BCl_3 유도결합 플라즈마를 이용하여 식각된 HfO_2 박막의 표면 반응 연구

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Surface reaction of HfO_2 etched in inductively coupled BCl_3 plasma

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Abstract : For more than three decades, the gate dielectrics in CMOS devices are SiO_2 because of its blocking properties of current in insulated gate FET channels. As the dimensions of feature size have been scaled down (width and the thickness is reduced down to 50 nm and 2 nm or less), gate leakage current is increased and reliability of SiO_2 is reduced. Many metal oxides such as TiO_2, Ta_2O_4, $SrTiO_3$, Al_2O_3, HfO_2 and ZrO_2 have been challenged for memory devices. These materials posses relatively high dielectric constant, but HfO_2 and Al_2O_3 did not provide sufficient advantages over SiO_2 or Si_3N_4 because of reaction with Si substrate.

Recently, HfO_2 have been attracted attention because Hf forms the most stable oxide with the highest heat of formation. In addition, Hf can reduce the native oxide layer by creating HfO_2. However, new gate oxide candidates must satisfy a standard CMOS process. In order to fabricate high density memories with small feature size, the plasma etch process should be developed by well understanding and optimizing plasma behaviors. Therefore, it is necessary that the etch behavior of HfO_2 and plasma parameters are systematically investigated as functions of process parameters including gas mixing ratio, rf power, pressure and temperature to determine the mechanism of plasma induced damage. However, there is few studies on the the etch mechanism and the surface reactions in BCl_3 based plasma to etch HfO_2 thin films.

In this work, the samples of HfO_2 were prepared on Si wafer with using atomic layer deposition. In our previous work, the maximum etch rate of BCl_3/Ar were obtained 20% BCl_3/ 80% Ar. Over 20% BCl_3 addition, the etch rate of HfO_2 decreased. The etching rate of HfO_2 and selectivity of HfO_2 to Si were investigated with using in inductively coupled plasma etching system (ICP) and BCl_3/Cl_2/Ar plasma. The change of volume densities of radical and atoms were monitored with using optical emission spectroscopy analysis (OES). The variations of components of etched surfaces for HfO_2 was investigated with using x-ray photo electron spectroscopy (XPS). In order to investigate the accumulation of etch by products during etch process, the exposed surface of HfO_2 in BCl_3/Cl_2/Ar plasma was compared with surface of as-doped HfO_2 and all the surfaces of samples were examined with field emission scanning electron microscopy and atomic force microscope (AFM).

Key Words : HfO_2, High-k dielectrics, BCl_3/Cl_2/Ar, ICP