MRAM 응용을 위한 자기 박막의 고밀도 플라즈마 식각

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High Density Plasma Etching of Magnetic films for MRAM Application

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Ⅰ. INTRODUCTION

MRAM (Magnetic random access memory) is known to possess many good intrinsic characteristics as a memory cell, some of which include non-volatility, high density, high speed, low power consumption, thermal stability and unlimited read/write operation. From the practical point of view, it is important to realize high density, among many others, in order for the MRAM to compete with other exiting technologies.[1-3]

Ferro magnetic thin films such as NiFe, NiFeCo, and MnNi are used as device materials of MRAMs. And most of them have a multi-layer composed diamagnetic film/magnetic film. To increase storage amount in the MRAM device requires the development of methods for producing of various geometrical structures. Therefore, both development of new magnetic materials and optimization of patterning process are required for MRAM application. Specially, etching technique must be guaranteed in order to accomplish sub-micron pattering.[4]

There are a lot of the reported etching techniques such as ion milling, lift-off, RIE (Reactive ion etching) and high density plasma etching. The ion milling method using physical sputtering has the problems that are low etch rate, low mask selectivity and redeposition of etch products on the sidewall. And the problems of RIE and lift-off are thermal instability due to high processing temperature and low yield, respectively while high density plasma etching promises a relatively high etch rate, low plasma induced damage, and easy control of processing.[5]

In this work, to elucidate the etch characteristics of the magnetic films deposited by RF magnetron sputtering technique, parametric study of ICP etching with Cl_2/Ar discharges has been carried out. We investigated etch rate, etch profile and surface morphology as the function of the processing parameters such as ICP source power, rf chuck power, operating pressure and etch gas concentration.

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Ⅱ. EXPERIMENTAL

NiFe, NiFeCo, MnNi, Ta, Co, Fe were deposited on Si(100) substrates by RF magnetron sputtering system. We also deposited about 6500Å thick SiO_2 on the magnetic films by PECVD (plasma enhanced chemical vapor deposition) as the hard mask material. All samples were lithographically patterned with AZ6612 photo-resist. After the etching, the samples were dipped in DI water to remove corrosive etch products.

Etching was performed in a planar type inductively coupled plasma (ICP) system (Vacuum Science ICP etcher, VSICP-1250A), in which the sample sits on an RF(13.56MHz) biased, He backside-cooled electrode. This chuck power controls the incident ion energy. The plasma ion density is controlled by the applied ICP source power (13.56MHz). The Cl_2/Ar mixture with total gas flow rate of 20 standard cubic centimeters per minute (sccm) was injected into the reactor through mass flow controller. Etch depths of the etched sample were obtained from stylus profilometry measurements after removal of the SiO_2. Surface morphology and etch profile were examined using atomic force microscope(AFM) operated in a tapping mode with a Si tip and scanning electron microscope(SEM) respectively.

Ⅲ. RESULTS & DISCUSSION

Figure 1 shows the effect of operating pressure on the etch rate and selectivity of magnetic films over SiO_2. The pressure varied from 5 to 30 mtorr, and the plasma conditions were 700 W ICP source power, 150 W rf chuck power and 50% Cl_2 concentration (10sccm Cl_2/10sccm Ar). The etch rates of NiCoFe, Ta, NiFe, MnNi and Fe decreased monotonically with operating pressure, while that of Co increased up to 20mtorr, and decreased at higher pressure. The dc bias increased with operating pressure. The results indicate that ion density plays an important role in etching.

The effect of Cl_2 concentration on the etch rate and selectivity were examined at constant ICP source power (700 W), rf chuck power (150 W) and operating pressure (5 mtorr). The results are shown in Figure 2. The etch rates of magnetic films decreased gradually with increasing the Cl_2 concentration, while dc bias increased with Cl_2 concentration. Most of the films show the same trend that etch rates are maximum at ~25% Cl_2. At low Cl_2 concentration, the etching is dominated by Ar ion sputtering, and thus is high. As the Cl_2 percentage increases, the etch rate decreased rapidly. We can come to a conclusion that physical sputtering is more significant than chemical etching in the etch mechanism.

The etch profile of etched magnetic films are shown in the SEM micrographs of Figure 3. The feature sidewalls are somewhat vertical and quite smooth.

Ⅳ. CONCLUSIONS

High density plasma etching of magnetic films has been carried out with Cl_2/Ar inductive coupled plasma discharges. The etch rate of NiCoFe, Ta, NiFe, MnNi and Fe decreased substantially with operating pressure, while that of Co increased up to 20 mtorr, and decreased at higher pressures. However the etch rates of magnetic films decreased gradually with increasing the Cl_2 concentration. The attainable etch rates of NiFe, NiCoFe, Ta, MnNi, Fe, Co were about 186, 171, 165, 243, 336, 215Å/min, respectively at moderate ICP conditions : 700W ICP source power, 150W rf chuck power, 5mtorr, and 25% Cl_2 concentration. The experimental results showed that the physical etching is more dominant than chemical etching in the etching of magnetic films.

