Proceedings of the World Congress on Engineering and Computer Science 2013 Vol I
WCECS 2013, 23-25 October, 2013, San Francisco, USA

An Enhanced Vacuum Pump System for Optimal Preventive Maintenance in the CVD Process

Insung Ko, Jongrak Park, Seckho Song, Hyunwook Lim

***Abstract*— Low pressure chemical vapor deposition (LPCVD) and plasma enhanced chemical vapor deposition (PECVD) processes are widely used in sub-nanometer technology. However, vacuum pump for CVD process often fails due to the accumulated by-products during deposition, and this is one of the major causes of wafer loss. This paper analyzes the failure mechanism of the vacuum pump in CVD and proposes a solution to improve vacuum pump system by enhancing clamping force of shaft on vacuum pump and by optimizing vacuum line to remove accumulation of powder. By applying the proposed solution, the failure rate per week caused by vacuum pump is greatly reduced by 85%.**

***Index Terms*—Chemical Vapor Deposition (CVD), Preventive Maintenance (PM), Vacuum Pump**

I. Introduction

In recent years, the semiconductor market has been rapidly growing, and chemical vapor deposition (CVD) has been one of the most important semiconductor process technologies. CVD utilizes the reaction of gaseous state compound on the heated surface to produce thin film deposited on the base material [1]. Major CVD process can be classified into three types by operating pressure and plasma methods: plasma enhanced chemical vapor deposition (PECVD), low pressure chemical vapor deposition (LPCVD), and atmospheric pressure chemical vapor deposition (APCVD). Among them, PECVD and LPCVD should be processed in a vacuum chamber which can be created by the vacuum pump.

During the CVD process, powder is generated as by-products in the vacuum chamber and is extracted by vacuum pump [2]. However, some remaining powder is accumulated on the vacuum line and pump, and thus it degrades the performance of the vacuum pump. Consequently, some particles are not extracted and drop on the wafer, which results in wafer loss [3]. Moreover, some powder accumulated on the vacuum pump may cause malfunction of the pump [4].

This paper is to analyze the failure mechanism of the conventional vacuum pump in the CVD system. A new vacuum pump system is also proposed to reduce particle by optimizing the vacuum line. Moreover, the proposed system has immunity to the remaining particles by applying gear fastening and pump shaft.

InSung Ko is with Samsung Electronics co., Ltd, and Samsung Institute of Technology, Yongin-City Gyonggi-Do, Korea (corresponding author to provide e-mail: is77.ko@samsung.com).
Jongrak Park (e-mail: j.park@samsung.com) and Seckho Song (e-mail: seckho.song@samsung.com) is with Samsung Electronics co., Ltd, Yongin-City Gyonggi-Do, Korea.

Hyunwook Lim is with Samsung Electronics co., Ltd, and Samsung Institute of Technology, Yongin-City Gyonggi-Do, Korea (e-mail: hyunwook.lim@samsung.com).

II. Vacuum Pump for CVD Process

A. A Vacuum Pump System for the CVD Process

Fig.1 shows the overall vacuum pump system including a chamber and a vacuum line for the CVD process equipment.

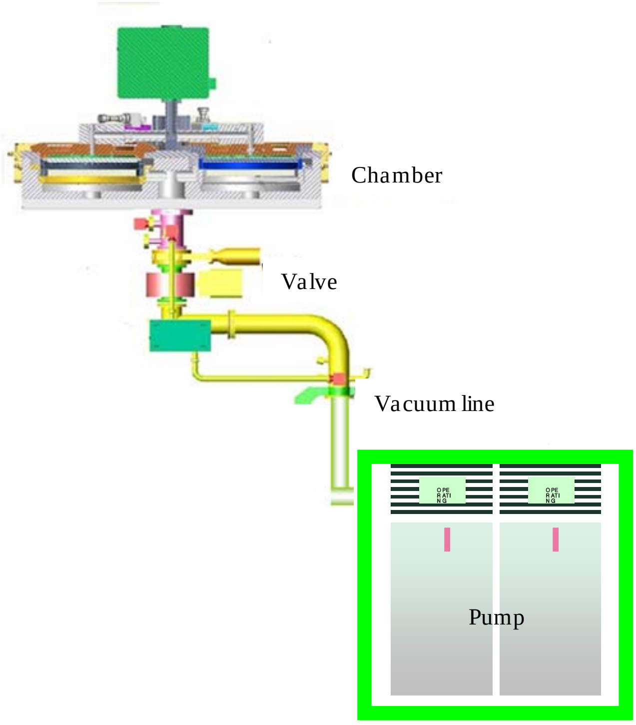

Fig. 1 The block diagram of the vacuum pump system for CVD process

Chemical gas flows inside the chamber and is pumped out through the vacuum pump at the bottom until the ambient pressure and temperature in the chamber satisfies the process conditions. When the pressure and temperature meets the requirement, the RF generator applies signal to produce plasma, and deposition process begins [5].

