Proc. 5th Int. Joint Symp. on Microelec. and Packaging,
IMAPS-Korea and IEEE-CPMT, Seoul, Korea, 2000.

Etching Characteristics of Fine Ta Patterns with Electron Cyclotron Resonance Chlorine Plasma

Sang Hoon Kim, Sang-gyun Woo, Jinho Ahn

Department of Materials Engineering , Hanyang University , Seoul 133-791, Korea

(E-mail ; cafri@hymail.hanyang.ac.kr)

Abstracts

We have studied etching characteristic of Ta film using Electron Cyclotron Resonance (ECR) etcher system. Microwave source power, RF bias power, and working pressure were varied to investigate the etch profile. And we have used two step etching method to acquire the good etch profile preventing the microloading effect.

1. Introduction

Next generation lithography requires masks with new structure fabricated by silicon process. We have studied etching characteristics of Ta, which is a strong candidate for absorber or scatterer patterns in NGL masks [1]. Many groups reported Ta etching with mixture gases, but we performed Ta etching with pure chlorine chemistry and got clear 0.2μm line & space patterns through step etching process.

2. Experimental

Ta film with 3000Å thickness was deposited on SiO_2 (300Å)/p-type Si using DC magnetron sputter. SiO_2 hard mask (800Å) was deposited with RF sputter on top of Ta film, and 3500Å-thick negative photoresist (SAL 606) was coated. Line & space patterns were delineated by e-beam writing in the range of 0.5μm – 0.2μm. ECR plasma downstream etcher was used to etch hard mask and Ta film, and SF_6/N_2 chemistry was used for SiO_2 etching. For Ta etching, process conditions like microwave power, RF bias power and working pressure were changed at fixed Cl_2 flow rate (15sccm), and the etch profiles were investigated by field emission SEM. Optical emission spectrum was investigated to measure the plasma composition.

3. Results and Discussion

The etch characteristics of Ta film with the variation of RF bias power is shown in Fig. 1. As can be seen, higher bias power results in a better etching profile. RF bias induces ion assisted etching and helps to form anisotropic profile [2]. In addition to that, physical etching is necessary for removing the oxide layer formed on top of the Ta [3]. The Cl atom intensity (the major etching species) measure by OES (725.6nm) increases with

RF bias but is not very sensitive to it (Fig. 2). From this result, we can see that RF bias power mainly contributes to surface oxide removal and ion assisted etching. Fig. 3 compares the etch profiles at various working pressure. Lower pressure exhibit a better profile with vertical sidewall slope. This is due to the increased mean free path of ions and radicals with decreasing working pressure through reduced scattering events [2]. The generation of Cl-related etching species is not dependent on the working pressure as can be seen in Fig. 4.

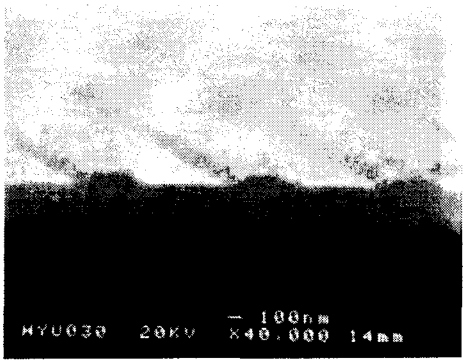
From the above results, we set up the etching condition with RF bias of 150W and working pressure of 3 mTorr at microwave power of 900W. While the line & space patterns above 0.25μm were clearly defined, patterns smaller than 0.2μm exhibit nonuniform etching according to the depth and the pattern density (Fig. 5). This microloading effect comes from the nonuniform distribution of etching species. To reduce this microloading effect, we performed two step etching with 10-min. interval at vacuum for the removal of etch product. The second step etching was performed at higher microwave power (1200W vs. 900W first step), and this does effectively increase the reactive species concentration as can be seen in Fig. 7. About 33% increase in Cl atom intensity by increasing microwave power from 900W to 1200W is observed by OES measurement. This higher Cl atom intensity is speculated to result in a thicker sidewall passivation layer of $TaCl_x$, which is nonvolatile [2]. This two step etching with etch product evacuation results in a clear etch profile with 0.2μm line & space patterns through minimizing the microloading effect (Fig. 6 (b)). The mechanism for improvement of etching profile will be discussed in detail through surface chemical analysis.

