Journal of Loss Prevention in the Process Industries 43 (2016) 280–291

Contents lists available at ScienceDirect

Journal of Loss Prevention in the Process Industries

journal homepage: www.elsevier.com/locate/jlp

Study of high-tech process furnace using inherently safer design strategies (III) advanced thin film process and reduction of power consumption

Chih-Cheng Lu [a], Kuo-Chi Chang [a], Chun-Yu Chen [b, *]

[a] Institute of Mechanical and Electrical, Taipei University of Technology, Taipei, 10608, Taiwan, ROC
[b] College of Design, Vanung University, Tao-Yuan City, 32061, Taiwan, ROC

ARTICLE INFO

Article history:
Received 26 October 2014
Received in revised form
16 May 2016
Accepted 29 May 2016
Available online 30 May 2016

Keywords:
Inherently safer design
LPCVD
Thin film deposition
22 nm IC process
Reduction of power consumption
FMEA

ABSTRACT

Semiconductor manufacturing is the economic backbone of Taiwan. Although efforts have been made to improve production capacity and achieve full load production, manufacturers are still unable to effectively control the power consumption situation during the failure of full load production due to special circumstances. Those processes do not conform to the characteristics of inherently safer design, which increases process risks. The objective of this research was to investigate the effects of power consumption reduction on the process furnace, maintaining the same production capacity in the existing 22 nm advanced semiconductor process. In this study, TEOS was used as the raw material for LPCVD process simulation, experimentation, and exploration. The adopted LPCVD reactor was of the commercial batch type; the process experiments simulated the IPD process applied on the 22 nm MOSFET, with a thickness of 5000 Å and process time of 60 min. The simulation results of different batches were compared with the experimental values, and the simulation values were consistent with the experimental values by adjusting the different ka values. The reactor contained processes for 125 wafers and 100 wafers. According to the simulation and experimental results, the thin film deposition results were acceptable. Finally, the heating zone output current was explored specifically for two batches of wafers in the 12″ furnace tube process. In the process of the first batch, as there were only 100 wafers, 18.05 A was reduced by shutting off the 5th heating zone. The machine had a voltage of 220 V and converted power output up to 3971 W, accounting for 26% (15265.8 W) of the entire machine. This significantly reduced power supply of the entire machine and hazard potential, which is consistent with the characteristics of inherently safer design. Moreover, there were fifteen 12″ tube furnace machines in the experimental workshop of this study, and shutting off unnecessary heating zones could reduce 59565 W/H of the power supply and hazard potential. Finally, the 12″ tube film process machine electrical hazards and damage control measures were analyzed by using FMEA method, and confirmed that the research results were in line with the expected attenuation strategy of ISD. This approach has increased the safety level, but also reduced operating costs, which is an important achievement of this study.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Semiconductor manufacturing is the economic backbone of Taiwan. Although efforts have been made to improve production capacity and achieve full load production, manufacturers still cannot effectively control the power consumption situation during the failure of full load production due to special circumstances. This increases the process risks and fails to meet the spirit of inherently safer design. Under the influence of the global financial crisis of 2008, Taiwan's semiconductor manufacturers have significantly reduced production capacity. Consequently, in the processing of numerous batches, while only a part of the pieces can be put into production, all process parameters are enabled. Taking LPCVD for example (as shown in Fig. 1), the 12″ furnace tube machine is the batch process and the number of wafers in each batch process is 150. If the production capacity utilization rate is 70%, then 105 wafers are put into production in each batch; however, the process parameters of the process machine of each batch must be

* Corresponding author.
E-mail address: chency1617@gmail.com (C.-Y. Chen).

http://dx.doi.org/10.1016/j.jlp.2016.05.030
0950-4230/© 2016 Elsevier Ltd. All rights reserved.

List of the acronyms

1. STI shallow trench isolation
2. TEOS, Si $(OC_2H_5)_4$ tetraethyl orthosilicate
3. IPD inter-poly dielectric
4. MOSFET metal-oxide-semiconductor field-effect transistor
5. LPCVD low pressure chemical vapor deposition
6. CD critical dimensions
7. ILD inter layer dielectric
8. PMD pre-metal dielectric
9. IMD isolation metal dielectric
10. T temperature
11. MF mole fraction
12. F flow rate
13. P pressure
14. PR photo resist
15. FMEA failure mode and effects analysis
16. ○ experiment result
17. △ modified result

comprehensively considered, as the enterprises are unable to effectively develop the process parameter control scheme. Regarding thin film deposition, temperature is an important process control parameter. Some studies have estimated the simulation results of the influence on process temperature distribution by shutting off heating zones (Chen et al., 2013a).

