Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 105 (2017) 688 – 693

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

Improvement of Heat and Mass Transfer Performance in a Polysilicon Chemical Vapor Deposition Reactor with Field Synergy Principle

L.S An, Zh Yang, G.Y Zhong, Y.W Liu*

Key Laboratory of Thermo-Fluid Science and Engineering of MOE School of Energy and Power Engineering, Xi'an Jiaotong University, Xi'an , Shaanxi 710049, P R China

Abstract

In this paper, two-dimensional numerical model has been established to investigate the convective heat and mass transfer performance in the silicon CVD process. Wave-like and trapezoid-like obstacles are introduced to enhance the interruption within the fluid flow. The dimensionless criterions *Nu* and *Sh* are obtained to measure the heat and mass transfer performance. In addition, the field synergy principle is applied to reveal the relationship between the synergy degree of multiple physical fields (velocity vector, temperature gradient and concentration gradient of multiple components) and heat and mass transfer performance. The numerical results show that, compared to conventional straight channel, the novel channels increase the *Nu* and *Sh*, reduce the synergy angle between the velocity vector and temperature gradient, as well as the velocity vector and the concentration gradient of six main components. In brief, the two improved flow channels have a better convective heat and mass transfer performance.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.

Key words: polysilicon; CVD; heat and mass transfer; field synergy principle

1. Introduction

In recent years, photovoltaic (PV) power generation has experienced rapid growth. The chemical vapor deposition (CVD) of silicon from chlorinated or hydrogenated precursors has been one of the important methods in the production of high purity silicon and the dominant deposition process is still accomplished in the Siemens process [1]. The search for higher production rates of Si and a reduction of

* Corresponding author. Tel.: (86)29-82668789; fax: (86)29-82668789.
E-mail address: ywliu@xjtu.edu.cn.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
doi:10.1016/j.egypro.2017.03.376

its production costs have been often stressed as a necessity for the growth of this industrial sector. Therefore, a thorough and detailed research of CVD process with multi-physical and complex chemical phenomena is fairly essential.

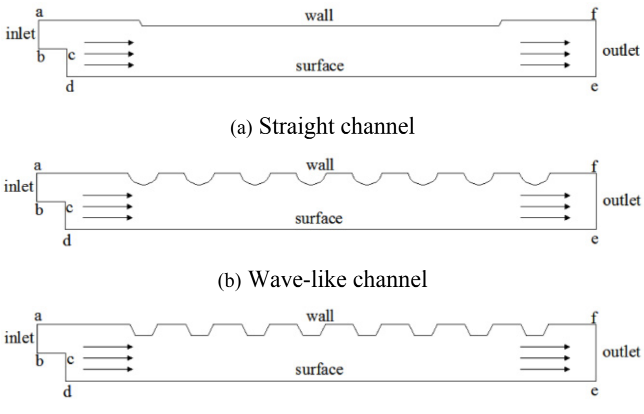
Many researchers [2-5] had used mathematical models to study the complex chemical reactions and silicon deposition characteristics under various operating conditions. However, the advance in the research of yield and quality of silicon is very slow. A new approach, the field synergy principle is introduced to the study on the enhancement of convective heat and mass transfer performance in CVD process. Guo et al. [6] initially proposed a new understanding of enhancing convective heat and mass transfer for the parabolic fluid flow situation. They transformed the convective term of the energy equation into the form of a dot product of velocity vector and temperature gradient, integrated the transformed energy equation over the thermal boundary layer. In 2005, Guo and his coworkers renewed the concept of FSP (the good synergy between the velocity vector and the temperature gradient) [7]. In recent years, the concept called as field synergy principle had been comprehensively reviewed on the recent development of study by Tao and He [8].

In the study, wave-like and trapezoid-like obstacles are introduced into fluid flow with complex chemical reactions to improve the convective heat and mass transfer performance of the CVD process. The dimensionless criterions *Nu* and *Sh* are obtained to measure the convective heat and mass transfer performance. In addition, the field synergy principle is applied to reveal the relationship between the synergy degree of multiple physical fields (velocity vector, temperature gradient and concentration gradient of multiple components) and heat and mass transfer performance.

2. Model descriptions

2.1. Geometric model

The deposition reaction carries out in two-dimensional models with the same equivalent diameter as illustrated in Fig 1. The interruption within the fluid flow is induced by wave-like and trapezoid-like obstacles. It consists of a surface (de), an inlet (ab), an outlet (ef) and a wall (af, bc ad cd) in the model. The lengths of ab, bc, cd, de, ef and af are 0.05 m, 0.05 m, 0.05 m, 0.95 m, 0.1 m and 1 m.



(a) Straight channel

(b) Wave-like channel

(c) Trapezoid-like channel

Fig.1. Three type of CVD reaction channel

2.2. Governing equations and boundary conditions

The governing equations are expressed as follows:

Continuity equation: