

Surface-directed spinodal decomposition in hafnium silicate films

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Introduction

The thickness decrease of the traditional gate dielectrics, SiO_2 and SiO_xN_y , in complementary metal oxide semiconductor transistors leads to a significant increase in direct tunneling current through the gate stack. Pseudobinary alloy system $(\text{HfO}_2)_x(\text{SiO}_2)_{1-x}$ is one of the potential high- κ dielectrics that might replace SiO_2 as the gate insulator in future transistors to reduce the gate leakage current. In this study, the structure of the $(\text{HfO}_2)_{0.25}(\text{SiO}_2)_{0.75}$ films, specifically, the depth distribution of Hf, was characterized by cross-sectional high resolution transmission electron microscopy (HRTEM), which showed evidence of surface-directed spinodal decomposition (SDSD) in $(\text{HfO}_2)_x(\text{SiO}_2)_{1-x}$ system.

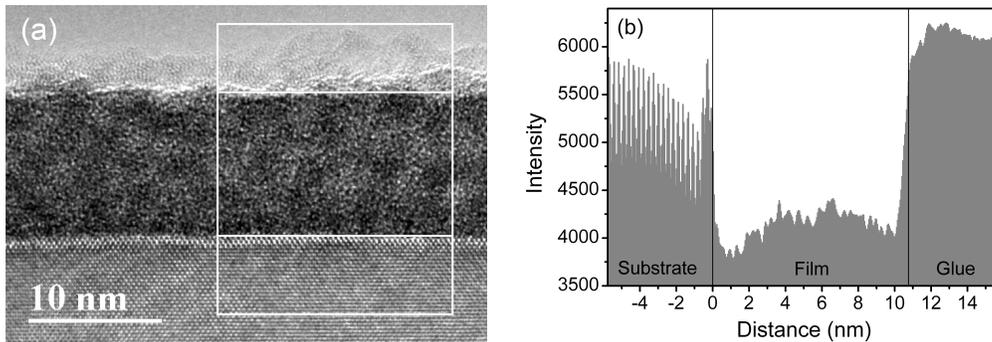


Figure 1: (a) HRTEM image of a $(\text{HfO}_2)_{0.25}(\text{SiO}_2)_{0.75}$ film after rapid thermal anneal (RTA), dark areas have a higher Hf concentration than bright areas; (b) line intensity profile integrated over the width of the rectangle shown in (a), this profile represents a Hf distribution normal to the film surface, a lower intensity indicates a higher Hf concentration.

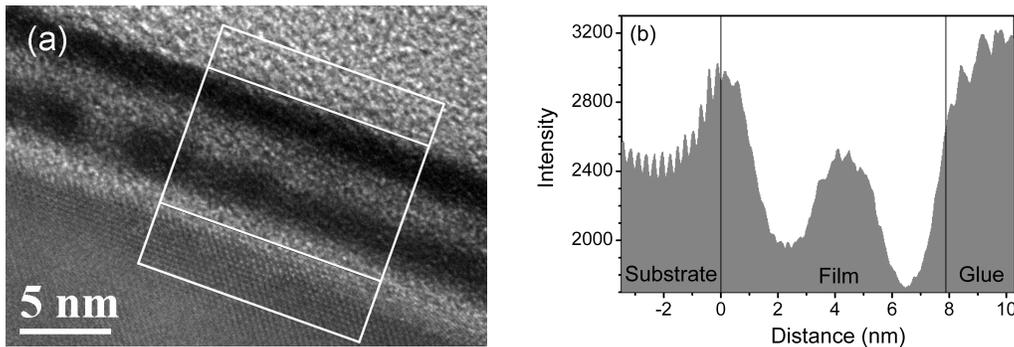


Figure 2: (a) HRTEM image of the film shown in Fig. 1 after RTA, HF etch, RTA; (b) line intensity profile integrated over the width of the rectangle shown in (a).

When a two-component system in its spinodal region is confined in a thin film geometry, SDSD could occur if one of the two components is preferentially attracted to the film surfaces. In SDSD, a composition wave normal to the film surface forms at the surface and decays as it propagates into the film bulk because of thermal noise. In a thick $(\text{HfO}_2)_{0.25}(\text{SiO}_2)_{0.75}$ film, the composition wave is not observed (Fig. 1). When the thickness of this film is reduced to a value that is comparable to the composition wavelength, a wave like Hf distribution normal to the film surface appears (Fig. 2).*

Work performed in the Nanofabrication Facility:

The RTA was performed on Jipelec JetFirst. The $(\text{HfO}_2)_{0.25}(\text{SiO}_2)_{0.75}$ film was etched by 0.4% HF in the fume hood. The etch rate was monitored by M2000V Variable Angle Spectroscopic Ellipsometer.

* J. Liu, X. Wu, W. N. Lennard, and D. Landheer, Phys. Rev. B 80, 041403 (2009).