A Comparative Examination of Polyoxide Films Performance Grown by Conventional Dry Thermal (900°C) or Plasma Assisted (400°C) Oxidation Techniques

Fuminobu Imaizumi, Tatsufumi Hamada, Shigetoshi Sugawa, Herzl Aharoni1,2 and Tadahiro Ohmi1
Department of Electronic Engineering, Graduate school of Engineering, Tohoku University, Aza-Aoba 05, Aomaki, Aoba-ku Sendai
980-8579, Japan Tel: +81-22-217-7124, Fax: +81-22-263-9395, E-mail: imaiizumi@see.ecei.tohoku.ac.jp, 1New Industry Creation Hatchery Center, Tohoku University, Aza-Aoba, Aomaki, Aoba-ku Sendai 980-8579, Japan 2Department of Electrical and Computer Engineering, Ben-Gurion University of the Negev, Beer-Sheva 84105, Israel. Fax: +972-8-6472-949 email: herzl@ee.bgu.ac.il

1. Introduction
The poor electrical characteristics of present commercial interpolyoxide films in non-volatile flash memories, grown by conventional thermal oxidation is caused mainly by the roughness of the interpolyoxide/poly-Si interface, resulting from the high interpolyoxide growth temperature(900°C). In this work, polyoxide films are grown by microwave excited high-density plasma technique, at 400°C[1,2], exhibiting significantly superior performance, i.e. lower leakage currents and sustain higher electric fields. A first report is made concerning the growth of polyoxinitride films by this technique. These improved properties enhance the data retention capabilities of non-volatile memories.

2. Experimental
Aluminum gate MOS capacitors (Fig. 1) were fabricated, with four types of insulating films. (1) with conventional dry gate oxide film (900 °C) grown on single crystal (100) Si. This capacitor serves as a reference. The gate insulators of the other three capacitors were grown on poly-Si film, i.e. (2) polyoxide that was grown by conventional dry oxidation at 900°C. The two other capacitors included (3) gate polyoxide and (4) gate polyoxinitride films grown by KrO2(973) or KrO2/NH3(96.5/3.0/0.5) microwave (2.45GHz) excited high-density (>1012 cm-2) plasma technique respectively at 400°C.

3. Results and Discussion
Fig. 2 shows transmission electron microscope (TEM) image of a typical aluminum gate MOS capacitor, with KrO2 plasma grown polyoxide film on poly-Si film. Fig. 3 shows atomic force microscope (AFM) image (1μm×1μm) of the: (a) bare poly-Si film surface (before polyoxide film growth), (b) surface of the KrO2 polyoxide film(400°C), (c) surface of the polythermal polyoxide film(900°C). Both (b) and (c) are grown on poly-Si films. The textures of Fig.3(a) and Fig.3(b), exhibit similar structure, resulting from the low polyoxide growth temperature (400°C), causing only small changes in the grain size of the underlying poly-Si film. Fig.3(a) and Fig.3(c) on the other hand show significant change in the surface texture, which is caused by two main factors. The first is the movement and the growth of the grain size of the underlying poly-Si film due to the high polyoxide growth temperature (900°C). The second is that the conventional dry thermal oxidation is crystal orientation dependent. This is demonstrated in Fig. 4 which show the thickness dependence of SiO2 films grown on three single crystal substrate orientations. Clearly the thermal oxidation exhibit orientation dependence, while the KrO2 plasma oxidation exhibit practically no orientation dependence. This arise from the generation of O in the plasma, which possess smaller size with respect to O and despite the low growth temperature(400°C)[3], diffuse faster than O through the polyoxide growing film, assisted by the Kr ion bombardment.
Fig. 1 Schematic diagram of the Al gate MOS capacitor.

Fig. 2 TEM cross-section image of the MOS capacitor of Fig. 1.

(a) Bare poly-Si surface (before oxidation)
(b) Surface of Kr/O₂ plasma grown polyoxide film (400°C; T₀ₓ=18nm)
(c) Surface of Dry thermal polyoxide film (900°C; T₀ₓ=20nm)

Fig. 3 AFM images of poly-Si and polyoxide films surfaces.

Fig. 4 Oxide thickness vs. oxidation time of (a) dry thermal and (b) Kr/O₂ plasma, oxide films, grown on three orientations Si substrates.

Fig. 5 Interface trap densities obtained in MOS capacitors fabricated on three Si substrate orientations with:
(a) dry thermal gate oxides (b) Kr/O₂ plasma grown gate oxides.

Fig. 6 J-E relations of MOS capacitors, with polyoxide gate insulators:
(a) J-E characteristics (b) F-N Plot.

Fig. 7 J-E relations of MOS capacitors with polyoxinitride gate insulators:
(a) J-E characteristics (b) F-N Plot.

Reference