References

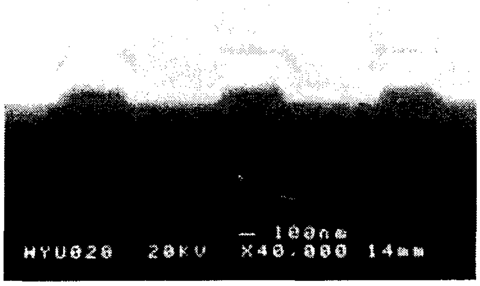
[1] Yoh Somemura, et al., JJAP, Vol.31, pp 4221-4227, 1992

[2] Shinji Sugihara, et al., JJAP, Vol.31, pp 4200-4204, 1992

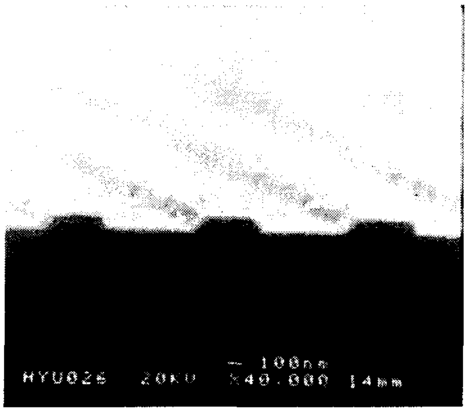
[3] Masao Yamada, Masafumi Nakaishi, and Kenji Sugishima., J.Electro.Soc. Vol.138, No.2,1991



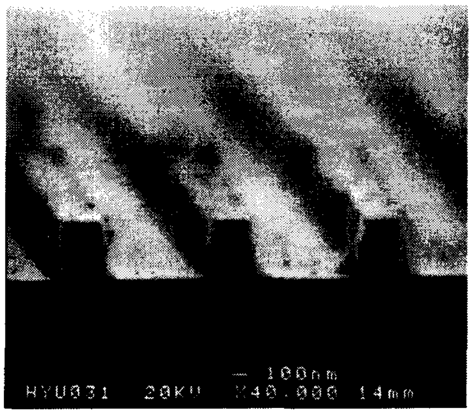
(a) RF power = 0W



(b) RF power = 50W



(c) RF power = 100W



(d) RF power = 150W

Fig 1. The etch characteristics of Ta film with the variation of RF power.

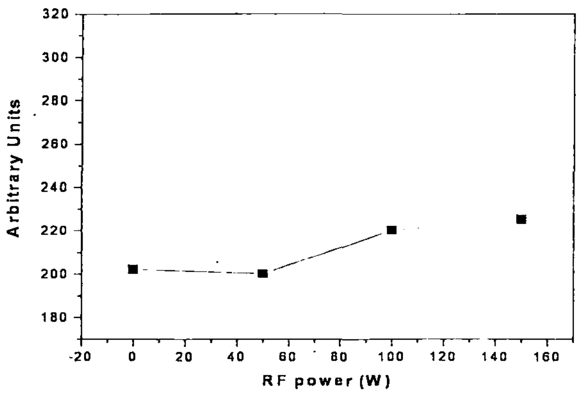
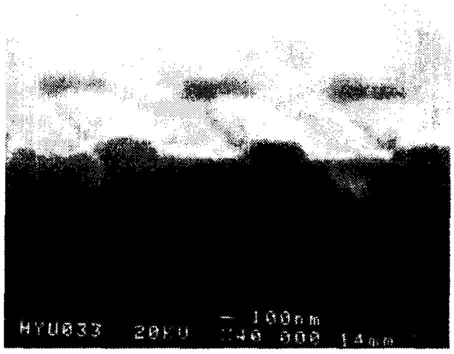
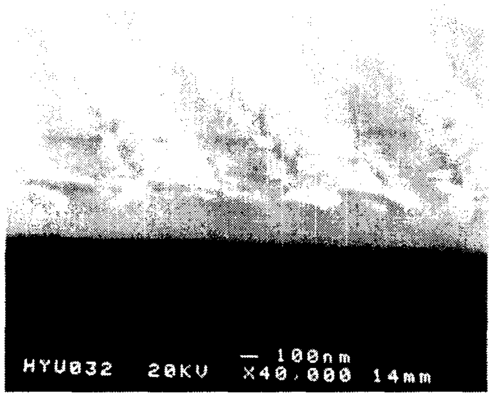


Fig 2. The results of OES analysis of Cl atom intensity with the variation of RF power

(a) 3mTorr



(b) 8mTorr



(c) 15mTorr

Fig 3. The etch characteristics of Ta film with the variation of working pressure.

