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Excimer laser gas usage reduction technology for semiconductor manufacturing

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ABSTRACT

ArF and KrF excimer lasers are widely used as a light source for the lithography process of semiconductor manufacturing. The excimer lasers consume laser gas mixture in a discharge chamber as laser media, and more than 96% of the gas mixture is Neon. Recently Neon supply and demand balance became critical situation; the price has risen two years ago due to the instability of politics and economy in Ukraine. Although Neon price decreased now, its price is still higher than two years ago. Gigaphoton has released gas consumption reduction, called Total Gas Management (TGM) series, as part of the green activities. Conventional gas consumption reduction (eTGM) achieved 50% gas consumption reductions from the former gas control (sTGM) by optimizing the laser gas control.

In order to reduce gas consumption further, Gigaphoton has been developing new gas recycle system hTGM. hTGM purifies used gas so that laser can use it repeatedly. Field evaluation of KrF-hTGM system has been started. The system was connected to five KrF laser systems and achieved 85% of the gas recycling ratio, keeping stable laser performance. Also, internal evaluation of ArF-hTGM system has been started. The system was connected to one ArF laser and achieved 92% of the gas recycling ratio, keeping stable laser performance.

Keywords: Lithography, Green, Rare gas, Neon, Excimer laser, hTGM

1. INTRODUCTION

Gigaphoton is carrying out mainly two activities as green innovation of our excimer laser for semiconductor lithography tool. One is gas consumption reduction for decrease of Neon and Helium supply and increase gas price due to supply shortage. The other is electricity usage reduction for environmentally-friendly green factories. In this paper, latest development status of gas reduction is reported.

One major component of an excimer laser system is Neon that is used as a buffer gas. Since Neon gas is accounting for more than 96% of the laser gas mixture, a fairly large amount of Neon gas is consumed to run DUV excimer lasers. The price of Neon was stable until 2014. However, due to country's instability both in politics and economics in Ukraine, the main producer of Neon gas today, supply reduction has become an issue. This concern is not only based on price increases, but has escalated to the point of supply shortages in 2015. This situation is serious for the semiconductor industry, which represents the leading consumer of Neon gas in the world. Gigaphoton already developed Neon usage reduction technology called eTGM and realized 50% reduction from the past [1][2]. As next generation technology, gas recycling system called hTGM has been developing.

2. GAS RECYCLING SYSTEM

To combat recent global supply issue of rare gas resources, especially Neon gas, Gigaphoton extends its expertise in green technologies through its EcoPhoton program designed to significantly reduce the earth resource consumption. The eTGM system applied to all types of lasers reduces Neon gas consumption into half amount compared to conventional TGM system. Since the excimer laser energy is sensitive to impurities [3], the impurity concentration control is important and impurity concentration control is performed by continuous gas evacuation and fresh gas injection. But, the rare gases such as Argon, Krypton, and Neon are continuously released into air. Next

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generation hTGM system enables recycling of used laser gas without affecting laser performance. Fig.1 shows concept of hTGM. Impurities generated by discharge in the excimer laser chamber exhausted to the gas recycle system. In the system, exhausted gas contained impurities are purified and return to laser.

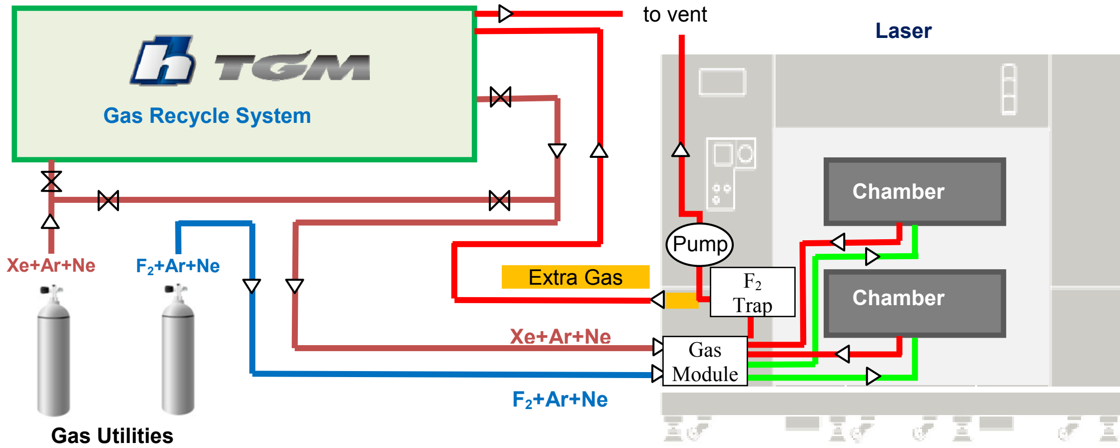

Fig.1 hTGM concept

2.1 Prototype hTGM system overview

Fig.2 shows the hTGM system platform. Used laser gas is exhausted and delivered to tank A. After the tank A is filled with enough amount of used gas, it will be transferred to tank B through filters which remove impurities. When a sufficient amount of recycled gas is filled in the tank B, recycled gas is supplied to the laser through the mass flow meter A (MFM A). If the gas is insufficient in the tank B, Cylinder gas is supplied to the laser through the MFM B. All necessary data such as gas pressure, temperature and gas amount are monitored and stored to calculate gas recycle ratio.

