doi: 10.1017/S143192760909566X
Microsc Microanal 15(Suppl 2), 2009

Low Loss EELS Study of The Ultrathin $SrTiO_3$ Film Grown on The Si Single Crystal

D. Su*, M. Couillard**, M. Sawicki***,C. Broadbridge***, and Y. Zhu*

*Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, NY, 11973

**Semiconductor Insights, Inc. 3000 Solandt Rd, Kanata, Ontario, Canada, K2K 2X2

*** Department of Physics, Southern Connecticut State University, 501 Crescent Street, New Haven, CT, 06515

$SrTiO_3$ (STO) is a promising candidate for thin film applications in high-K capacitors and tunable microwave devices because of its high permittivity, low dielectric loss and high tunability. To make it reality, the growth of the STO film need to cooperate into the silicon based technology. Though the epitaxial STO films have been successfully grown on (001) silicon substrate ten years ago, the nature of interface and the growth mechanism are still not under investigation [1,2].

In this work, electron energy loss spectroscopy (EELS) carried out in a scanning transmission electron microscopy (STEM) has been used to study a Si/SrTiO3/Si sandwich structural sample. Three-unit-cell thick STO layer was grown on (001) Si by MBE.[1] The epitaxy has been confirmed as (001)STO//(001)Si and STO[110]//Si[100] by XRD and electron diffraction. A 50nm amorphous Si was deposited on the top of STO film. We focus our study on the valence excitation region (Fig.1). We find that the interface plasmon excitation is not clearly visible for the STO thin film. The modes from both the bulk Si plasmon and the STO bulk Plasmon are found in STO film. The Si bulk plasmon in the STO layer is from the delocalized signal from the excitation of modes far from the electron trajectory[3,4]. The energy of Si bulk plasmon shifts 1 eV toward the low energy direction and the STO bulk plasmon shifts 1.4 eV toward the low energy direction(Fig.2). This result is different with the previous reports in Si/SiO2 interface and Si/Co multi-layers [5, 6]. The shifts of plasmon peaks are considered as a interface effect. Our experimental data are simulated by the dielectric function theory [3]. Energy loss function, optical absorption, and surface loss function derived from the EELS image using a Kramers-Kronig analysis are shown in Fig.3. Our results provide information of local electronic excitation near the interface.

References:

[1] R. A. Makee, F. J. Walker, adn M.F. Chisholm, Phys. Rev. lett. 81, (1998)3014

[2] L. Fitting Kourkoutis, C. Stephen Hellberg, V. Vaithyanathan, H. Li, M. K. Parker, K. E. Anderson, D. G. Schlom, and D. A. Muller, Phys. Rev. lett. 100, (2008)036101

[3] M. Couillard, A. Yurtsever, and D. A. Muller, Phys. Rev. B, 77, (2008)085318

[4] M.G. Walls and A. Howie, Ultramicroscopy, 28, (1989)40

[5] A. Howie, and R. H. Milne, Ultramicroscopy, 18, (1985)427

[6] P. Rez, X. Weng, N. J. Long and A. K. Petford-long, Phys. Rev. B 42, (1990)9182

[7] We thank Dr. F. J. Walker for providing the samples. We acknowledge the support by US Department of Energy BES, under contract No. DE-AC02-98CH10886. The research of M.S. and C.B. was partially supported by NSF Grant MRSEC DMR05-20495. Use of MRSEC DMR05-20495 facilities is also acknowledged.

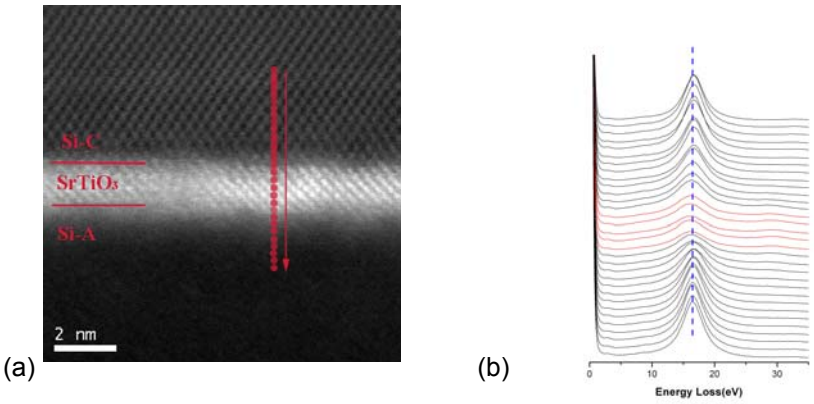

Fig.1 (a) A STEM_ADF image of Si/STO/Si sandwich structure. (b) a EELS scan along line marked in (a). The scan is from -2.5nm in Si substrate to the 2 nm in the amorphous Si layer.

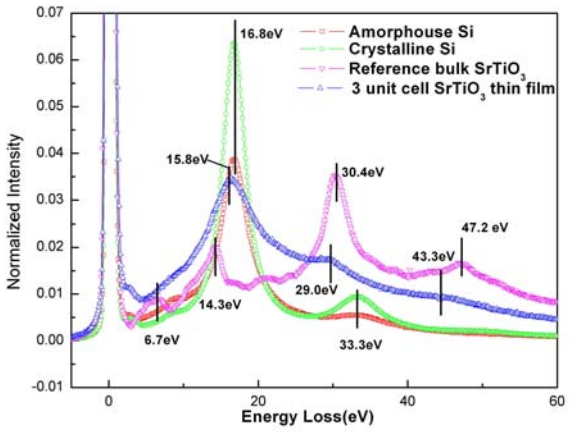

Fig.2 The low loss EELS from Si substrate, STO film and amorphous Si layer with longer acquire time. The low loss EELS of the bulk STO sample is also given as a reference.

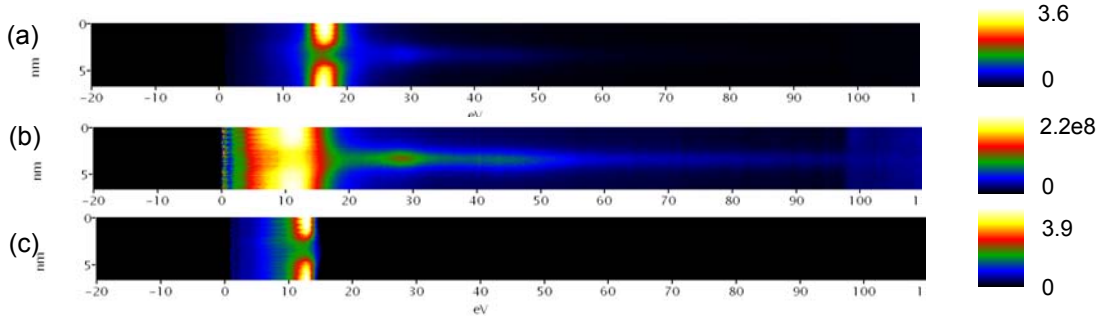

Fig.3 Energy loss function(a), Optical absorption(b), and Surface loss function derived from the line scan EELS image.

https://doi.org/10.1017/S143192760909566X Published online by Cambridge University Press