Computer Simulation of WSi_x CVD VLSI Processing to Obtain Uniform Film Properties

K. Sugawara, T. Muranushi, Y. K. Chae,*
Y. Shimogaki,* H. Komiyama,* and Y. Egashira**
College of Eng., Nihon Univ., Koriyama, Fukushima, 963-8642 Japan
*Department of Chemical System Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0117, Japan
**Department of Chemical Science and Engineering, Osaka University, 1-3 Toyonaka, Osaka 560-0043, Japan

Introduction

Chemical vapor deposition (CVD) films are widely used to make Very Large Scale Integrated Circuits (VLSIs). For optimum VLSI performance, precise control of both film thickness and composition is required. Numerical simulations can be used to specify reactor geometry and operating conditions to optimize these film parameters. For this purpose, we simulated CVD processes and determined the effect of the gas outlet position and abnormal gas inflow conditions on the radial distribution of the film deposition rate, composition, and uniformity.[1-3] In this work we simulated the effect of gas inflow and outlet position located at the bottom or in the sidewall of the reactor, with the objective of obtaining uniform film properties.

Experimental Method

CVD of tungsten silicide (WSi_x) films is used to make low-resistance gate electrodes in VLSIs. We used WF_6/SiH_4 CVD to deposit WSi_x films on Si wafers. We used a 250mm-diameter cold-wall, single-wafer type reactor with 130mm-diameter wafers, a gas volume ratio of WF_6:SiH_4:Ar = 1:100:500, gas velocity of 1 m/s and a deposition temperature of 300ºC. For a gas inlet 68 mm in radius and the gas outlet position located at the bottom of the reactor, simulated deposition rates and film composition were within 5% of measured values.[2] This close comparison validated the accuracy of our model. We then used this model to simulate film deposition rates and composition for other inlet and outlet conditions.

Numerical Model

We modeled the CVD system using commercially available computational fluid dynamics (CFD) software, FLUENT Ver. 4.5 (Fluent Inc.). We represented the reactor using cylindrical coordinates. We solved for the velocity and temperature distributions, and to determine the radial distribution of the film thickness and composition, we solved mass transport equations, including the effect of gas-phase and surface reactions on the Si substrate. The film-formation reaction model was developed by analyzing the reaction kinetics for a simplified reactor. The model included a radical chain reaction model. [4,5]

We made simulations for the following conditions: gas inlet radii of 48, 52, 56, 60, 64, 68, 72, 76, and 78 mm and gas outlets located either at the bottom or in the sidewall of the reactor.

Results

Although we made simulations for a variety of inlet radii and for two outlet positions, we only show the results for the conditions that yielded the most uniform films in the radial direction. The simulated film deposition rate and composition distributions are shown in Figs. 1 and 2, respectively, for a gas inlet radius of 68 mm and with the outlet in the sidewall. An index of distribution of the radial deposition rate can be expressed as (maximum rate – minimum rate)/ (average rate), and a similar index can be defined for the film composition as (maximum composition – minimum composition)/ (average composition). For an inlet radius of 68 mm, the simulated radial indices were 0.6% and 0.2% for the film deposition rate and composition, respectively, whereas the measured indices of the experimental film deposition rate and composition were 15% and 4%, respectively.

To obtain uniform radial distributions of film deposition rate and composition, there is an optimum gas inlet diameter and gas outlet. CFD-based simulations can be used to optimize such parameters. The results shown here indicate how such simulations can be used to optimize CVD design and operating conditions.

References

1 K. Sugawara et al., ECS Seattle Meeting Extended Abstract, No. 481 (1999).
2 K. Sugawara et al., ECS Toronto Meeting Extended Abstract, No. 903 (2000).
3 K. Sugawara et al., ECS Washington, DC Meeting Extended Abstract, No. 884 (2001).
4 Y. K. Chae et al., thin solid films, 320, 151 (1998).
5 Y. K. Chae et al., J. Electrochem. Soc., 146, 1780 (1999).

Fig. 1. Influence of gas inlet radius on radial distribution of CVD WSi_x film deposition rate.

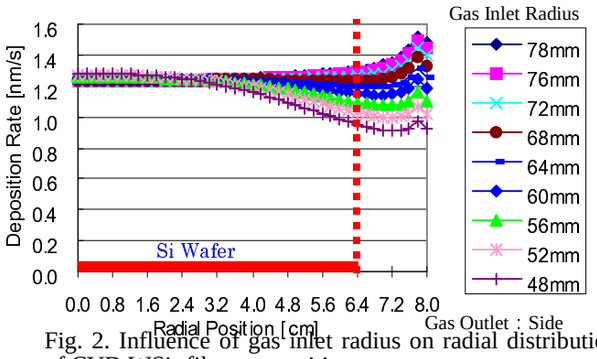
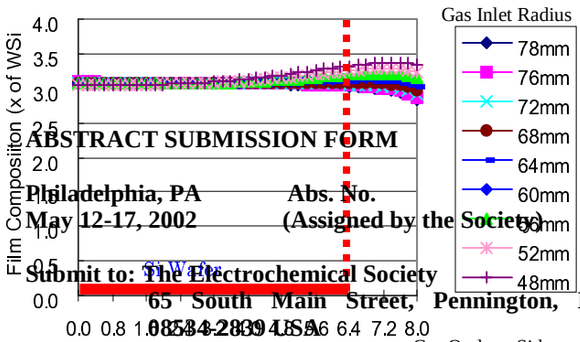


Fig. 2. Influence of gas inlet radius on radial distribution of CVD WSi_x film composition.



ABSTRACT SUBMISSION FORM

Philadelphia, PA Abs. No.
May 12-17, 2002 (Assigned by the Society)

Submit to: The Electrochemical Society 65 South Main Street, Pennington, NJ 08534-2839 USA

With a copy to the Symposium Organizer(s) – by January 2, 2002

Symposium Code and Title: M1-Electrochemical Processing in ULSI Fabrication and Electro- deposition of and on Semiconductors V

Sponsoring Division(s)/Group(s): Electrodeposition /Dielectric Science and Technology/ Electronics

Title of Paper: Computer Simulation of WSix CVD VLSI Processing to Obtain the Uniform Film Properties

Author(s), with complete mailing address(es)

1 Katsuro Sugawara,
Department of Computer Science, College of Engineering, Nihon University
Tokusada, Tamura-machi, Koriyama-shi, Fukushima- ken, 963-8642, Japan

Phone: +81-249-56-8825
Fax: +81-249-56-8863
E-mail: sugawara@cs.ce.nihon-u.ac.jp

2 T. Muranushi, Student
College of Eng., Nihon Univ., Koriyama, Fukushima, 963-8642 Japan

3 Y. K. Chae,
Department of Chemical System Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0117, Japan

4 Y. Shimogaki,
Department of Material Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0117, Japan

5 H. Komiyama, Department of Chemical System Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0117, Japan

6 Y. Egashira
Department of Chemical Science and Engineering, Osaka University, 1-3 Toyonaka, Osaka 560-0043, Japan

Do you plan to present more than one paper at this Meeting? No.

Do you require any audio-visual equipment? LCD

Check here to receive information about membership in The Electrochemical Society, Inc. Information will be sent to author(s) #1 listed above

Poster Session is more preferable to explain details.