Abs. 1299, 206th Meeting, © 2004 The Electrochemical Society, Inc.

A one page cover sheet

1) Title of presentation

Ge-MIS structures by direct nitridation of Ge

2) Principal author name, affiliation, complete address, telephone and FAX numbers, and e-mail address

First author	**Tatsuro Maeda**
Organization	**MIRAI-AIST**
Address	**AIST Central4. 1-1-1 Higashi**
City	**Tsukuba**
State	**Ibaraki**
Zip	**305-8562**
Country	**JAPAN**
TEL	**029-861-5122**
FAX	**029-861-2642**
Email address for correspondence	**t-maeda@mirai.aist.go.jp**
Suggested subcommittee for consideration	**Epitaxy and Processing Committee**

3) Person to whom correspondence should be sent, if other than the principal author

4) Identification as regular, invited or student paper

regular

5) Suggested area in which their abstract best fits

Epitaxy and Processing Committee

Ge-MIS structures by direct nitridation of Ge

T. Maeda[1], T. Yasuda[1], M. Nishizawa[1], N. Miyata[1],
Y. Morita[1], and S. Takagi[1, 2]
[1]MIRAI-AIST, AIST Central4. 1-1-1 Higashi, Tsukuba
305-8562 JAPAN
[2]The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku,
Tokyo 113-8656 JAPAN
email:t-maeda@mirai.aist.go.jp

A Ge channel MOSFET has been considered as one of promising devices for future high-speed CMOS technology, because it offers high carrier mobilities for larger drive current and a small band gap for supply voltage scaling. To make surface channel devices, the formation of gate dielectrics is challenging because of the lack of a stable germanium oxide. The germanium oxide, which is hydroscopic and water-soluble, hinders the processing and application of Ge CMOS devices. Direct nitridation of Ge can be another technique to make dielectrics on Ge with good interface properties. However, in comparison with Si nitridation, Ge nitridation has been scarcely investigated yet. In this work, we present here the first demonstration of pure nitridation of clean Ge substrate using a plasma process at low temperatures.

Starting substrates were (100) oriented, n-type Ge wafer. The surface cleaning and nitridation were carried out in a reaction chamber with ultrahigh vacuum system operating at base pressures in the 10^{-10}Torr range with DC plasma source. The chemical compositions of the nitrided films were analyzed using in-situ AES and ex-situ XPS.

Two step annealing, out-gassing and subsequent thermal decomposition of chemical oxide, is necessary to prepare oxide-free clean surface of Ge substrates. Figure 1 shows the Auger spectra of (a) Ge chemical oxide and (b) clean surface after flashing at 600°C. We have confirmed that thermal desorption of chemical oxides and carbon atoms occur at a high temperatures of 600°C, leading to clean surface. Immediately after obtaining the clean surface, the plasma nitridation was performed with DC power of 45W at 300°C. Fig. 1 (c) indicates the existence of nitrogen without oxygen and carbon on the Ge nitrided surface. XPS study was made for discrimination of nitrogen chemical states as shown in Fig. 2. The N 1*s* component in Ge nitride at a binding energy of 397.0eV was detected, close to nitrogen in the Si nitride environment (Si_3N_4) [1]. The Ge 3*d* chemical shift in the nitrided surface is small (2.3eV) as compared to the oxide component (3.8eV). These behaviors are similar to those of the Si 2*p* spectra in SiO_2 and Si_3N_4. From the ratio between N 1*s* and Ge 3*d* (nitrided) intensity, we estimated the chemical composition to be nearly Ge_3N_4. The thickness of Ge_3N_4 film was monitored by spectroscopic ellipsometry. Also, refractive index at 632.8nm and optical band gap of Ge_3N_4 were 2.1 and 4.5eV, respectively. These values correspond to those of deposited Ge_3N_4 films [2].

