Amorphous to polycrystalline phase transition in La_2O_3 films grown on a silicon substrate forming Si-doped La_2O_3 films[†]

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Currently, the semiconducting industry is heavily reliant on Si-based electronic devices. SiO_2 has been used as a principal dielectric in Si-based industry owing to its good film properties and stability in the complementary metal-oxide-semiconductor (CMOS) process. However, its low dielectric constant has raised issues of low performance of device and large leakage current with decreasing gate thickness, channel length, *etc.* Consequently, extensive efforts have been made to find alternative dielectrics with high-permittivity (κ) on Si as a replacement for SiO_2. One of important conditions for high-κ dielectric is that the dielectric layer should not result in the formation of silicide or SiO_2 interfacial layer between silicon wafer and dielectric layer. Intriguingly, it has been shown that upon the deposition of La_2O_3 is deposited on Si, La silicate is formed rather than a SiO_2 interfacial layer.[1]

In this study, we used a pulsed laser deposition (PLD) method to obtain a high-quality La_2O_3 film on a Si substrate. Using a high-resolution transmission electron microscope (HRTEM) it was observed that approximately 10 nm thick amorphous La_2O_3 layer was initially formed on Si. Subsequently, and then a polycrystalline La_2O_3 layer was formed on top of the amorphous La_2O_3 layer, as Fig. 1(a), which is attributed to Ostwald's step rule, this is a metastable state formation prior to the formation of a stable state of a material. HRTEM images also suggested that no interfacial oxide layer was formed between La_2O_3 and Si. Furthermore, through an in-depth study using Rutherford backscattering (RBS), performed at the RIKEN Pelletron accelerator facility, it was further confirmed that La-Silicate interfacial layer is extremely reduced, as Fig. 1(b). Rather, the results of X-ray photoelectron spectroscopy atomic depth profile analysis, using Ar^+ ion beam sputtering, indicated the presence of La-silicate present over the entire La_2O_3 film, as Fig. 1(c). This suggests that Si diffuses through whole thick La_2O_3 films, thereby forming Si-doped La_2O_3 films. Our study suggests that employment of advanced growth technique may improve the status of high-κ gate oxide of La_2O_3 gate oxide in CMOS industry.

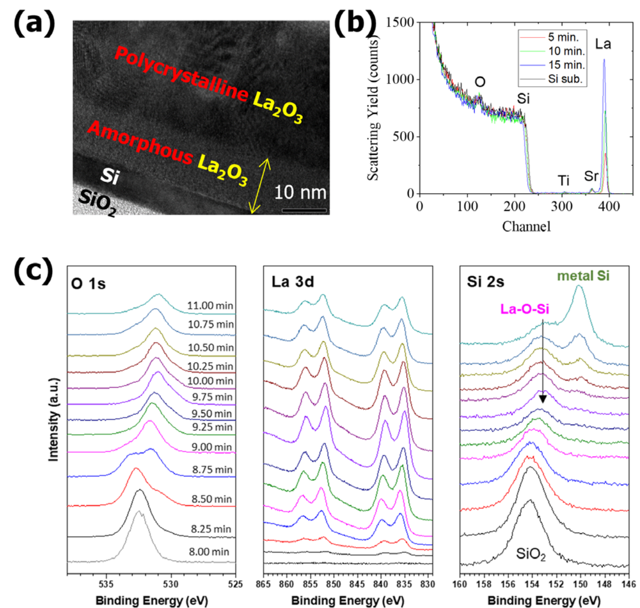

Fig. 1. (a) Transmission electron microscope image of polycrystalline/amorphous La_2O_3 films, (b) Rutherford backscattering, and (c) X-ray photoelectron spectroscopy atomic depth profile of La_2O_3/Si.

Reference

1) T. Kawanago *et al.*, Proc. 41st European Solid State Device Research Conf., Helsinki, Finland, 2011-4, p. 67.

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