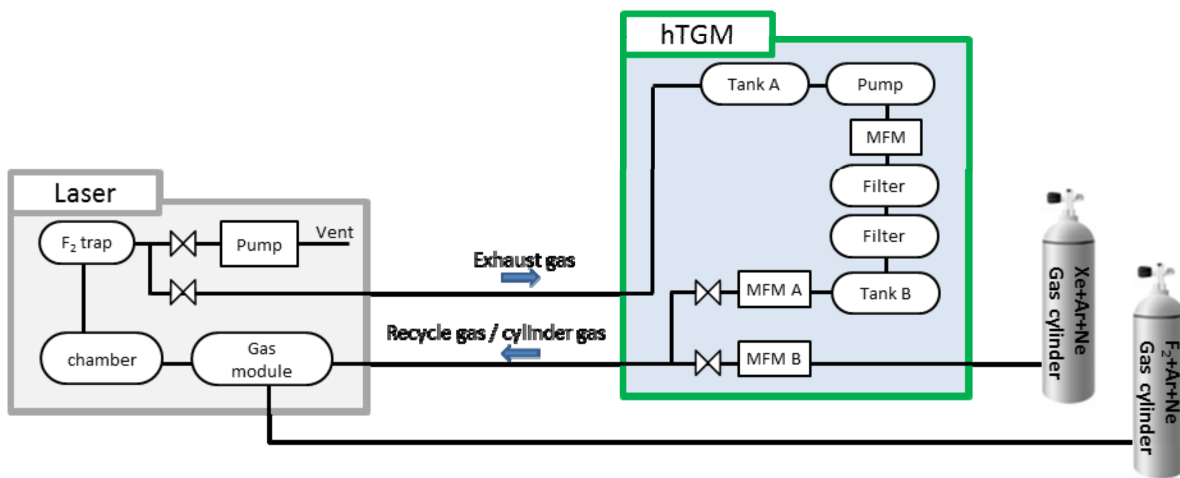

Fig.2 hTGM system over view

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2.2 Laser performance with KrF hTGM system

KrF laser performance using recycled gas supplied from hTGM system (Fig.3) has been confirmed. Based on gas capacity of hTGM system, the laser has started to use recycled gas after vertical green dot line. Fig.4 shows pulse count and laser key performance data of energy stability and wavelength error. Each laser performance shows no significant difference before and after using recycled gas.

