Etching characteristics of ArF and EUV resists in dual-frequency superimposed capacitively coupled $CF_4/O_2/Ar$ and $CF_4/CHF_3/O_2/Ar$ plasmas

권봉수[a], 김진성[a], 박영록[a], 안정호[a], 문학기[a], 정창룡[a], 허욱[a], 박지수[a], 이내응[a*], 이성권[b]
[a*]성균관대학교 신소재공학부 (E-mail : nelee@skku.edu), [b]하이닉스 반도체

Abstract : In this study, the deformation and etch characteristics of ArF and EUV photoresists were compared in a dual frequency superimposed capacitively coupled plasma (DFS-CCP) etcher systems using $CF_4/O_2/Ar$ and $CF_4/CHF_3/O_2/Ar$ mixture gas chemistry which are typically used for BARC open and Si_3N_4 etching chemistry, respectively. Etch rate of the resists tend to increase with low-frequency source power (P_{LF}) and high-frequency source (f_{HF}). The etch rate of ArF resist was higher than that of EUV resist.

1. Introduction

As the degree of device integration continuously increases for the fabrication of Si semiconductor devices, a shorter wavelength such as 193 nm ArF excimer laser and 13.5nm extreme ultra-violet (EUVL) is needed to increase the resolution of lithography. Currently double patterning technology (DPT) using ArF excimer laser is being developed for patterning down to 32nm node. Extreme ultra-violet lithography (EUVL) with a potential of resolving features below 32 nm is also a leading candidate for the 32 nm node and beyond. EUVL in its current form requires novel photoresist materials with high sensitivity to compensate for its lower operating source power [1]. In this study, we compared the ArF and EUV resists etching characteristics using $CF_4/O_2/Ar$ and $CF_4/CHF_3/O_2/Ar$ plasmas in a DFS-CCP etching system under different process parameters such as bias power combination (P_{HF}/P_{LF}), gas flow ratio and frequency combination (f_{HF}/f_{LF}).

2. Experimental

An 8-inch DFS-CCP dielectric etcher was used for the experiments. The schematic of the DFS-CCP etch system used in the present experiment was shown elsewhere [2]. The system is equipped with the three different HF power sources (13.56, 27, and 60 MHz) and a LF power source (2 MHz). The chamber is evacuated by a turbo molecular pump with the pumping speed of 1500 *l*/sec and backed by a combined booster and dry pumping system.The operating pressure was controlled automatically at 230 mTorr during etching by adjusting a throttle valve.

The non-patterned ArF and EUV resists with a thickness of 180 and 188 nm were prepared on Si wafer substrates, respectively. Etch rates of the ArF and EUV resists were measured by optical method (ST-2000 DLXn) and field-emission scanning electron microscopy (FE-SEM). The chemical information of the ArF and EUV resists surfaces etched under different etching parameters was determined from the C1*s* and F1*s* spectr are corded by X-ray photo electron spectroscopy (XPS). Optical emission measurements of the F radical species in the plasma was obtained by optical emission spectroscopy (OES) in order to understand the difference in the etch behaviors of the resists in the $CF_4/O_2/Ar$ and $CF_4/CHF_3/O_2/Ar$ plasmas.

3. Results and discussion

Etch characteristics of resists were first investigated in $CF_4/O_2/Ar$ plasmas. Fig.1 shows the etch rates of the ArF and EUV resists etched by varying the O_2 and CF_4 gas flow ratio, from 0.2 to 0.8, in the $CF_4/O_2/Ar$ (300sccm) plasma. Hereafter, the numbers indicate the flow rates in sccm. The high-frequency source (f_{HF}), low-frequency source (f_{LF}), high- frequency source power (P_{HF}) and low-frequency source power (P_{LF}) were fixed at 27MHz, 2MHz, 600W and 300W, respectively. And etch time was limited to 20s. The ArF and EUV resist etch rates were increased with increasing the O_2 flow ratio due to increased oxygen radicals. And Fig. 2 shows the etch rates of the ArF and EUV resists etched by varying the P_{HF}, from 200 to 500W. f_{HF}, f_{LF} and P_{HF} were fixed at 27 MHz, 2 MHz and 600 W, respectively. And gas flow condition was fixed at 30 CF_4/20 O_2/300 Ar. Also the etch time was 20 s. Etch rate of the ArF and EUV resists gradually increased with increasing P_{LF} due to the increased ion bombardment energy.

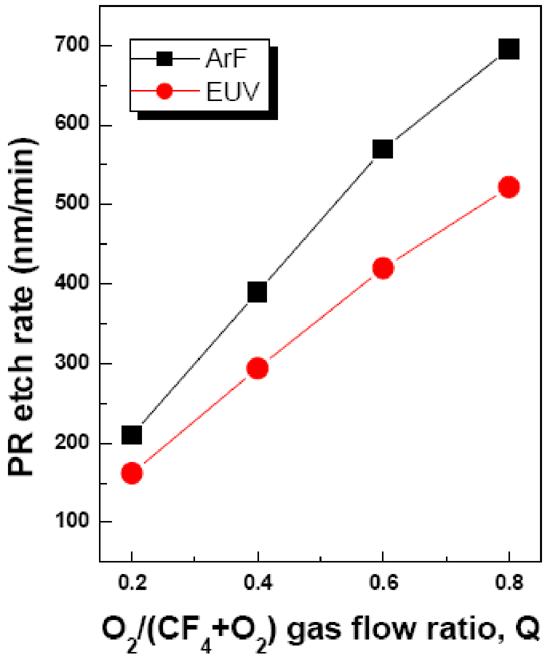

Figure 1. Etch rates of ArF and EUV resists as a function of the CF_4/O_2 gas flow ratio variation

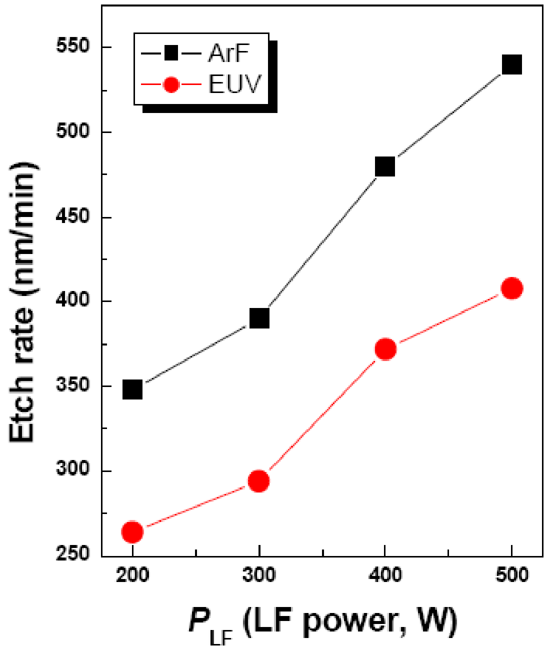

Figure 2. Etch rates of ArF and EUV resists as a function of the low-frequency bias power (P_{LF}) variation.

References

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