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Characteristics of Ru Etching Using O_2/Cl_2 Plasmas

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The characteristics of Ru etching using O_2/Cl_2 plasmas were investigated by employing inductively coupled plasma (ICP) etcher and helicon etcher. The changes in the Ru etch rate, Ru to SiO_2 etch selectivity and Ru electrode etching slope with varied process variables were scrutinized. A high etching slope and a smooth surface after etching were attained using O_2/Cl_2 inductively coupled plasma. We discovered that the Ru surface etched using O_2/Cl_2 plasma contains a lesser amount of the O element than when using O_2 plasma.

Keywords : Ru, etching, ICP, helicon

1. INTRODUCTION

As the dimensions of dynamic random access memory (DRAM) devices are getting smaller, high dielectric materials such as barium strontium titanate (BST) and tantallium pentoxide (Ta_2O_5), need to be used for the fabrication of capacitor structure [1,2].

Although platinum (Pt) has commonly been utilized as an electrode material, it presents a difficulty in patterning and thus in forming a bottom electrode. Several research groups have reported that obtaining a sufficient PT etch selectivity to the mask material is extremely difficult [3-6].

On the other hand, ruthenium (Ru) is expected to be patterned by chemical etching because a volatile etch product can be produced during the etching process [7,8]. Previous researchers reported that volatile RuO_4 can be generated from RuO_2 which is an intermediate phase of the Ru etching reaction.

However, there are not many systematic studies on the basic characteristics of Ru etching. In this study, we report the etching characteristics of Ru using O_2/Cl_2 inductively coupled plasma (ICP) and helicon plasma. Although both ICP and helicon plasmas are classified as high density plasma, the ICP is inclined to chemical etching and the helicon plasma is inclined to ion bombardment in our experimental range. We investigate the Ru etch rate, Ru to SiO_2 mask etch selectivity, and Ru etching slope with varied process conditions including the $Cl_2/(O_2+Cl_2)$ gas flow ratio and bias power. We investigate the Ru surface after etching employing Auger electron spectroscopy (AES), x-ray photoelectron spectroscopy (XPS), and transmission electron microscopy (TEM).

2. EXPERIMENTAL PROCEDURE

A storage node pattern with a critical dimension (CD) of 0.15 μm was used in our experiments. The top view of the storage node pattern indicates that the storage node is an oval type and space CDs along the short axis and the long axis are 150 nm and 250 nm, respectively. The sample structure was substrate/TiN 500Å/Ru 4000Å/TiN layer 600Å/SiO_2 mask 3000Å. SiO_2 mask, instead of photoresist mask, was used for patterning the Ru, because oxygen gas was the main etchant in our experiments. The SiO_2 mask was patterned by CF_4/N_2/Ar gas. The TiN layer was inserted between the Ru and SiO_2 mask layer to prevent the contamination of the etching chamber during the SiO_2 mask etching due to Ru exposure. The TiN layer was patterned by Ar/Cl_2 gas. Since Ru cannot be etched by halogen gases only due to the high boiling point of their etch products, we used O_2 and Cl_2 gases, expecting that the volatile RuO_4 to be produced [7,8].

We have used an inductively coupled plasma (ICP) etcher and a helicon etcher in this work. For experiments using ICP plasma, a DPS centura ICP tool commercially available from Applied Materials, Inc. was used. During etching, the $Cl_2/(O_2+Cl_2)$ gas flow ratio was 0.1–0.3, the source power was 1000–1800 W, the bias power was 100–300 W, the pressure was 10–50 mTorr and the total gas flow rate was 100–400 sccm. The cathode temperature was set to 45°C and the helium pressure was set to 15 Torr.

For the experiments using helicon plasma, m=0 helicon etcher commercially available from Trikon, Inc. was used. The helicon wave plasma sources were operated at the excitation frequencies of 13.56 MHz. During etching, the $Cl_2/(O_2+Cl_2)$ gas flow ratio was 0.1–0.3, the source power 1000–

