Titanium dioxide gate dielectric for strained-germanium heterolayers

S. Chakraborty, S. Das, M. K. Bera and C. K. Maiti
Department of Electronics & ECE,
Indian Institute of Technology, Kharagpur 721302, India
corresponding author. e-mail: ckm@ece.iitkgp.ernet.in,
Tel: +91 3222 281475 Fax: +91 3222 255303

As the CMOS device downscaling reaches its fundamental limits, alternative techniques for device performance enhancement must be developed. Channel engineering using high-mobility Ge seems to be a potential option to improve the performance of the CMOS devices. Enhancements in carrier mobilities have been observed in Si/SiGe heterostructures leading to a number of novel device structures [1]. In this work, we report on the low temperature deposition of TiO_2 on strained-Ge layer and the electrical properties of the deposited films by using a metal-insulator-semiconductor (MIS) structure. The starting substrate was n-type Si (100) with resistivity 10-20 Ω-cm. Relaxed graded $Si_{1-x}Ge_x$ buffers (x = 0.6) were then deposited by UHV compatible low pressure chemical vapor deposition using silane (SiH_4) and germane (GeH_4). Next, strained-Ge layers were deposited at 800°C (pressure ~ 0.092-0.150 Torr) and the total film thickness was 1-1.2 µm. Thin films of TiO_2 (high-k gate dielectric) were deposited at a low temperature (150°C) by plasma enhanced chemical vapor deposition (PECVD) using titanium tetrakis isopropaxide (TTIP), $[Ti(OC_3H_7)_4]$ as an organometallic precursor. The thickness of the TiO_2 film was found to be ~140Å (EOT~33.4Å).

A TEM micrograph (Fig. 1) shows the complete hetero-structure of strained-Ge layer. Fig. 2 shows that the Raman peaks are present at 290 cm^{-1} and 400 cm^{-1} and 465 cm^{-1} wave numbers due to Ge-Ge, Si-Ge and Si-Si bonds, respectively. The high frequency (1 MHz) C-V and G-V characteristics of as-deposited TiO_2 films on strained-Si layer are shown in Fig. 3. The interface trap density (D_{it}) at midgap and fixed oxide charge density ($Q_{f/q}$) was calculated using Hill's single frequency approximation method [2]. The extracted values of D_{it} and $Q_{f/q}$ are 5.14×10^{11} $eV^{-1}cm^{-2}$ and 1.46×10^{12} cm^{-2} respectively. Fig. 4 shows the high frequency (400 kHz) C-V characteristics of the as-deposited sample before and after constant current stressing (2mA/cm^2). It is observed that the C-V curves shift towards the negative voltage direction after stressing. This indicates the generation of positive charges in the dielectric. Fig. 5 shows the I-V characteristics before and after constant current stressing of 2mA/cm^2 for 100s and 325s. It is evident that there is no significant stress induced leakage current (SILC) in the sample, indicating no serious trap is generated by current stress. To obtain charge trapping behavior, the changes in gate voltage (ΔVg) need to be studied. The changes in the gate voltage to maintain a constant current (2mA/cm^2) injected through gate was studied. Positive gate voltage shift (Fig. 6) confirms that as-deposited sample exhibits electron trapping. In conclusion, electrical properties of TiO_2 films have been investigated. The stress induced leakage current is negligible, indicating a good reliability property of the deposited TiO_2 films on strained-Ge films.

[1] C. K. Maiti and G. A. Armstrong, "Applications of silicon-germanium heterostructure devices," Inst. of Physics Pub, UK, 2001.
[2] W. A. Hill and C. C. Coleman, Solid-State Electron., 23, pp. 987-93, 1980.

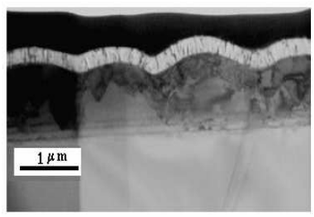

Fig. 1 Cross-sectional TEM image of strained-Ge layer.

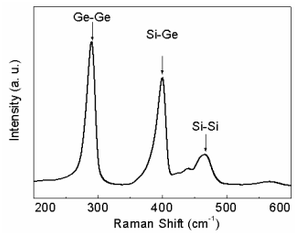

Fig. 2 Raman spectra of strained-Ge layer.

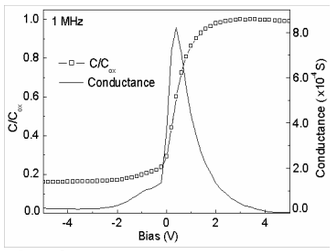

Fig. 3 High frequency (1MHz) C-V and G-V characteristics of as-deposited TiO_2 films on strained-Ge layer.

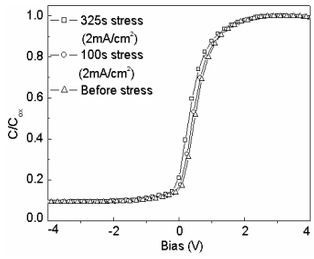

Fig. 4 C-V characteristics before and after constant current stressing (2mA/cm^2).

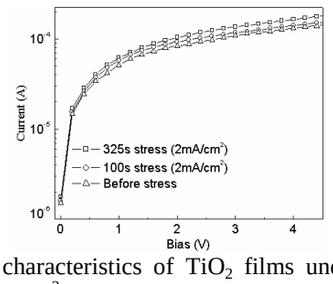

Fig. 5 I-V characteristics of TiO_2 films under constant current (2mA/cm^2) stressing.

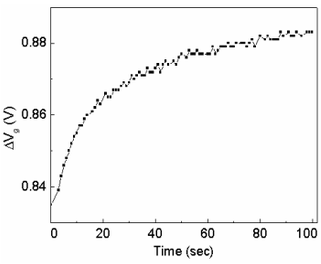

Fig. 6 Gate voltage shift vs. stress time for TiO_2 films on strained-Si layer under constant current stressing.