Influence of the Excitation Frequency Increase Up to 140 MHz on the VHF-PECVD Technology

S. Leszczynski[1], B. Leszczynska[1], M. Albert[1], J.W. Bartha[1], U. Stephan[2], J. Kuske[2]

[1]Dresden University of Technology, Semiconductor and Microsystems Technology Laboratory, Dresden, Germany

[2]Forschungs- und Applikationslabor Plasmatechnik GmbH, Dresden, Germany

Abstract

Introduction

The plasma enhanced chemical vapor deposition technology (PECVD) is one of the important deposition techniques for amorphous (a-Si:H) and microcrystalline (µc-Si:H) silicon thin film and solar cell fabrication. The deposition process is based on the surface reactions at the interface between a substrate and reactive plasma phase. The gas molecules are introduced into the discharge area, and due to electron impact reaction are broken down into reactive particles in the dissociation process. These precursors can form chemical binding on the substrate surface forming a new layer of solid material.

The process developed at Dresden University of Technology enables the deposition of homogenous a-Si:H and µc-Si:H layers on large area substrates at high deposition rates using linear plasma sources and the very high excitation frequencies up to 140 MHz (Figure 1) . In the VHF range the electric field wavelength inside of the PECVD reactor is comparable with electrode dimensions (500x100mm) which causes building of standing waves inside the deposition chamber. Therefore the homogeneity of the electric field has been simulated to exam the influence of electrical properties on the homogeneity of deposited layers.

Use of COMSOL Multiphysics®

First, a simplified model of the linear plasma source and the substrate carrier as a two electrode system and vacuum as a medium between has been created and defined using the RF-Module.

Next, a detailed 3D-CAD geometry model of the deposition chamber has been introduced using extern CAD software (Figure 2) and imported into COMSOL Multiphysics®. Due to plain symmetry conditions defined in the model, only quarter of the structure has been taken into the consideration. Additionally, the conducting bulk elements have been modeled and reduced to the boundary surfaces.

This model configuration lowers significantly the required computation power and consequently the amount of time need for solving the problem.

As a last step, the argon discharge has been introduced using the enhanced Plasma Module.

Results
The electric field distribution inside the simplified linear plasma source has been simulated and compared with measured deposition rate profiles of intrinsic amorphous silicon layers at several frequencies (Figure 3). Furthermore the optimized power coupling geometry has been introduced to achieve better field homogeneity (Figure 4).

The detailed model of the plasma source has been electrically simulated for several frequencies (81.36 - 140 MHz) and compared with electrical measurements of the real structure.

The simulation results have been used to create an electrical lumped model of the source.

Conclusion
The presented work shows that simplified geometry models with reduced physical description give important information about homogeneity of deposited layers in a real complicated deposition system.

Comparison of the electrical properties of the model and the real object confirmed the possibility to electrical model highly complicated 3D structures. The lumped model of the structure is being used to improve of the electrical feed.

Due to high the complexity of the silane plasma used in the real process, the less complex argon plasma modeling has been chosen as a method for understanding basic process properties.

Reference

1. B. Leszczynska et al., High-rate deposition of silicon thin film layers using linear plasma sources operated at very high excitation frequencies (80-140 MHz), Proc. of SPIE, 8470, 847009 (2012)

Figures used in the abstract

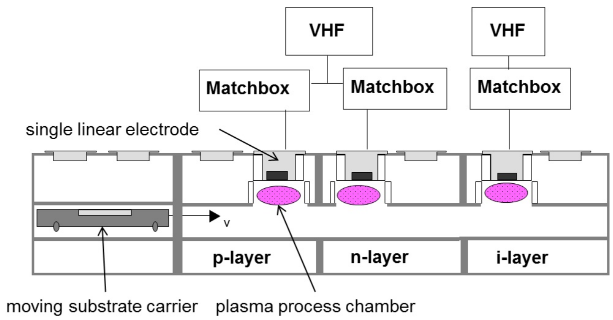

Figure 1: Schematic view of the VHF-inline deposition system

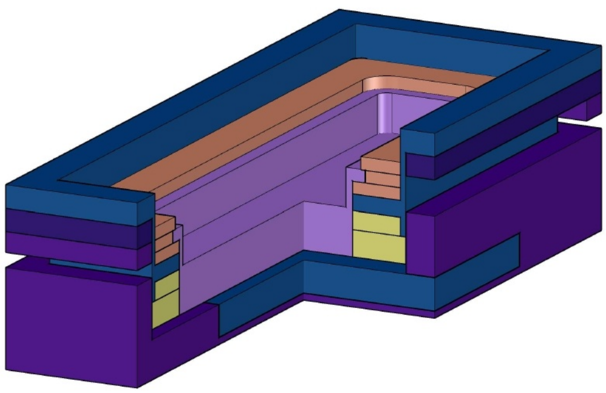

Figure 2: 3D CAD model of the single plasma source

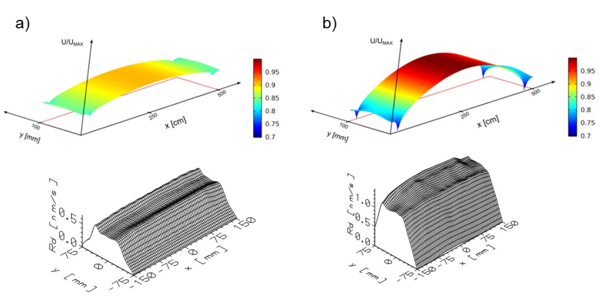

Figure 3: Electromagnetic field distribution between the plasma source electrodes compared with amorphous silicon layer deposition rate profiles at the 81.36 (a) and 140 MHz (b) excitation frequency

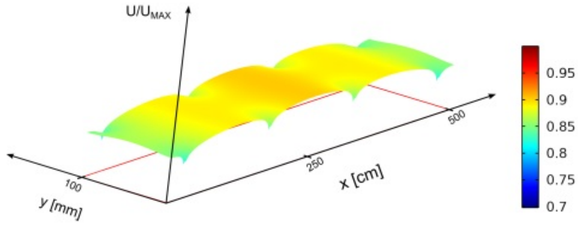

Figure 4: An optimized power coupling solution at the 140 MHz excitation frequency