ACKNOWLEDGEMENT

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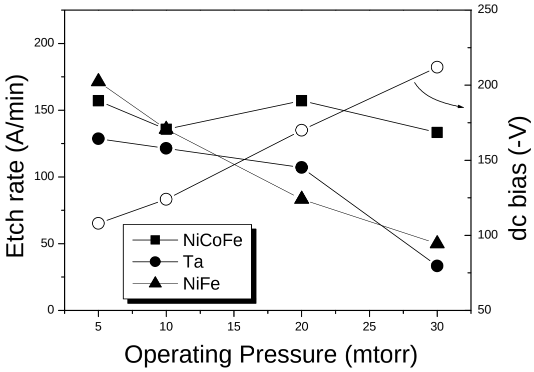
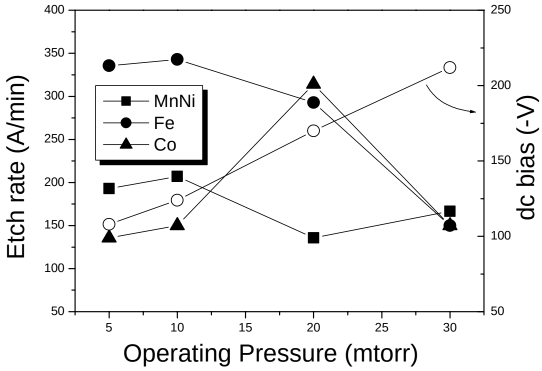




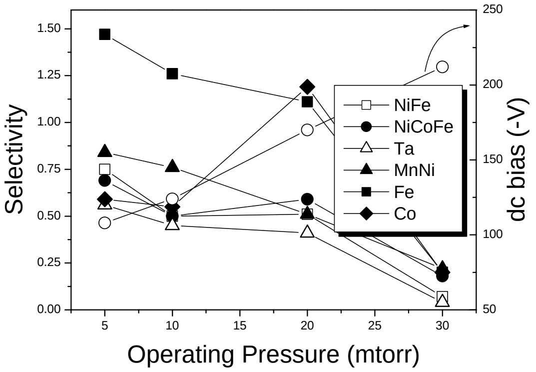
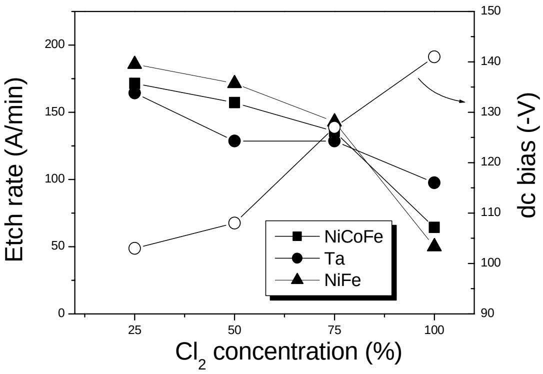
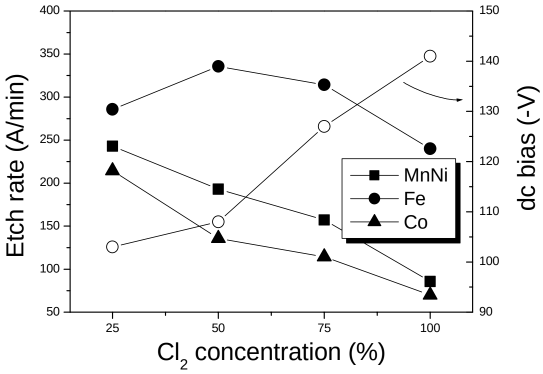


Figure 1. Effect of operating pressure on the etch rate and selectivity of NiFeCo, Ta, NiFe (left), and MnNi, Fe, Co (right) at 700W ICP, 150W rf, and 50% Cl_2





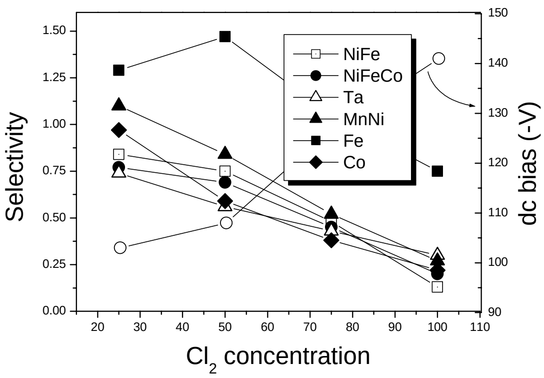


Figure 2. Effect of Cl_2 concentration on the etch rate and selectivity of NiFeCo, Ta, NiFe (left) and MnNi, Fe, Co (right) at 700W ICP, 150W rf, and 5mtorr.

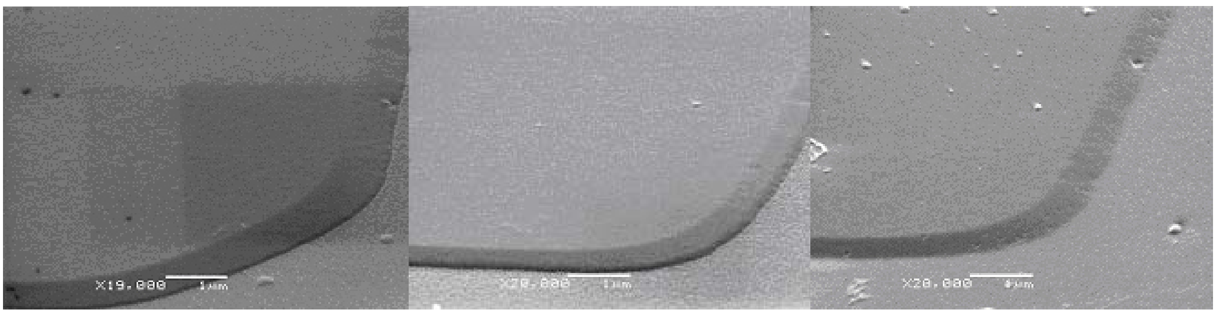


Figure 3. SEM micrographs of etch profiles of NiFe (left), NiCoFe (middle), Ta (right) at 700 W ICP, 150 W rf, 5mtorr, and 50% Cl_2 concentration.