

Low-dielectric constant SiCN charge trapping layer for nonvolatile memory applications

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1. Introduction

Charge trapping nonvolatile semiconductor memory architecture, embracing MONOS and TANOS type memories, has attracted considerable attention as a promising solution both for standalone and embedded memory applications. In this architecture, electron and hole trapping phenomena by point defects distributed in a silicon nitride film and in the vicinity of the silicon nitride-silicon dioxide interface are applied to data storage. Although many efforts have been spent to replace the silicon nitride film with high-dielectric constant (high-k) insulator films, the silicon nitride film is still used as the charge trapping layer because of insufficient memory windows provided by the high-k films.

In the present work, to achieve a larger memory window and to reduce power consumption in the charge trapping memories, we studied memory functions of metal-oxide-SiCN-oxide-silicon structures with a low-dielectric constant (low-k) silicon carbon nitride (SiCN) film as the charge trapping layer.

2. Experimental procedure

Three types of samples with different film structures were fabricated on p-type (100) silicon substrates, (A) a SiCN single-layer structure and (B) a SiO_x-SiCN-SiO₂ structure. SiCN films with the relative dielectric constant of 4.8-4.9 were grown at 400 °C using Si(CH₃)₄ and NH₃ gases by PECVD. The refractive index of the SiCN films was found to be 1.87-1.90 at a wavelength of 634 nm using a spectroscopic ellipsometer. In the type B structure, a 2-nm-thick tunneling oxide film was formed by thermal oxidation, and a blocking oxide film of 15 nm in thickness was grown at 400 °C by PECVD. An aluminum film was deposited to form a metal gate electrode.

Electron spin resonance (ESR) was measured at room temperature with a JEOL JFS-FA200 X-band spectrometer. The external magnetic field was modulated with an amplitude of 0.3 mT at a frequency of 100 kHz. Defect density was derived by comparing the double numerical integral of the measured derivative power absorption spectrum with that obtained for a calibrated standard.

3. Results and discussion

3.1 ESR Signals

Figures 1(a) and 1(b) shows the ESR derivative power absorption spectra observed before and after exposing SiCN and SiCN-SiO₂ films to 4.9-eV UV illumination at room temperature. The SiCN thickness was 200 nm. The intensity of the ESR signals substantially increased after UV exposure. The g value and ΔH_{pp} of the signal were 2.003 and 1.2 mT, respectively, for the UV-illuminated film. Previous studies on silicon nitrides have shown that UV illumination at room temperature generates K⁰ centers characterized by a g value of 2.003 and ΔH_{pp} of 1.3 mT [1,2]. The K⁰ centers have been considered to be neutrally charged silicon dangling bonds [1]. In addition, it has been suggested that the silicon dangling bonds act as charge trap sites in silicon nitrides [1]. The characteristics of defect centers observed in the SiCN film were strikingly similar to those of K⁰ centers. The result leads us to suggest that the UV-induced ESR signals observed in the SiCN films were responsible for neutrally charged silicon dangling bonds. The K⁰ center density derived from ESR signals was $1.8 \times 10^{19} \text{ cm}^{-3}$.

3.2 Electrical characteristics

Figure 2 shows the shifts of flat-band voltage (V_{FB}) obtained after programming and erasing operations for the aluminum-SiO_x-SiCN-SiO₂-silicon capacitor with a 13-nm-thick SiCN film. The V_{FB} shifts of about 3 V were obtained. It is clear that the low-k SiCN films act as the charge trapping layer.

4. Summary

We have investigated the memory characteristics of a SiO_x-SiCN-SiO₂ stacked film. Charge trapping in the stacked film was accomplished in a short period of time. The low-k SiCN films acted as the charge trapping layer. The UV-induced ESR signals showed that silicon dangling bonds were present in the SiCN films.

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References

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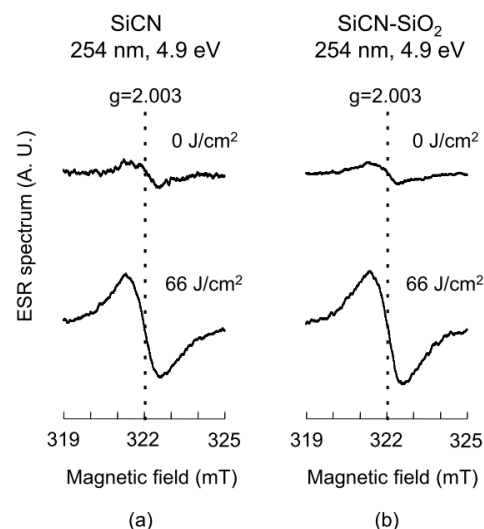


Fig. 1 ESR derivative power absorption spectra observed before and after exposing a SiCN film (a) and a SiCN-SiO₂ film (b) to 4.9-eV UV illumination at room temperature.

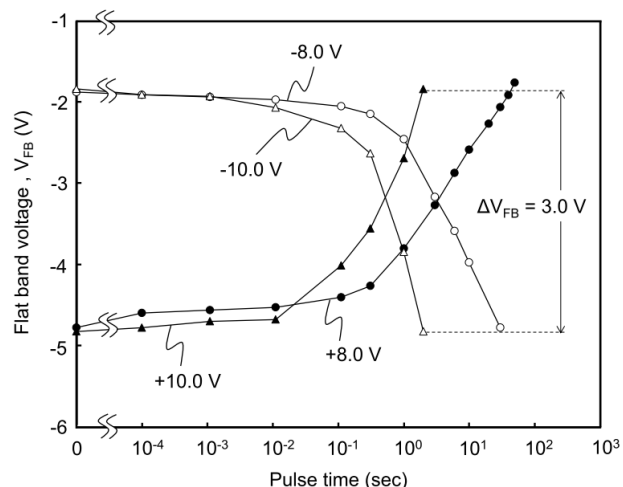


Fig. 2 Shifts of V_{FB} obtained after programming and erasing operations for the aluminum-SiO_x-SiCN-SiO₂-silicon structure with a 13-nm-thick SiCN film and a 2-nm-thick tunneling oxide film.