For the LPCVD process, the main process parameters include T, MF, F, and P. Among the parameters, temperature has the most affect on the thin film deposition rate, thus, it is the most important process parameter (Chen et al., 2013b); however, most current 12″ LPCVD vertical furnace tube machines are designed with five heating zones, as shown in Fig. 1. In the timing sequence of temperature control, the temperature of the furnace tube heating zone is first improved and transferred to the center of the furnace tube, thereby enabling wafer temperature to rise. When the temperature and heating time reach the set values, the reaction gas would be introduced into the reactor of the furnace tube for reaction, as shown in Fig. 2 (Harbeke et al., 1984). However, for process stability, most manufacturers do not make any changes after the temperature control is set, regardless of the number of wafers put into the process, even when an excessive power supply would result in additional and unnecessary risks. This does not meet the concept of

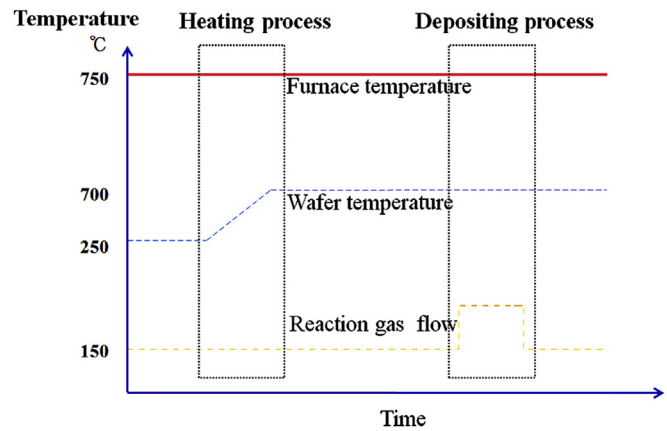
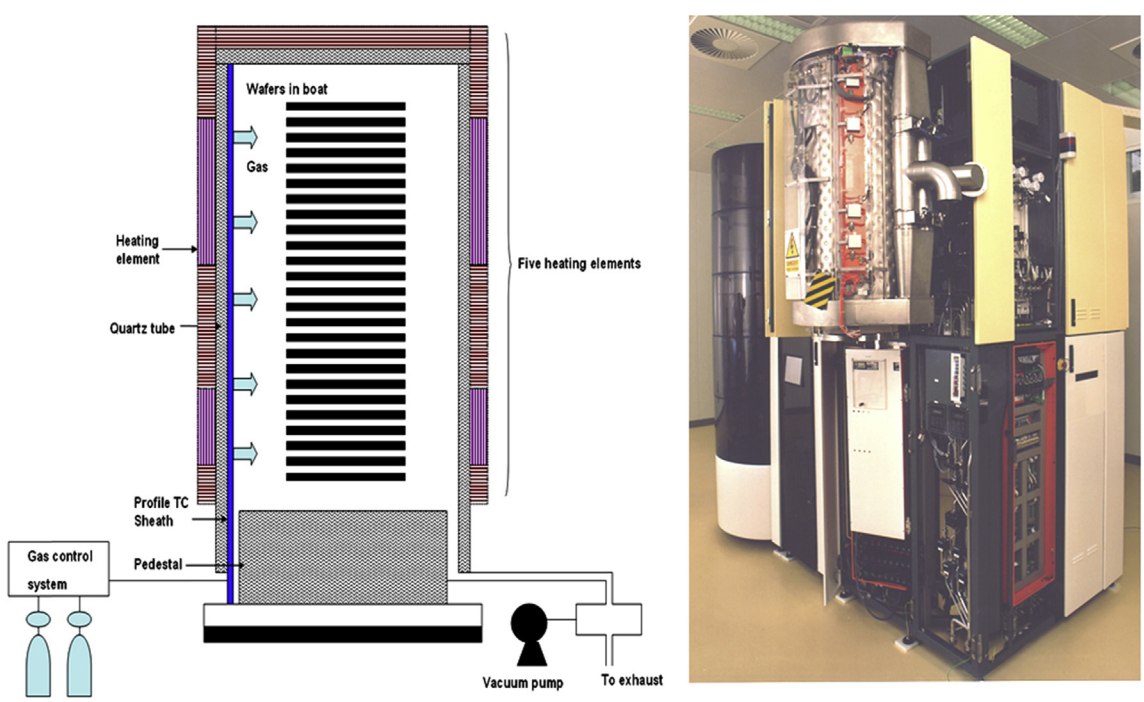


Fig. 2. Timing diagram of heating and depositing process of furnace, wafer, and reaction gas.



(a) Structure of 12 "LPCVD furnace tool (b) Commercialized 12 "LPCVD furnace tool settings

Fig. 1. The High-Tech process machine of 12″ LPCVD furnace.

Download English Version:

https://daneshyari.com/en/article/585933

Download Persian Version:

https://daneshyari.com/article/585933

Daneshyari.com