Performance enhancement of extremely thin body SiGe or Ge on insulator pMOSFETs fabricated by Ge condensation

Kwang-Won Jo, Mitsuru Takenaka and Shinichi Takagi
The University of Tokyo
Email: jkw@mosfet.t.u-tokyo.ac.jp

【Background】 Ultrathin GOI and SGOI MOSFETs have attracted much attention as p-channel devices, because of the high hole mobility (**μ_h**) with suppression of short channel effects. Here, strain engineering also plays a key factor to enhance the performance of pMOSFET. On the other hand, compressive strain (**ε_c**) can be easily relaxed in high Ge fractions because of various crystal defects induced during the Ge condensation [1]. We have succeeded in suppression of strain relaxation thorough an improved condensation method, composed of slow-cooling and a thinned initial SiGe layer in the previous report [2]. By employing this method, **μ_h** of 467 cm^2/Vs was obtained for 10 nm-thick GOI pMOSFETs with **ε_c** of ~1.75 % [2]. In this work, thinning of GOI and SGOI films fabricated by this condensation process is conducted down to 2 nm and compressively-strained 2-nm-thick ETB GOI and SGOI pMOSFETs are shown to operate with higher **μ_h** than the reported ones. Also, the impact of the ETB thickness on the electrical characteristics is quantitatively studied.

【Experiments】 In order to realize GOI pMOSFETs much thinner than in the our previous work [2], 100 % GOI and SGOI with Ge fractions of 70 % were thinned with atomic-scale thickness controllability by using ECR plasma oxidation/etching and TMAH wet etching, respectively. Fig. 1 (a) shows the GOI thickness (t_{GOI}), measured by ellipsometry, as a function of the number of ECR plasma oxidation/wet etching cycles. Fig. 1 (b) shows SGOI thickness (t_{SGOI}) as a function of etching time. The TEM images (Fig. 2) clearly show that 2.0-nm-thick GOI and 2.1-nm-thick SGOI (Ge 70 %) are uniformly fabricated without any visible defects. Fig. 3 shows measured **ε_c** as a function of t_{GOI} and t_{SGOI}. It is found that there is no strain relaxation down to 3 nm, while strain starts to get relaxed around 2 nm and is fully relaxed at 1 nm.

【Results】 Fig. 4 shows the I_d-V_g characteristics of GOI pMOSFETs with changing t_{GOI} from 10 nm to 2 nm. We have demonstrated the operation of GOI pMOSFET with high on/off ratio and high mobility in this GOI thickness range. However, it is found that the peak hole mobility dramatically degraded at 2 nm because of thickness fluctuation scattering with ETB GOI films [3], as shown in Fig. 4. This result is also consistent with strain relaxation Fig. 3. Fig. 5 shows the **μ_h**-N_s characteristics of the (S)GOI MOSFETs with the Ge fractions of 100 % and 70 % as a parameter of t_{SGOI} down to 2 nm. The mobility degradation with reducing the channel thickness is mitigated by application of compressive strain. It is also confirmed that higher μ_h in higher Ge fractions is maintained down to t_{SGOI} of 2 nm.

【Conclusion】 We have demonstrated ETB (S)GOI MOSFETs with the body thickness from 10 to 2 nm. The high **μ_h** due to high ε_c has been obtained by the combination of the improved Ge condensation method.

【References】 [1] S. Nakaharai et al., APL **83**, 3561 (2003) [2] K.-W. Jo et al., APL **114**, 062101 (2019) [3] X. Yu et al., IEDM 20 (2015)

【Acknowledgments】 This work was partly supported by JST-CREST Grant number JPMJCR1332, Japan, and JSPS KAKENHI Grant Number (17H06148).

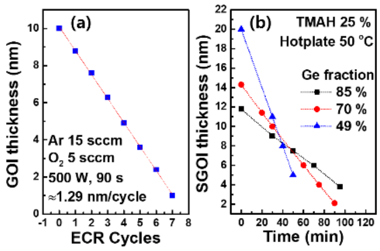

Fig. 1 t_{GOI} as function of cycles (a) t_{SGOI} as function of etching time (b)

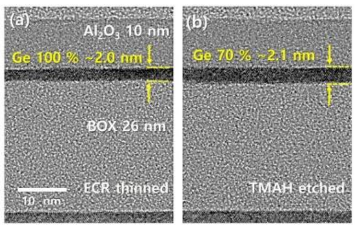

Fig. 2 TEM of ETB GOI 2 nm (a), and 2.1 nm (b)

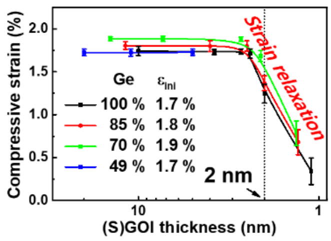

Fig. 3 t_{SGOI} dependence of ε_c

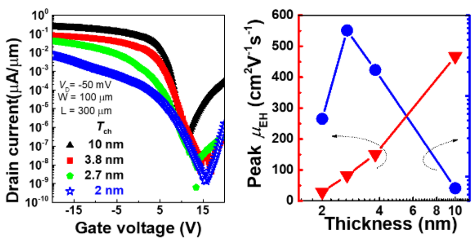

Fig. 4 I_D-V_G of ETB GOI pMOSFET, peak μ_h and on on/off ratio as function of t_{SGOI}

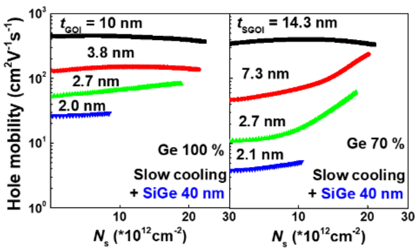

Fig. 5 t_{SGOI} dependence of μ_h as function of N_S to strained (S)GOI MOSFETs

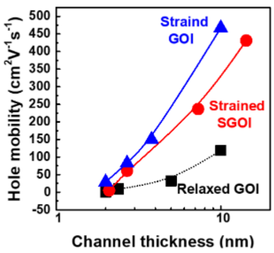

Fig. 6 t_{SGOI} dependence of μ_h degradation