The high-frequency (1MHz) Cg-Vg and Jg-Vg characteristics of Au/Ge_3N_4/Ge MIS structure are shown in Fig. 3. The Cg-Vg curve indicates good accumulation and inversion regions. No significant hysteresis is observed. The dielectric constant is estimated to be 9.5 close to the value of CVD Ge_3N_4 film [3]. The leakage current density measured under accumulation condition is considerably large with 42A/cm^2 at 0.5V gate. This large leakage current problem can be solved by combining with other insulating films such as high-k films deposited on top of Ge_3N_4 films. Pure Ge_3N_4 films have a possibility to use as not only a passivation layer but also a diffusion barrier of oxygen and impurities for Ge-MISFETs.

This work was supported by NEDO.

References
[1]L. Kubler, et al., Phys. Rev. B 38 (1988) 13113.
[2]D. M. Hoffman, et al., J. Vac. Sci. Technol. A 13 (1995) 820.
[3]G. A. Johnson, et al., J. Appl. Phys. 69 (1991) 3616.

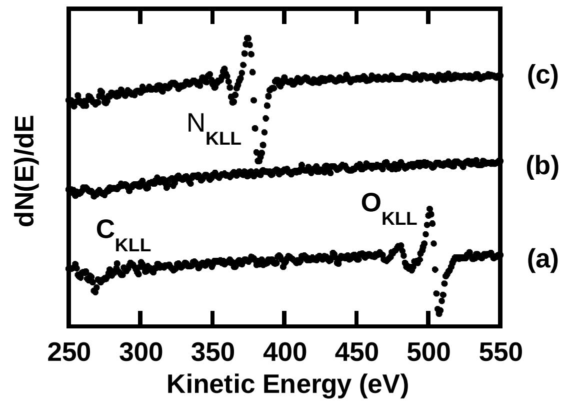

Fig. 1 Auger spectra of (a) Ge chemical oxide, (b) clean surface after flashing at 600°C and (c) nitrogen-plasma treated surface.

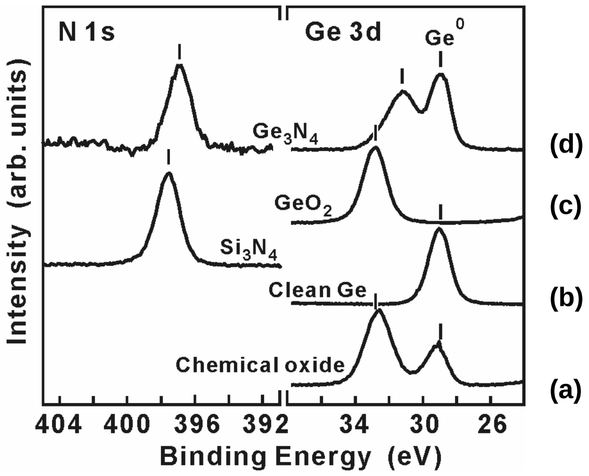

Fig. 2 Ge 3*d* and N 1*s* photoelectron spectra of (a) chemical oxide, (b) clean Ge, (c) thermal GeO_2 and (d) thin Ge_3N_4 film. N 1*s* spectrum of Si_3N_4 film is also shown as a reference.

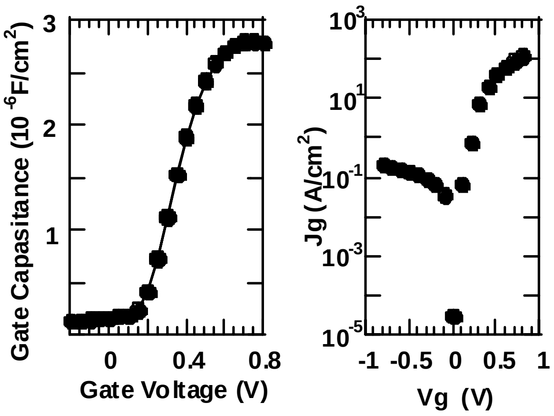

Fig. 3 Measured high-frequency (1MHz) Cg-Vg and Jg-Vg characteristics of the capacitor stacks with a thin Ge_3N_4 film on a Ge substrate.