



# Investigation of interface characteristics of Al<sub>2</sub>O<sub>3</sub>/Si under various O<sub>2</sub> plasma exposure times during the deposition of Al<sub>2</sub>O<sub>3</sub> by PA-ALD

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## ABSTRACT

Plasma-assisted atomic layer deposition (PA-ALD) is more suitable than thermal atomic layer deposition (ALD) for mass production because of its faster growth rate. However, controlling surface damage caused by plasma during the PA-ALD process is a key issue. In this study, the passivation characteristics of Al<sub>2</sub>O<sub>3</sub> layers deposited by PA-ALD were investigated with various O<sub>2</sub> plasma exposure times. The growth per cycle (GPC) during Al<sub>2</sub>O<sub>3</sub> deposition was saturated at approximately 1.4 Å/cycle after an O<sub>2</sub> plasma exposure time of 1.5 s, and a refractive index of Al<sub>2</sub>O<sub>3</sub> in the range of 1.65–1.67 was obtained. As the O<sub>2</sub> plasma exposure time increased in the Al<sub>2</sub>O<sub>3</sub> deposition process, the passivation properties tended to deteriorate, and as the radio frequency (RF) power increased, the passivation uniformity and the thermal stability of the Al<sub>2</sub>O<sub>3</sub> layer deteriorated. To study the Al<sub>2</sub>O<sub>3</sub>/Si interface characteristics, the capacitance-voltage (C-V) and the conductance-voltage (G-V) were measured using a mercury probe, and the fixed charge density (Q<sub>f</sub>) and the interface trap density (D<sub>it</sub>) were then extracted. The Q<sub>f</sub> of the Al<sub>2</sub>O<sub>3</sub> layer deposited on a Si wafer by PA-ALD was almost unaffected, but the D<sub>it</sub> increased with O<sub>2</sub> plasma exposure time. In conclusion, as the O<sub>2</sub> plasma exposure time increased during Al<sub>2</sub>O<sub>3</sub> layer deposition by PA-ALD, the Al<sub>2</sub>O<sub>3</sub>/Si interface characteristics deteriorated because of plasma surface damage.

## 1. Introduction

Atomic layer deposition (ALD) is a method of sequentially depositing thin films while placing two reactants in gaseous form into the chamber. A very thin film of atomic thickness can be grown via a self-limited reaction on the surface. In general, the ALD method is based on adsorption and desorption reactions, in which the precursor reacts with the substrate by surface adsorption and then by-products are purged and removed. Therefore, by controlling the number of reaction cycles, it is possible to adjust the thickness of the thin film, enabling the production of very thin films. In addition, the ALD method can deposit thin films with wide area uniformity and excellent step coverage [1]. In the Si solar cell, various metal oxides such as Al<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, HfO<sub>2</sub> and NiO<sub>2</sub> are used as a passivation material by using ALD method [2–6]. In particular, Al<sub>2</sub>O<sub>3</sub> is widely used for passivation material on a p-type substrate because Al<sub>2</sub>O<sub>3</sub> shows very excellent passivation

characteristics [7–9]. Two reasons for using Al<sub>2</sub>O<sub>3</sub> as a passivation material on a silicon substrate are as follows: 1) dangling bonds present on the Si surface can be reduced by SiO<sub>x</sub> formed at the interface during the process, and a low interface trap density can be obtained. (chemical passivation) 2) a negative fixed charge existing at the interface between Al<sub>2</sub>O<sub>3</sub> and Si causes band bending occurs to reduce the electron or hole concentration present on the surface (field effect passivation) and reduce the surface recombination rate [9,10]. Therefore, in order to apply Al<sub>2</sub>O<sub>3</sub> to the silicon solar cell, the thin film properties of Al<sub>2</sub>O<sub>3</sub> are important, but the interface property between Si and Al<sub>2</sub>O<sub>3</sub> is very important because the electrical characteristics of the silicon solar cell could be greatly influenced according to Al<sub>2</sub>O<sub>3</sub>/Si interface characteristics. In general, ALD using thermal energy is widely used to deposit Al<sub>2</sub>O<sub>3</sub>. However, the deposition rate is relatively slow and the window process range is narrow, making it difficult to control the process parameters. Plasma-assisted atomic layer deposition (PA-ALD) is an

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