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Investigation of interface characteristics of Al_2O_3/Si under various O_2 plasma exposure times during the deposition of Al_2O_3 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_2O_3 layers deposited by PA-ALD were investigated with various O_2 plasma exposure times. The growth per cycle (GPC) during Al_2O_3 deposition was saturated at approximately 1.4 Å/cycle after an O_2 plasma exposure time of 1.5 s, and a refractive index of Al_2O_3 in the range of 1.65–1.67 was obtained. As the O_2 plasma exposure time increased in the Al_2O_3 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_2O_3 layer deteriorated. To study the Al_2O_3/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_f) and the interface trap density (D_{it}) were then extracted. The Q_f of the Al_2O_3 layer deposited on a Si wafer by PA-ALD was almost unaffected, but the D_{it} increased with O_2 plasma exposure time. In conclusion, as the O_2 plasma exposure time increased during Al_2O_3 layer deposition by PA-ALD, the Al_2O_3/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_2O_3, TiO_2, HfO_2 and NiO_2 are used as a passivation material by using ALD method [2–6]. In particular, Al_2O_3 is widely used for passivation material on a p-type substrate because Al_2O_3 shows very excellent passivation characteristics [7–9]. Two reasons for using Al_2O_3 as a passivation material on a silicon substrate are as follows: 1) dangling bonds present on the Si surface can be reduced by SiO_x 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_2O_3 and Si causes band banding 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_2O_3 to the silicon solar cell, the thin film properties of Al_2O_3 are important, but the interface property between Si and Al_2O_3 is very important because the electrical characteristics of the silicon solar cell could be greatly influenced according to Al_2O_3/Si interface characteristics. In general, ALD using thermal energy is widely used to deposit Al_2O_3. 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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