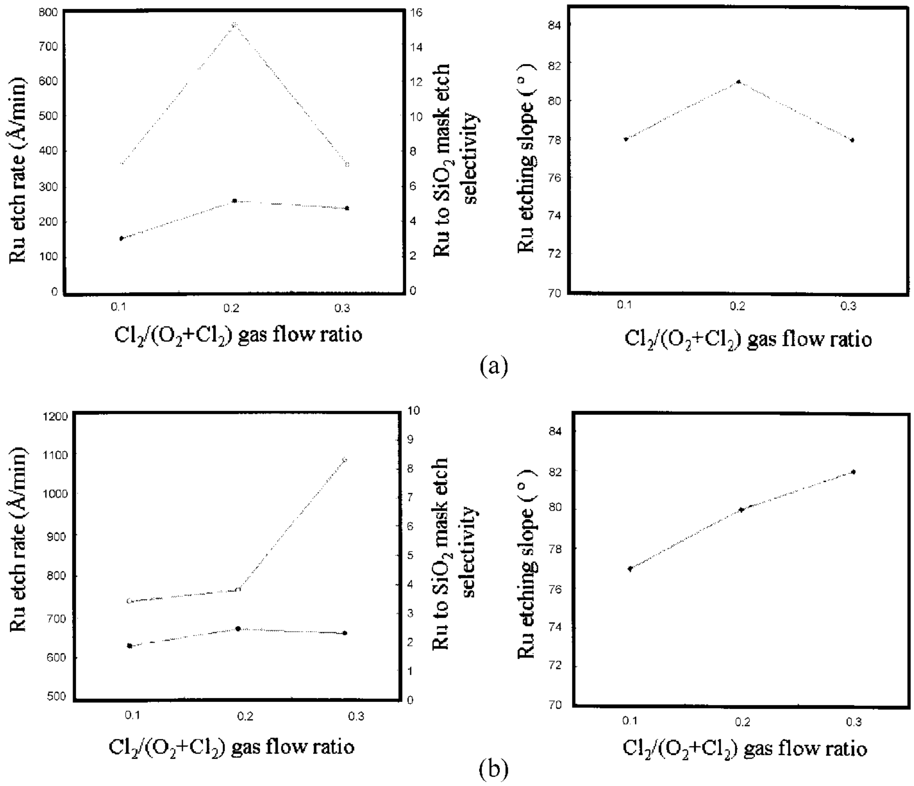

Fig. 1. Variation in Ru etch rate, Ru to SiO_2 mask etch selectivity and etching slope with varying $Cl_2/(O_2+Cl_2)$ gas flow ratios (a) using O_2/Cl_2 helicon plasma and (b) using O_2/Cl_2 inductively coupled plasma.

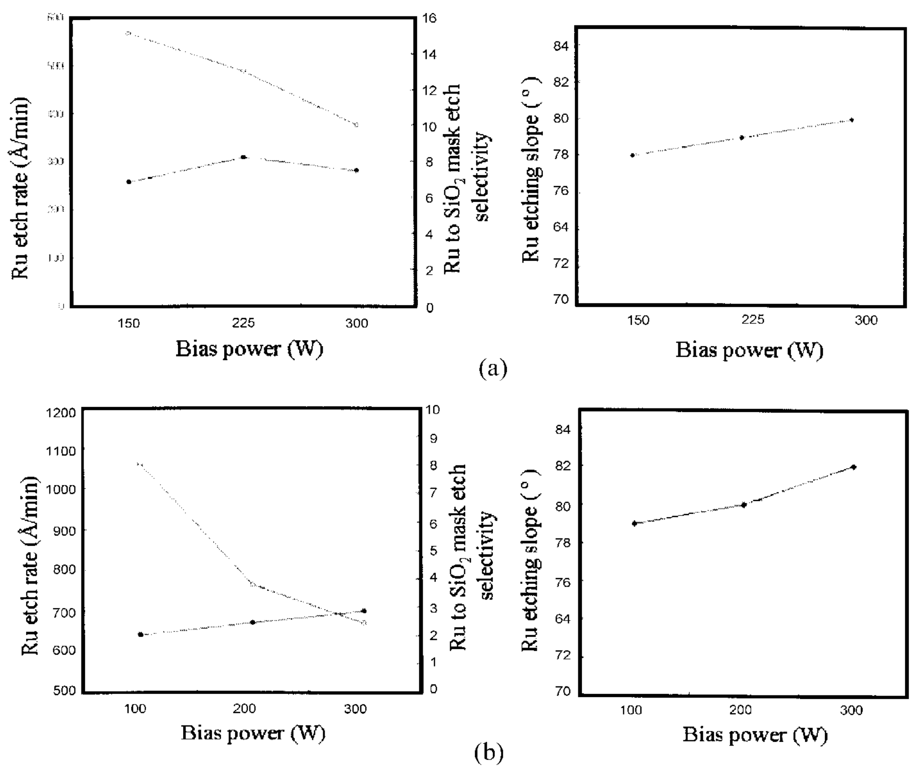

Fig. 2. Variation in Ru etch rate, Ru to SiO_2 mask etch selectivity, and etching slope with varying bias power (a) using O_2/Cl_2 helicon plasma and (b) using O_2/Cl_2 inductively coupled plasma.