Rapid Thermal Annealing of the Tantalum Silicate Thin Films Formed by Metalorganic Decomposition

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Recently, high dielectric constant (high-K) materials have been intensively investigated to replace SiO_2-based gate dielectrics in future metal-oxide-semiconductor field effect transistors (MOSFETs). Among these materials, tantalum oxide (Ta_2O_5) films are thought to be potential candidate for an alternative gate dielectric because of a large dielectric constant and lower leakage current. [1] Although the dielectric properties are fairly good, but an interfacial oxide growth and instability of Ta_2O_5 structure itself occur even though relatively lower crystallized temperature (<900ºC). Moreover, well crystallized oxides shows often rough surface morphology. In contrast, SiO_2-rich tantalum silicate alloys like (1-x)Ta_2O_5-xSiO_2 thin films have inspired to improve the interfacial properties as well as dielectric and insulating properties. However, the dielectric and insulating properties of (1-x)Ta_2O_5-xSiO_2 thin films may be strongly dependent on the fabrication method, and post deposition annealing process condition. In this paper, we report the characterization of (1-x)Ta_2O_5-xSiO_2 thin films on silicon after rapid thermal annealing (RTA). RTA has the potential to precise control of dielectric-silicon interface, bulk structure and carrier transport of the thin dielectric films. [2]

In this study, *p*-type Si (100) wafer was used as substrate. After the wafer cleaning, 2-methoxyethanol solution of mixed pentaethoxy tantalum ($Ta(OC_2H_5)_5$) and tetraethoxy silane ($Si(OC_2H_5)_4$) was directly deposited on the Si wafer by spin coating. After spinning, post-deposition RTA of the films was carried out under various conditions (e.g., varying temperature, time, and ambient) using rapid thermal processing apparatus. The crystallinity and surface morphology of the films were evaluated by X-ray diffractometry (XRD) and atomic force microscopy (AFM) respectively. The electrical measurements were conducted on films in MIS configuration.

Figure 1 shows the effect of RTA temperature on (1-x)Ta_2O_5-xSiO_2 (x=0.20) film thickness. Although RTA time does not seem to have a strong effect on the film thickness, a little bit change in film thickness for RTA temperature and ambient. The film thickness of oxygen ambient is thicker than that of nitrogen ambient and also increased with increasing RTA temperature above 900℃.

The XRD patterns of pure Ta_2O_5 films as a function of annealing temperature is shown in Fig. 2. After annealing, the peak intensity was found to be increased with increasing annealing temperature i.e., showed clear crystallization, while (1-x)Ta_2O_5-xTiO_2 (x=0.20) films did not show any significant changes relative to the as deposited case even though it was annealed at a higher temperature (1000ºC) as shown in Fig. 3. But RTA time did not seem to have a strong effect on structure and equivalent oxide thickness.

The capacitance-voltage characteristics of the 0.80Ta_2O_5-0.20SiO_2 films indicate that with increasing RTA temperature the capacitance increases. The maximum dielectric constant for the 0.80Ta_2O_5-0.20SiO_2 films was 13 after 900℃ RTA annealing. In addition, the leakage current was low as $1x10^{-8}$ A/cm^2 at 3 MV/cm.

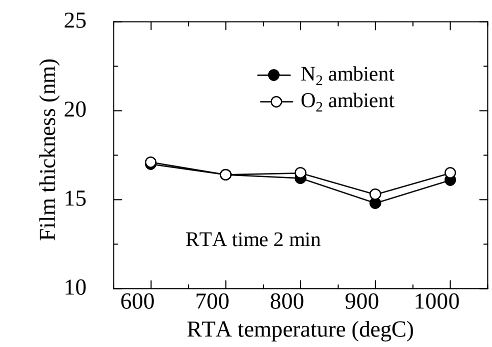

Fig.1. Effect of RTA temperature on the (1-x)Ta_2O_5–xSiO_2 (x=0.20) thickness at different ambient.

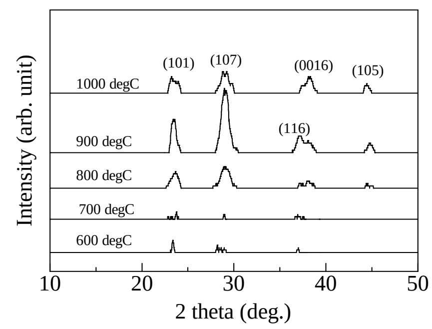

Fig.2. XRD patterns of Ta_2O_5 thin films annealed at various RTA temperatures.

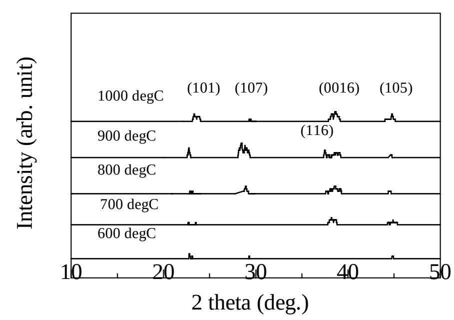

Fig.3. XRD patterns of 0.80Ta_2O_5-0.20SiO_2 thin films annealed at various RTA temperatures.

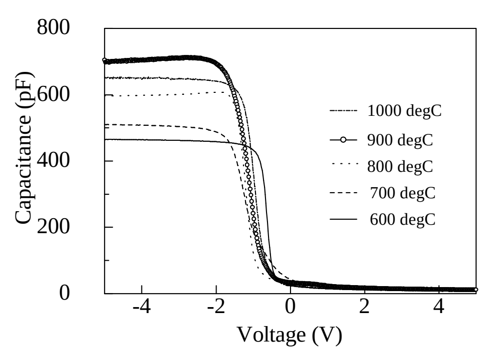

Fig.4. The *C-V* characteristics of 0.80Ta_2O_5-0.20SiO_2-based MIS structures at various RTA temperatures.

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References

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