

Regular Paper

Evaluation of Hydrogenated Amorphous Silicon Carbide ($a\text{-Si}_x\text{C}_{1-x}\text{H}$) Multilayer Films using Real-time In-Situ Infrared Reflection Absorption Spectroscopy during Film Deposition

Mitsuya MOTOHASHI^{1,*}, Satoshi KOUYA¹ and Ryosuke WATANABE²

¹Department of Information and Communication Engineering, Tokyo Denki University, 5 Senju-asahi-cho, Adachi-ku, Tokyo 120-8551, Japan

²Graduate School of Science and Technology, Hirosaki University, 3 Bunkyo-cho, Hirosaki-shi, Aomori 036-8561, Japan

Received Feb. 5, 2026; accepted for publication Feb. 27, 2026

Abstract

Atomic bonding states of grown hydrogenated amorphous silicon carbide ($a\text{-Si}_x\text{C}_{1-x}\text{H}$) multilayers were discussed using real-time in-situ infrared reflection absorption spectroscopy (IR-RAS). The layers were deposited by a radio-frequency glow discharge plasma using SiH_4 and CH_4 . The gas flowrate ratio, γ , used was $\{\text{CH}_4/(\text{SiH}_4 + \text{CH}_4)\}$. The intensity of the IR spectra of the upper layer had higher amplitudes when the γ of the lower layer was less than that of the upper layer. In addition, the IR intensity of the upper layer increased with decreased γ on the lower layer. These results indicated that the atomic bonding states of the upper layer were strongly dependent on those of the lower layer. Consequently, it was predicted that the nature of the lower layer would affect the surface reaction during film deposition.

Keywords: Amorphous silicon carbide, Multilayer, Chemical vapor deposition, IR-RAS,

1. Introduction

Hydrogenated amorphous silicon carbide ($a\text{-Si}_x\text{C}_{1-x}\text{H}$) multilayer films are considered useful for optoelectronic and quantum-effect device applications [1–6]. The optical and electrical properties of the $a\text{-Si}_x\text{C}_{1-x}\text{H}$ films can be adjusted by controlling the deposition parameters [7–13]. Recently, multilayer films have been used to improve the performance of existing devices and to fabricate novel devices. Furthermore, it is common to increase the number of layers and decrease the thickness of each layer in these multilayer films. However, it is well known that, for an amorphous silicon film, a boundary layer forms between the film and substrate. The nature of the materials used for the films and substrates, affects the characteristics of this boundary layer [14–17]. However, the effect of the lower layer of an $a\text{-Si}_x\text{C}_{1-x}\text{H}$ multilayer film on the upper layer has not yet been thoroughly discussed. Consequently, developments of $a\text{-Si}_x\text{C}_{1-x}\text{H}$ multilayer components are currently based on trial and error, hindering device production. In the glow discharge method, film deposition employs three processes: decomposition of the source gas, radical reaction in the vapor phase, and growth surface reaction [18,19].

*Corresponding author: mmitsuya@cck.dendai.ac.jp.

The surface reaction changes in real time during film deposition and is the final step in film growth, which means that the surface condition determines film quality. To date, only a few studies report real-time structural analysis of $a\text{-Si}_x\text{C}_{1-x}\text{H}$ multilayer films. Therefore, it is necessary to study in detail the deposition of each layer on the surface of a film using a real-time method.

In a previous proposal, we examined the effect of the lower layer on the optical characteristics of the upper layer in a double-layered film deposition while varying the substrate temperature. For this study, real-time in-situ infrared reflection absorption spectroscopy (IR-RAS) [20–22] and electron spin resonance (ESR) were used. We noted that the hydrogen concentration with respect to the bond between Si and H, and the electron defect density of the upper layer in the double layers was greater than that of a single layer [23, 24]. However, to date, there has been no discussion on the effect of varying source gas flowrate ratio, γ , $\{\text{CH}_4/(\text{SiH}_4 + \text{CH}_4)\}$. Therefore, the effect of varying γ on the bonding configuration in the multilayer was studied using real-time in-situ IR-RAS in this paper.