

## Etching reactions of magnetic thin films by ion irradiation in methanolplasma etching processes

メタノールプラズマエッチングプロセス中のイオン照射による  
磁気材料エッチング反応

Tomoko Ito, Kazuhiro Karahashi, and Satoshi Hamaguchi  
伊藤智子, 唐橋一浩, 浜口智志

*D*Center for Atomic and Molecular Technologies, Graduate School of Engineering, Osaka University,  
2-1 Yamadaoka, Suita, Osaka 565-0871, Japan

大阪大学大学院工学研究科原子分子イオン制御理工学センター, 〒565-0871 大阪府吹田市山田丘2-1

Dry etching processes based on CH<sub>3</sub>OH is a candidate for selective etching of magnetic thin films. In this study, we have examined etching processes of Co and Ta thin films by energetic CO<sup>+</sup>, O<sup>+</sup>, C<sup>+</sup> or OH<sup>+</sup> ions, which are considered to be major etchants of CH<sub>3</sub>OH plasmas. We have determined the etching yields and analyzed surface reactions, using a mass-selected ion beam system. The etching yields of Co by CO<sup>+</sup> ions are higher than that by O<sup>+</sup> ions but lower than the yields of possible physical sputtering, which are estimated from interpolation of sputtering yield data of inert atom ions. From XPS analysis for O<sup>+</sup> irradiated Co surfaces, oxidation is found to occur under O<sup>+</sup> irradiation, which suggests that the oxide layer hinders sputtering by ion bombardment. It is found that little oxidation occurs on Co surfaces under CO<sup>+</sup> ion irradiation and etching by CO<sup>+</sup> ion bombardments proceeds. On a Ta surface, on the other hand, in the both cases of O<sup>+</sup> and CO<sup>+</sup> irradiations, oxidation occurs and its etching yield is far smaller than the yield of its possible physical sputtering. Etching characteristics by OH<sup>+</sup> irradiation were also studied in a similar manner.

### 1. Introduction

Dry etching of magnetic thin films is a crucial step in micro fabrication of magnetic random access memories (MARMs) and read/write heads for magnetic data storages. Argon (Ar) ion milling seems to be almost the only etching technique available in the current manufacturing processes. However Ar ion milling is incapable of achieving anisotropic and selective etching of magnetic films (Ni, Co etc.) over hardmasks (Ta, Ti etc.) and therefore highly selective reactive ion etching (RIE) of magnetic thin films is a highly sought-after technology. RIE processes based on CH<sub>3</sub>OH is a candidate for selective etching of magnetic thin films[1]. In this study, we have examined etching processes of Ni, Co and Ta thin films by energetic CO<sup>+</sup>, O<sup>+</sup>, C<sup>+</sup> or OH<sup>+</sup> ions, which are considered to be major etchants of CH<sub>3</sub>OH plasmas.

### 2. Experimental

The ion beam system can irradiate a sample (e.g.,

Co, or Ta) film surface with mono-energetic single-species ions (e.g., CO<sup>+</sup>, or Ar<sup>+</sup> ions) in ultra-high vacuum conditions [2]. The reaction chamber, where a sample is placed, is equipped with a quadrupole mass spectrometer (QMS), and an X-ray photoelectron spectroscopy (XPS) (Fig.1). The XPS is used for *in-situ* chemical analyses of irradiated sample surfaces. The kinetic energies of O<sup>+</sup>, CO<sup>+</sup>, O<sup>+</sup>, C<sup>+</sup> and OH<sup>+</sup> ion beams used in this study were in the range of 300-1000eV. The etching yields were determined from depth profiles of irradiated surfaces measured by stylus profilometry. The 200nm thick sample films were deposited on Si substrates by sputtering deposition prior to the beam experiments.

### 3. Results

The etching yields are determined from measured depth profiles of irradiated surfaces and ion fluxes. The etching yields of Co by CO<sup>+</sup> ions are higher than that by O<sup>+</sup> ions but lower than the yields of possible physical sputtering, which are estimated from interpolation of sputtering yield data of inert atom ions (He<sup>+</sup>, Ne<sup>+</sup>, Ar<sup>+</sup>, Kr<sup>+</sup> etc.)(Fig.2). XPS analysis for O<sup>+</sup>

irradiated Co surfaces, oxidation is found to occur under  $O^+$  irradiation(Fig.3), which suggests that the oxide layer hinders sputtering by ion bombardment. It is found that little oxidation occurs on Co surfaces under  $CO^+$  ion irradiation and etching by  $CO^+$  ion bombardments proceeds.