B. Failure Analysis of the Conventional Vacuum Pump

Fig.2 shows the operating mechanism of the conventional vacuum pump. When the system starts to produce deposition, powder is produced in the chamber. As the vacuum pump continues to work, this powder is then pumped out from chamber through the vacuum line. The powder then flows into the gas inlet of the vacuum pump, and flows out to gas

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

outlet in the ideal case. However, some of the powder remains in the pump and is deposited on the wall of the pump. As a result, the space between the outside wall of the pump and the roots becomes narrower, and thus causes the overload of the shaft and grip elements which operate the roots.

Eventually, this invokes gear timing problem and slip problem which cause the shaft to be twisted, and therefore the vacuum pump stops to work. As a result, backstream occurs and thus it leads to the serious particle defects on the wafer surface and yield loss in the following process.

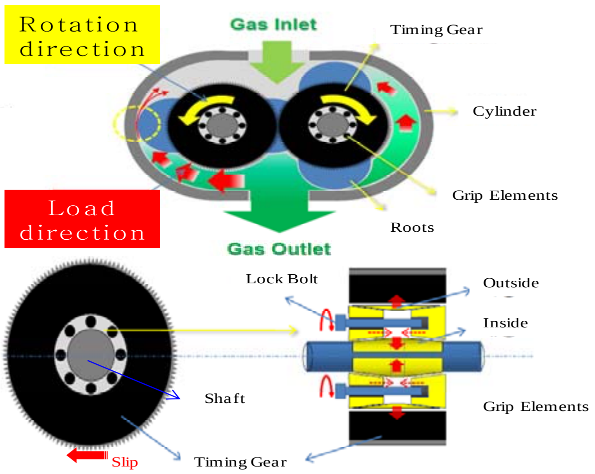

Fig. 2. A conventional clamping method for the vacuum pump.

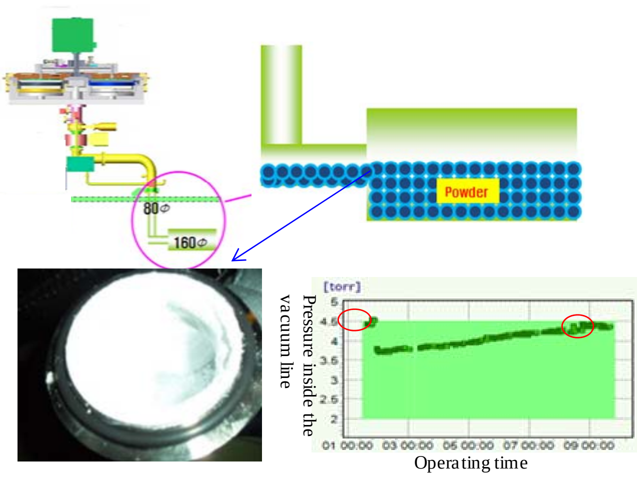

Fig.3 The effect of powder accumulation on pressure of vacuum line

C. Effects of the Vacuum Line on the Accumulation

Fig. 3 shows that the vacuum line is seriously affected by the accumulated SiO_2 powder. As a result, the pressure inside the vacuum line increased gradually when the operating time passed and the accumulation also grew worse as shown in Fig. 3. Therefore, the efficiency of the vacuum pump was severely deteriorated by the blocked vacuum line.

III. New Methods

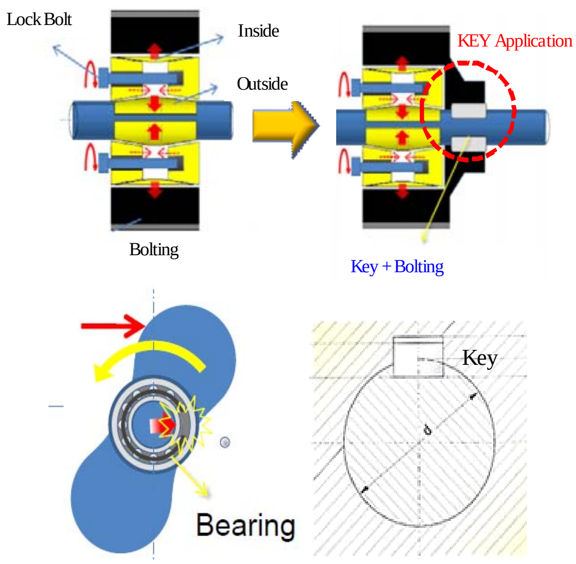

Fig. 4. The proposed clamping method for the vacuum pump.

A. The Proposed Vacuum Pump

Fig. 4 shows the proposed clamping method of timing gear and the shaft. The conventional clamping method is based on the fundamental of inflation of the grip element after the insertion of the shaft of timing gear, and the clamping force is 24N·m. However, this force cannot guarantee the perfect grip, and a slip may occur with the increasing accumulation of powder and overload of roots in the pump. Although the shaft can be easily removed for preventive maintenance in this method, more frequent interrupt for maintenance is the major disadvantage for productivity. Therefore, the clamping force must be enhanced to improve productivity. In this paper, a new method is proposed to increase the clamping force by adding a key and a bolt on the shaft of vacuum pump. The proposed dual square key can move freely in the furrow on the shaft, and therefore the shaft and timing gear are strongly combined. As a result, the clamping force is greatly increased from 24N·m to 60N·m after applying the proposed vacuum pump,

B. The Improvement of the Vacuum Line

In Fig. 3, it is analyzed that the accumulation of powder is caused by the small diameter of the vacuum line. Therefore, the vacuum line must be improved to reduce accumulation of powder. In this paper, large-diameter vacuum line is proposed. The 160 Ø of vacuum line replaced the previous 80 Ø of vacuum line.

