to them. This may be a reason of plasma confining. And these electrons with high energy can ionize the argon gas atoms by the collision process. As the mean-free-pass is long at low argon gas pressure, the electrons may move back and forth between two targets. The effective confining of plasma seems to depend on such a reciprocating motion of high energy electrons.

On the other hand, in the gradient magnetic field as shown in Fig. 9, the electrons do the drift motion perpendicular to the both direction of magnetic gradient and magnetic line of force. So, at the center region of targets, which is surrounded by barrier of magnetic field, the plasma density may become easy higher than that of the edge of target.

In the case of a targets-slanted type, the secondary electrons extracted from one of targets could not return in discharge plasma again. So, the plasma can not be confined and only a little increasing of discharge current could be observed with increase of the target voltage. However, when one of target holders was rotated to 180° and the planes of each targets were facing to parallel, the secondary electrons from target planes can move back and forth again. So, the discharge plasma seems to be confined between two targets. Namely, it was found that the facing arrangement of two targets is a very important factor for FTS system.

CONCLUSION

Facing targets sputtering (FTS) system has many advantages for preparing the films with high performance due to the unique layout of targets and substrates. In this study, the improvements of the deposition rate and the distribution of film thickness have been attempted by slanting the targets. However, in the case of a targets-slanted type, only a little increase of the discharge current was observed with increasing of the target voltage. From the results of the plasma analysis and the measurement of magnetic field distribution for standard type of

FTS system, it was estimated that the effective confining of plasma is achieved by the confining of secondary electrons with high energy extracted from the target plane. In the case of a targets-slanted type, the secondary electrons could not return in discharge plasma again after extracting from one of the targets. So, the plasma with high density could not be maintained.

In conclusion, it was confirmed that the facing arrangement of two targets should be very essential factor for effective confining of plasma for FTS system.

REFERENCES

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