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Deposition of MgO Thin Film with RF Sputtering Assisted by Surface-Wave Excited Plasma

表面波プラズマ支援RFスパッタによるMgO薄膜の堆積

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A sputtering deveice without using magnet that is realized by a conbination of an surface wave source and an RF bias system and is applied to deposition of MgO film. The minimum sustainment pressure is compared by changing the target materials from SiO_2 to MgO and increase in the sustainment pressure is observed in the case of the MgO target. A modification of the microwave coupling structure reduces the minimum sustainment pressure down to 3 mTorr that is low enough for the sputter film deposition. Deposition rate as high as 36 nm/min that is high enough for the MgO deposition is obtaind by this sputtering device.

1. Introduction

In modern semiconductor technologies, oxide thin films are widely used not only as simple insulating films but also as functional materials such as transparent conducting films or tunnel barrier films. For example, indium tin oxide (ITO) and indium gallium zinc oxide (IGZO) films are used in liquid crystal display panels[1] as transparent conducting films and semiconductors, respectively. Magnesium oxide (MgO) film is used in magnetic random access memory (MRAM) as magnetic tunnel junction films. In various thin film deposition technologies such as plasma-enhanced chemical vapor deposition method[2-4] or evaporation method, plasma sputtering method is known as one of common technology because of its applicability to the deposition of high-melting-point materials on glass or polymer substrates. However, drawback of the sputter deposition is non-uniform plasma production that results in non-uniform film thickness as well as non-uniform film quality. So far, mechanical movement of the magnet (and the plasma) has been commonly used to improve the film uniformity. In our previous study, we have shown that high energy negative ions are localized not at high plasma density regions but *at low plasma density regions*, and this fact suggests that the movement of the magnet (and the plasma) results in uniform irradiation of high energy negative ions on the depositing film surface. Such problem can be solved only when high-density and uniform plasma is realized at low pressures without using the magnet.

So far, we have developed various kinds of surface wave plasma sources those can produce uniform and high density (10^{17}~10^{18} m^{-3}) plasma[3]. Furthermore, we have recently developed a new microwave-plasma coupling antenna that can reduce plasma sustainment pressure less than 1 Pa. Such improved antenna can be applied to sputter deposition that requires low-pressure process to keep high deposition rate.

In this study, fundamental properties of the sputter deposition of the MgO film are investigated.

2. Experimental

Schematic of the experimental set-up has been shown in elsewhere[5] and is briefly indicated. A cylindrical vacuum vessel was equipped with the microwave sputtering device and a turbo-molecular pump. Ar gas was fed to the vessel through a mass flow controller at a flow rate of 20 sccm. Pressure was varied by a conductance valve. Microwave power (2.45 GHz, <700 W) was coupled to the plasma through a dielectric sputter target (MgO plate). An RF bias electrode of 8 cm square was placed on the backside of the target. Negative bias voltage was applied to the target surface by applying the RF power to the bias electrode.

3. Results and Discussions

Figure 1 shows minimum pressure for the plasma sustainment as a function of the microwave power in the cases of SiO_2 and MgO targets. RF power is not applied in this experiment. In the case of the SiO_2 target, the minimum sustainment pressure decreases with the microwave power and is ~4 mTorr at microwave powers of ~600 W. In the case of the MgO target, however, the minimum sustainment pressure is rather high compared with that of the SiO_2 and is ~8 mTorr at microwave powers above ~600W. In this sputtering source, plasma is sustained by surface wave propagation along the dielectric target interface and the minimum electron density for the wave sustainment increases with increasing the permittivity of the dielectric material. Higher sustainment pressure in the case of the MgO is presumably due to higher permittivity of MgO target and resulting difficulty of sustaining high electron density at low pressures. To further reduce the sustainment pressure for the sputtering purpose, the structure in the vicinity of the slot antenna is modified to enhance the microwave power coupling to the plasma. Figure 2 compares the minimum sustainment pressure as a function of the microwave power before and after the antenna modification with an RF bias power of 300 W. The minimum sustainment pressure of ~7 mTorr before the modification is reduced down to ~ 3 mTorr after the modification and this minimum pressure is enough to conduct the sputter deposition.

Figure 3 shows sputter deposition rate of MgO film as a function of the RF power in the cases of with and without the microwave power. In the case of conventional RF sputter, deposition rate is rather low and is 20 nm/min at an RF power of 700 W. By applying the microwave power, however, the deposition rate is enhanced by a factor of three and is 36 nm/min. The result shows the importance of the microwave power for increasing the ion flux to the target.

4. Summary

In summary, a new sputtering device that was composed of a microwave source and an RF bias system was applied to the deposition of MgO film. The minimum sustainment pressure (~3 mTorr) that was suitable for the sputter deposition was realized by a modification of the antenna structure. MgO films were deposited by this device and deposition rate as high as 36 nm/min was obtained.

References

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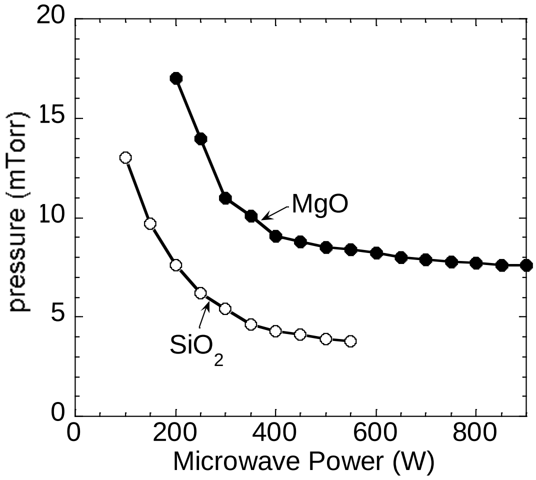

Fig. 1 Minimum sustainment pressure vs. microwave power for SiO_2 and MgO targets.

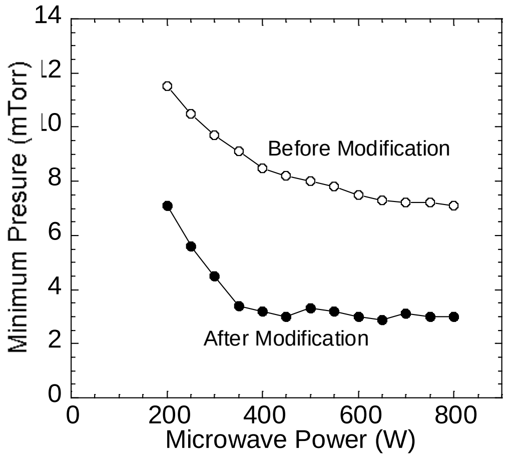

Fig. 2 Minimum sustainment pressure of MgO target before and after the modification of the microwave coupling to the plasma.

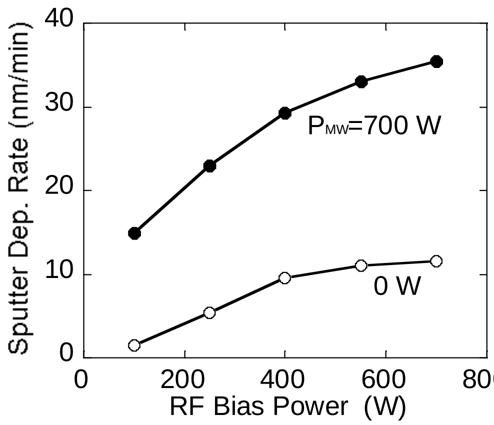

Fig. 3 MgO deposition rate as a function of the RF bias power with (700W) and without microwave power.