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SUMMARY OF Ph.D. DISSERTATION

School Integrated Design Engineering	Student Identification Number	SURNAME, First name SATAKE, Koji

Title

Numerical modeling of plasma enhanced chemical vapor deposition of microcrystalline silicon thin films

Abstract

Plasma enhanced chemical vapor deposition (PECVD) has promoted the application of hydrogenated microcrystalline silicon (μcSi:H) to solar cells and thin film transistors (TFTs) because of the ease of large area deposition and low temperature process. Understanding of the relationship between plasma process conditions and deposition phenomena is fundamental to designing the processes to obtain desirable deposition rates and film properties. The major focus of this work presents a model to predict μcSi:H film deposition through not only plasma kinetics but also film growth kinetics connected with plasma-produced chemical species. And the model aids determining process parameters and designing PECVD reactors to produce thin film materials for industrial applications.

Chapter 1 introduces the background and the purpose of this thesis with discussing the difficulties in modeling of PECVD due to the diversity in length and time scales and the lack of deposition uniformity under very high-frequency (VHF) plasma.

In Chapter 2, the thesis continues with presenting a model for discharge kinetics, gas-phase chemistry, and ion kinetics in a plasma sheath. The calculated results of neutral and ion fluxes onto the substrate show that the plasma with higher excitation frequency of 70 MHz than that of conventional 13.56 MHz increases the flux ratio of H/SiH_3 and decreases the incident ion energy. These features of VHF plasma have the advantage of μcSi:H film deposition.

Chapter 3 reports the study of ion bombardment of the μcSi:H film growing surface using molecular dynamics simulations. The influence of ion bombardment on surface chemistry and nucleation is clarified. VHF plasma with higher than a few hundreds mTorr suppresses the bulk damage due to incident ions and is useful for obtaining high quality μcSi:H films.

Chapter 4 deals with a total modeling of the μcSi:H film growth in a capacitively coupled plasma reactor. This model can predict the deposition rate and the film properties such as the crystal grain orientation and the hydrogen content. The relationship between the external process parameters and the deposition rate and the film properties is clarified and an optimization of process parameters is demonstrated.

Chapter 5 contains a study of the uniformity of VHF plasma for a large area deposition using the transmission-line modeling. The fact that the plasma uniformity is mainly governed by the standing wave of voltage distribution on a powered electrode is clarified with comparison between experiments and calculations. The model reveals the relationship between the plasma conditions and the attenuation and the wave length of the standing wave. Finally a time modulation method of the standing wave can deposit a film with uniformity of ±20% over a 1.4m×1.1m substrate.

This thesis first presents a model to predict μcSi:H film using PECVD and large area VHF plasma distribution and contributes the industrial application of PECVD to large area and high quality μcSi:H film depositions.