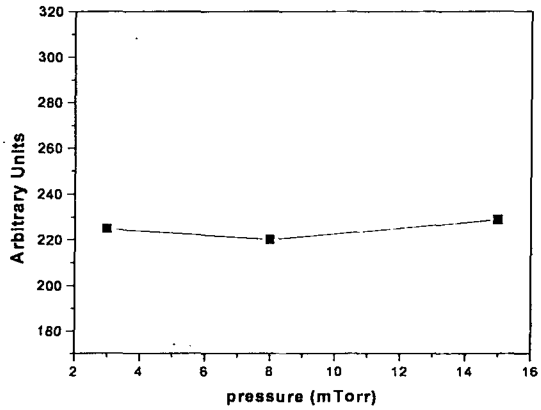
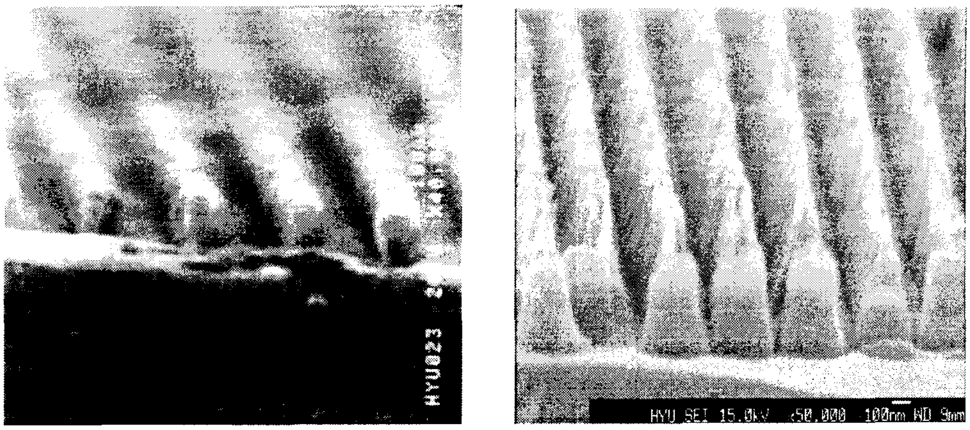
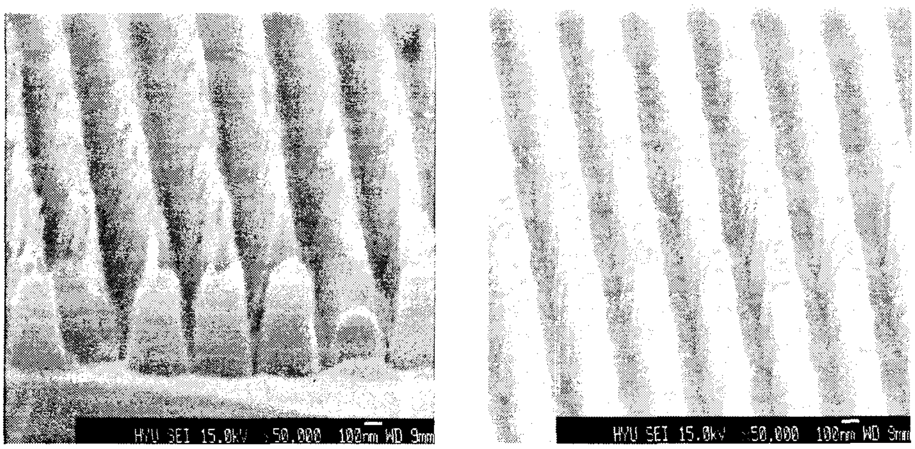


Fig 4. The results of OES analysis of Cl atom intensity with the variation of working pressure



(a) 0.25um (b) 0.2um

Fig 5. The etch characteristics of Ta film with the variation of pattern size: (a)0.25um, (b)0.2um-microloading effect (RF power: 150W, microwave source power: 900 W, working pressure: 3 mTorr).



(a) without step etching (b) with two step

Fig 6. The etch characteristics of Ta film with the 0.2um pattern size. (a)without step etching RF power:150 W, microwave source power: 900 W, working pressure: 3 mTorr. (b) with two step 1st step - RF power: 150 W, microwave source power:900, working pressure: 3 mTorr., 2nd step - RF power:150 W, microwave source power: 1200 W, working pressure : 3 mTorr.

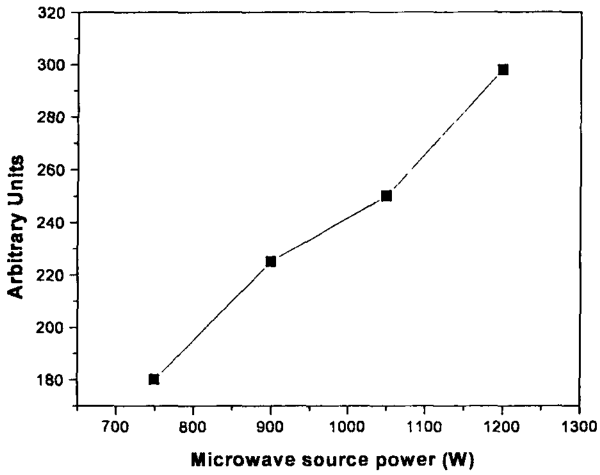


Fig 7. The results of OES analysis of Cl atom intensity with the variation of microwave source power.