# Annealing behaviours of open spaces in thin $Al_2O_3$ films deposited on semiconductors studied using monoenergetic positron beams

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Metal-oxide-semiconductor gate stacks for GaN-based power devices have been studied extensively. The deposition of gate oxides is known to introduce carrier traps at the interface, and they are the major obstacles in device fabrication. Because the interfacial reaction of the insulator and GaN could occur easily, knowledge on the interface reaction between oxides and GaN is a key to developing GaN-based MOS devices. We used monoenergetic positron beams to study reactions between $Al_2O_3$ and GaN and annealing behaviors of open spaces in $Al_2O_3$ [1]. 25-nm-thick $Al_2O_3$ films were deposited on GaN by using ALD method. After the deposition, the samples were annealed up to 900°C for 5 min in $N_2$ atmosphere. Figure 1 shows *S*–*E* curves for $Al_2O_3$/GaN before and after annealing treatments. The *S* value at $E \cong 1$ keV corresponds to the annihilation of positrons in the $Al_2O_3$ film. After annealing at 800°C, observed increase in *S* at $E=2$ keV was due to the trapping of positrons by vacancies introduced by the reaction between $Al_2O_3$ and GaN. The inset shows the depth distributions of *S* obtained from fitting. The lifetime spectra of positrons in $Al_2O_3$ were measured, and they were decomposed into three components. For as-deposited sample, the values of $\tau_1$, $\tau_2$, and $\tau_3$ were obtained as 0.262 ns (54%), 0.580 ns (45%), and 1.77 ns (1%) respectively. The positron lifetimes in $\gamma$ -$Al_2O_3$ were simulated. Fig. 2 shows the atomic configurations used in the calculation and positron density distributions. It was found that $\tau_1$ agreed with the calculated positron lifetimes for clusters of $V_{Al}$. Annealing behaviours of open spaces in $Al_2O_3$ was discussed based on the experiments and simulation.

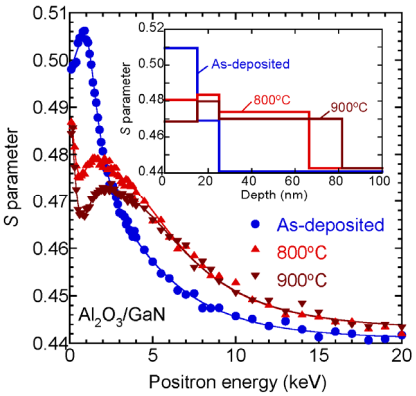


**Fig. 1** *S*–*E* curves for $Al_2O_3$/GaN. The inset shows the depth distributions of *S*.

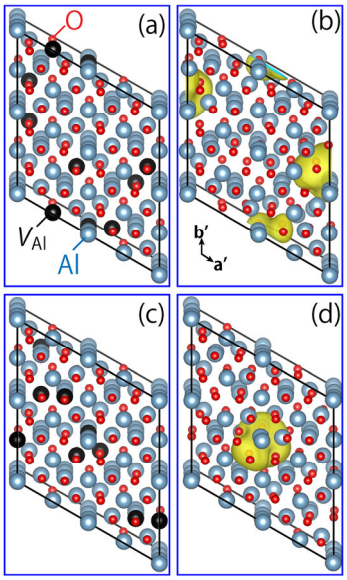


**Fig. 2** Atomic configurations of γ-$Al_2O_3$ [(a) and (c)] and distributions of positron densities [(b) and (d)].

**References**

[1] A. Uedono *et al.*, *J. Appl. Phys.* **123**, 155302 (2018).

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