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Carbon etching with a high density plasma etcher

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Abstract

Generating suitable passivation on the carbon sidewall is a major challenge facing carbon etching especially for films thicker than 500 nm. Patterning carbon hard mask stacks for sub 90 nm technologies was tested for three different O_2-based chemistries using an inductively coupled plasma etch tool. The results show that the etched carbon profiles are highly dependant upon the O_2 flow and the total time of the etch process. Extended over etch times quite often initiates lateral etching and rapid loss of profile and critical dimension. An $HBr/O_2/N_2$ chemistry has been shown to provide the best options for profile control and more resistance to profile loss during extended over etching than the other chemistries which were tested during this study.

Keywords: Etch; Carbon; Hard mask; ICP; HBr

1. Introduction

Amorphous hydrogenated carbon films are showing promise as future hard mask candidates for sub 90 nm plasma etch applications [1]. These amorphous carbon films can be deposited by a PECVD process and are compatible with the other materials and processes currently used in semiconductor manufacture. A major benefit of these carbon films is that they can be deposited and patterned over a wide range of film thickness and can be easily removed by O_2 or H_2 based plasma.

Patterning suitable carbon stacks for hard mask applications poses some difficulties however. To address the challenges for sub 90 nm critical dimension (CD) requirements, profile control across the wafer is critical. In order to control profiles and CDs, the correct etching chemistries must be used.

This paper outlines early process development using a high density plasma from an inductively coupled etch tool, the Applied Materials Centura® DPS® system configured with DPS II processing technology. Three different etch process chemistries

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were tested and the results for each of these shall be discussed in turn.

2. Carbon hard mask integration

In order to use carbon as a hard mask for state of the art lithography applications, we have to be able to structure carbon films over a range of film thickness with the resist budgets available for the challenging CDs encountered. These resist budgets limit the thickness of a material that can be etched when using a resist mask. With carbon hard masks, it is typical to cap the carbon films with a dielectric material. Silicon oxy-nitride (SiON) is a suitable material to cap the carbon films [2]. This SiON film serves as a hard mask for defining the carbon films, which can be many times thicker than the SiON film itself. In addition, the SiON is there to protect the carbon films from the effects of any lithography rework processes required.

High selectivity to SiON during carbon etching is an essential pre-requisite for a successful carbon hard mask etch process otherwise CD control would be compromised.

All tests were performed on 300-mm wafers having the same film stack and the same lithography conditions each time. The lithography used a 75 nm line-space pattern typical of an active area mask used in DRAM manufacture. The resist used was a typical 193-nm resist with a bottom organic anti-reflective coating (Barc) being used to assist with the lithography requirements.

3. Carbon etching

The motivation behind this work was to test the suitability of high density plasma etch tools. Inductively coupled plasma (ICP) etch tools, like DPS II, differ greatly from the older reactive ion etching (RIE) tools [3,4]. Ionization and molecular fragmentation is typically greater and this combined with the low pressure etching regimes (hence lower residence times) give rise to very different types of etch processes compared to what is typically seen for a more traditional RIE tools.

The extra process controls options which the DPS II provides were of prime interest. Two of the new features for DPS II were the tunable gas splitter and the source power current divider, both of these controls being designed for CD fine tuning. In addition, DPS II gives the user the ability to run chamber dry cleans (without a wafer being present). These so called intermediate chamber cleans (ICC) were seen as an advantage for better process control, lower defectivity and as a means of controlling memory effects with multi-step processes.

Before etching carbon, it was necessary to first open the Barc and the SiON capping layer. This was done using a CF_4/Ar plasma which provided suitable selectivity to resist and to the underlying carbon film. CDs could be tuned very successfully using the combination of the gas splitter and source coil current divider. All subsequent structures referred to in this paper were opened with the same Barc/SiON process step. Fig. 1 shows the typical situation after Barc/SiON window etch. The taper seen in the SiON layer was included as a means of increasing CD.

The basic starting point for carbon etching was an O_2/N_2 plasma. These gases had previ-

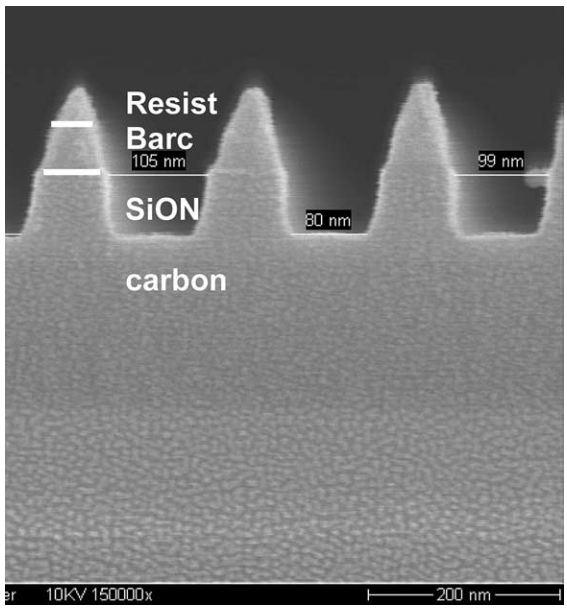

Fig. 1. Profile after Barc/SiON etch.