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Mobility enhancement in Compressively Strained SiGe channel pMOSFET with HfO2/TiN gate stack

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Introduction

It is now known that integrating strained Si channel in nMOS with high k dielectric and metal gate [1] will completely recover the surface phonon limited mobility [2] degradation inherent to high k dielectrics. In this paper, we describe the preparation, characterization, and integration of coherent compressively strained SiGe channel with high Ge concentrations with HfO2/TiN gate stack and demonstrate the same beneficial effect in pMOS devices.

Experimental results

Compressively strained pseudomorphic SiGe films were first grown on Si (001) substrates with LPCVD. The epi SiGe composition and relaxation was studied with XPS, X-ray diffraction, and Raman spectroscopy [3] techniques. Fig. 1 and Fig. 2 showed that, within the Ge concentration (20%-30%) and the thickness (150A-300A) range studied, the SiGe layers are close to fully compressively strained. The shallow trench and ion implantation are used for isolation and active area formation, followed by the atomic layer deposition (ALD) of HfO2 gate dielectric (Toxe=14.5A in inversion) and TiN metal gate deposition. Fig 3 shows the smooth HfO2/SiGe interface in the transistor channel region. No dislocation defects within the SiGe film are seen across the 0.8um TEM image region. Fig.'s (4)–(7) are the electrical characteristics of the pMOSFET's which exhibits a 60% hole mobility enhancement due to the 1.25% compressive strain of the 30% Ge SiGe channel.

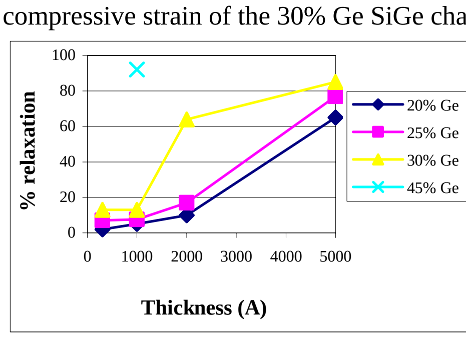

Fig. 1 The SiGe strain relaxation with respect to Ge concentration and Epi layer thickness determined by (004) XRD peak position and Ge concentration. The 45% Ge SiGe is 90% relaxed at 1000A.

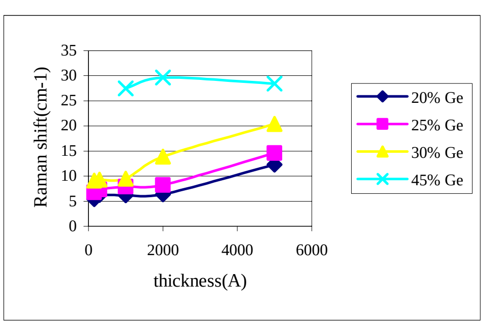

Fig. 2 The Raman shift of Si-Si in SiGe, relaxation with respect to Ge concentration and thickness.

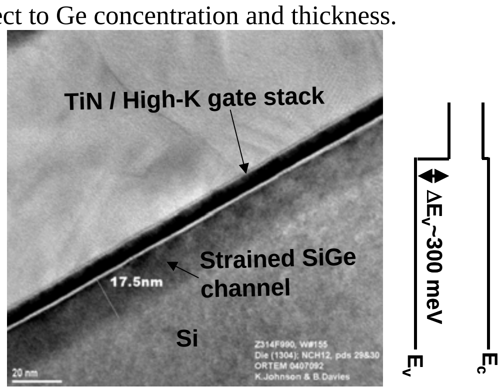

Fig. 3 Cross sectional TEM showing the SiGe channel, HfO2/TiN gate stack structure.

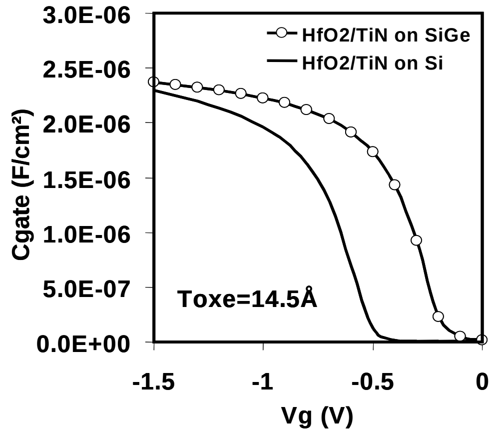

Fig. 4 Split C-V characteristics in inversion showing 14.5A Toxe (1nm EOT) achieved with HfO2/TiN gate stack on Si and strained SiGe transistors with 0.3V Vt difference.

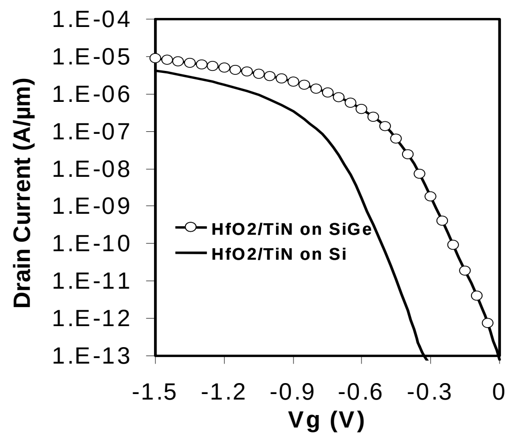

Fig. 5 Long channel Id-Vg characteristics of Si and strained SiGe channel devices with HfO2/TiN gate stack.

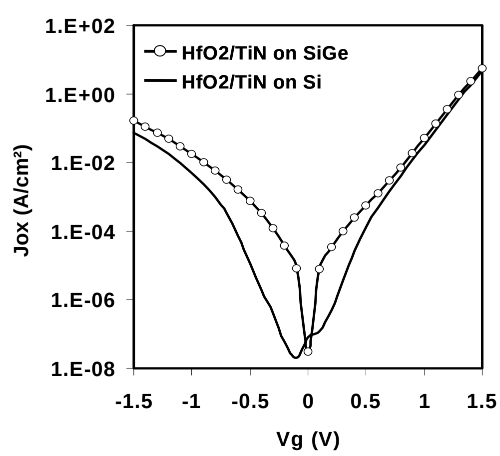

Fig.6 Ig-Vg plots show similar characteristics of HfO2/TiN gate stack on silicon and strained SiGe channel.

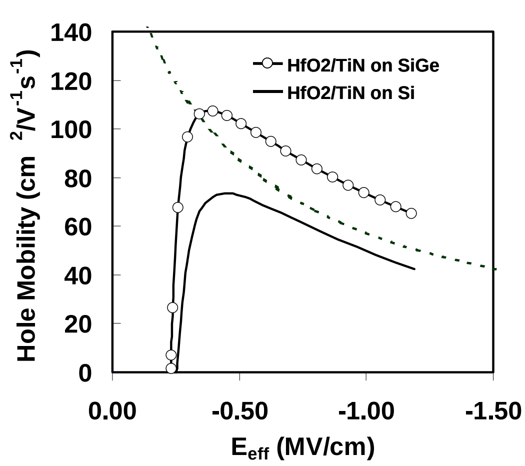

Fig. 7 Inversion hole mobility as a function of transverse effective E-field in compressive SiGe channel with HfO2/TiN gate stacks, compared to Si control.

References

[1] S. Datta, et al., page 653 IEDM 2003.
[2] E. Gusev, et al., IEDM Tech Dig. P451, 2001.
[3] J. C. Tsang et al. J. Appl. Phys. 75(12), P8098 (1994).