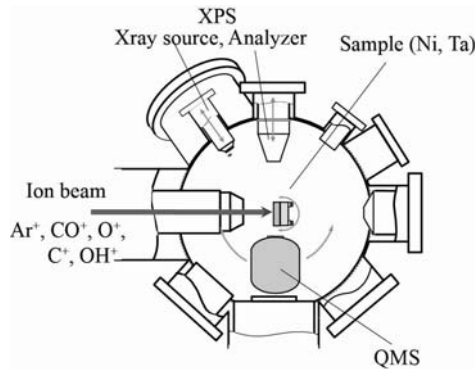


Fig.1 schematic view of scattering chamber.

On a Ta surface, on the other hand, in the both cases of  $O^+$  and  $CO^+$  irradiations, oxidation occurs and its etching yield is far smaller than the yield of its possible physical sputtering (Fig4, Fig.5). Therefore we have found that high selectivity of Ni and Co etching against hard masks (Ta, TaN) arises from the prevention of sputtering by mask oxidation. Etching characteristics by  $OH^+$  irradiation were also studied in a similar manner.

This work was supported by the Semiconductor Technology Academic Research Center (STARC).

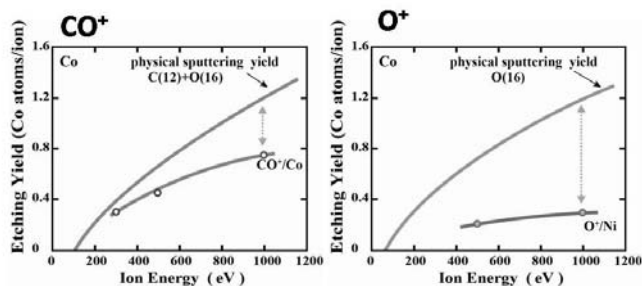


Fig.2. Etching yield of Co

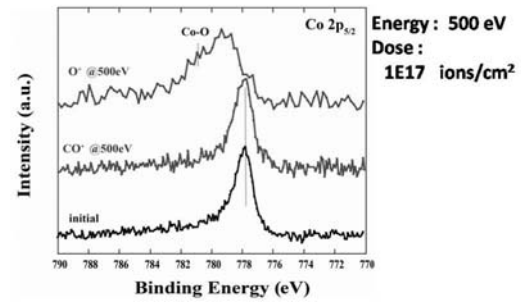


Fig. 3XPS spectra Co2p

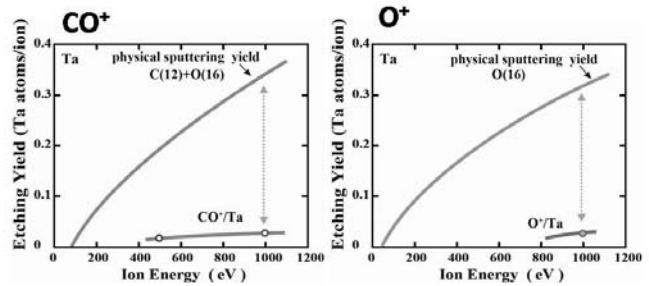


Fig.4. Etching yield of Ta

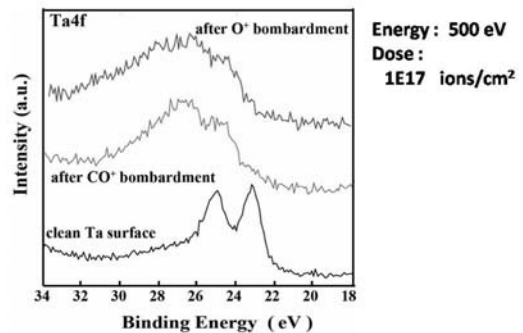


Fig. t XPS spectra Ta4f

#### References

- [1] K. Kinoshita *et al.*, Jpn. J. Appl. Phys. 49(2010) 208JB02.
- [2] K. Karahashi *et al.*: J. Vac. Sci. Technol. A 22(2004) 1166.