Fig.5 shows that the pressure inside the vacuum line is greatly reduced and the accumulated SiO_2 powder is greatly removed after improvement.

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

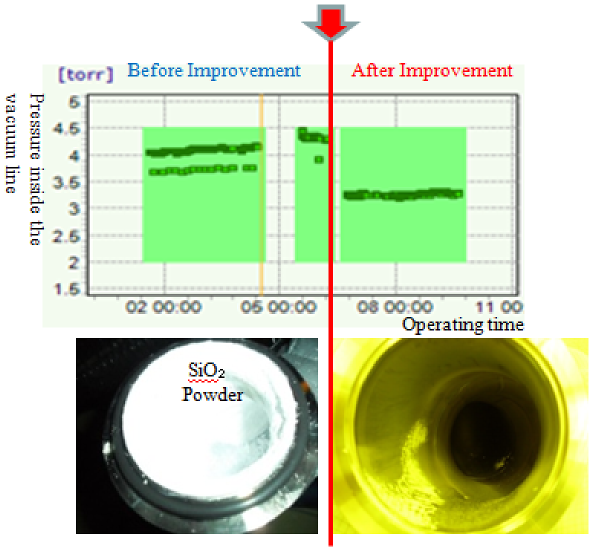

Fig. 5. The comparison of the pressure inside the vacuum line before and after improvement of vacuum line

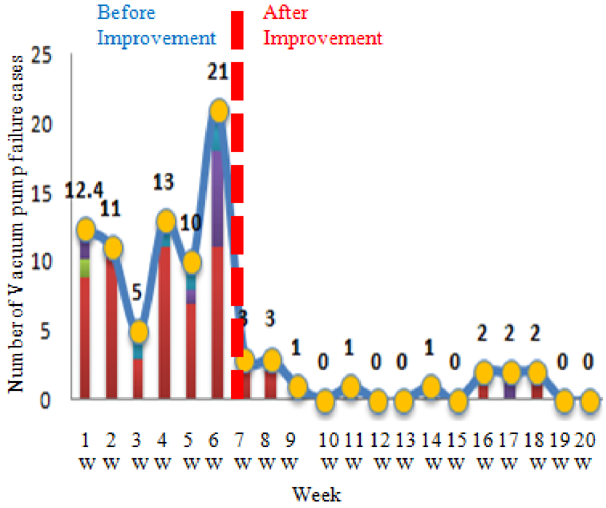

Fig. 6. Comparison of the number of failures due to the vacuum pump before and after improvement.

C. *Improvement of Vacuum Pump Failure*

Fig. 6 shows the comparison of the number of vacuum pump failures before and after applying the overall proposed methods. The maximum number of failures per week due to vacuum pump was 21cases before improvement. When the proposed methods were applied after 27 week, the number of failure cases was greatly decreased to from 21 to 3 cases, and about 85% of improvement was achieved. Therefore, it is proven that the proposed methods are very effective to reduce vacuum pump failure and to improve productivity.

IV. Conclusion

In this paper, the vacuum pump failure in the CVD process was analyzed, and the root cause was explained. The weak clamping force and small diameter of the vacuum line were the root causes of powder accumulation and the result of vacuum pump failure. A new vacuum pump was proposed to enhance clamping force, and the diameter of vacuum line was increased. As a result, accumulation of powder was greatly reduced and the number of failure due to the vacuum pump is dramatically decreased after improvement.

References

[1] Zhang Minglong, Xia Yiben, Wang Linjun, Shen Hujiang, Gu Beibei "Performance of CVD diamond alpha particle detectors" *Solid State Communications, Volume 130, Issue 8, May 2004, Pages 551-555*

[2] T. Kim et. Al., Particle formation during low-pressure. Chemical vapor deposition from silane and oxtgen; Measurement and film properties, J . Aerosol Sci. 34, 2003, 691.

[3] Zeyu Li, Liansheng Li, Yuanyang Zhao, Gaoxuan Bu, Pengcheng Shu "Theoretical and experimental study of dry scroll vacuum pump" *Vacuum, Volume 84, Issue 3, 5 November 2009, Pages 415-421*.

[4] H. Wook. Kim and H.S Yoo, "Alternatives for B/W Process Pump Fail Reduction" Samsung Electronics Semiconductor Thesis TGN-20110819043 November , 2011

[5] Shao. Wen. Hu, et.al J. Phys. Chem. A107,1635(2003) Letters 26, 1857-1865, 2005.

ISBN: 978-988-19252-3-7
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)