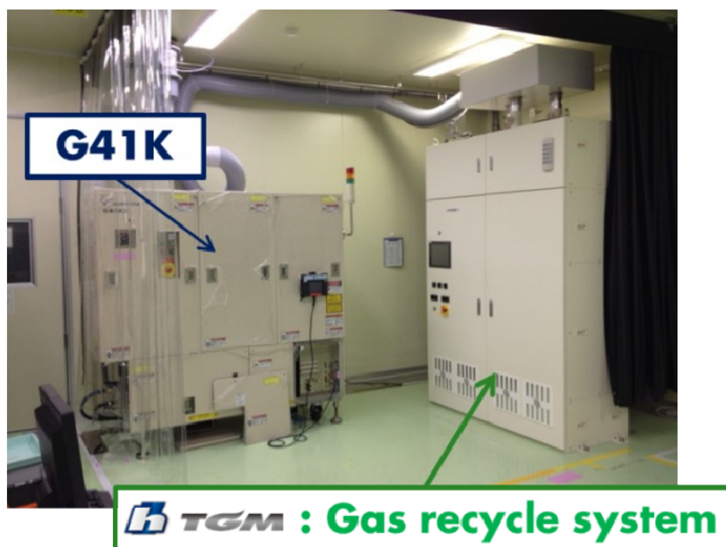

Fig.3 hTGM system

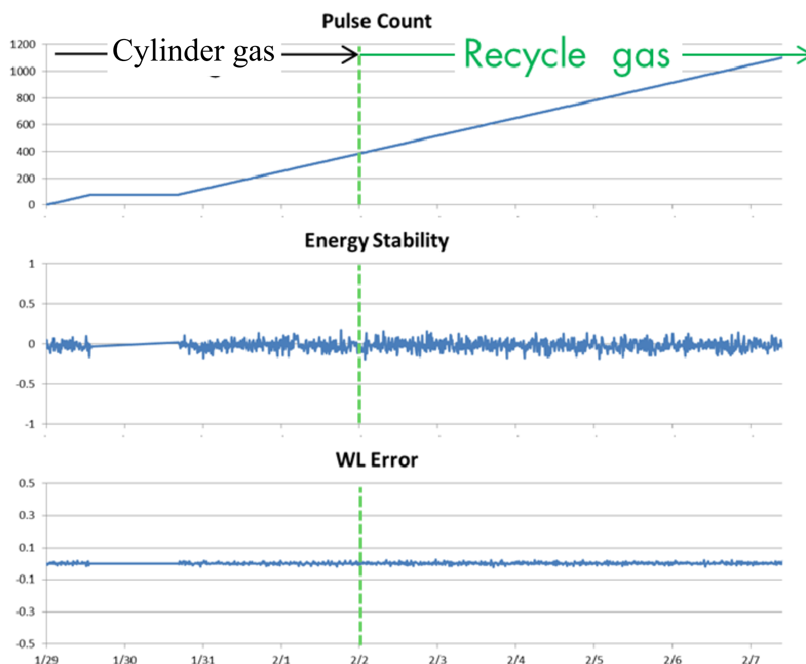

Fig.4 Laser performance using recycled gas

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Fig.5, 6, 7 and 8 show the recycle rate and the laser performance monitored for six months. One KrF-hTGM system was connected to five lasers and evaluated laser performance for six months. Fig.5 shows the usage of accumulated recycled gas, accumulated cylinder gas and the gas recycling rate. KrF-hTGM achieved 85% of the gas recycling ratio. Fig.6, 7 and 8 show laser key performance data, energy dose sigma (%), bandwidth (pm) and wavelength error (pm). Laser performance shows no significant difference before and after using recycled gas.

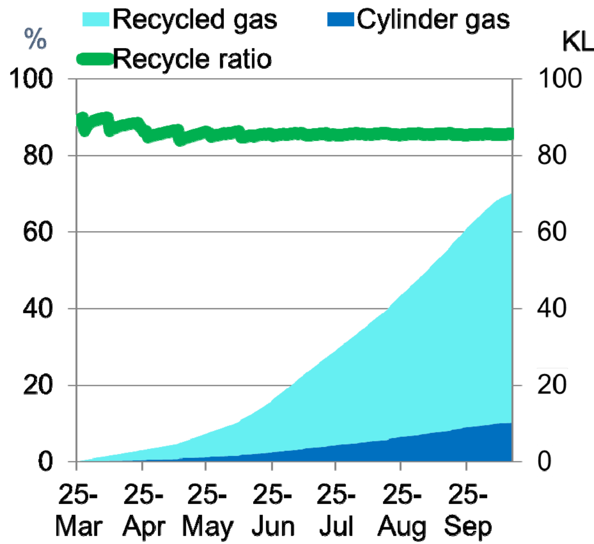

Fig.5 KrF-hTGM gas recycle ratio

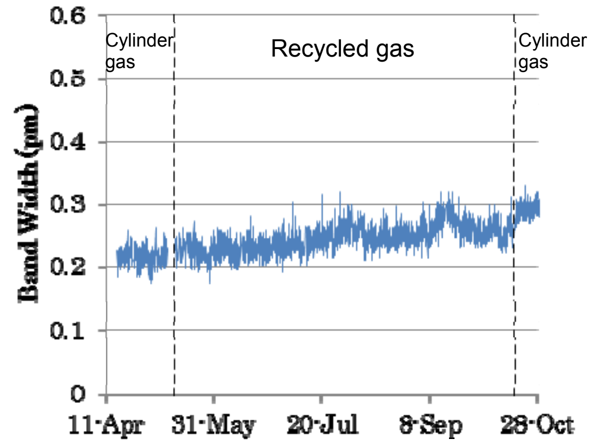

Fig.7 Bandwidth [pm]

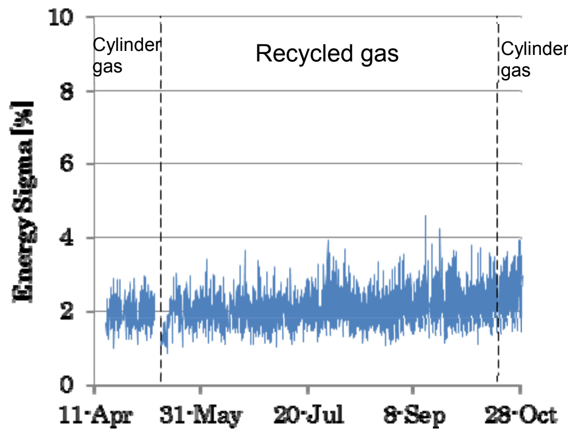

Fig.6 Energy dose sigma [%]

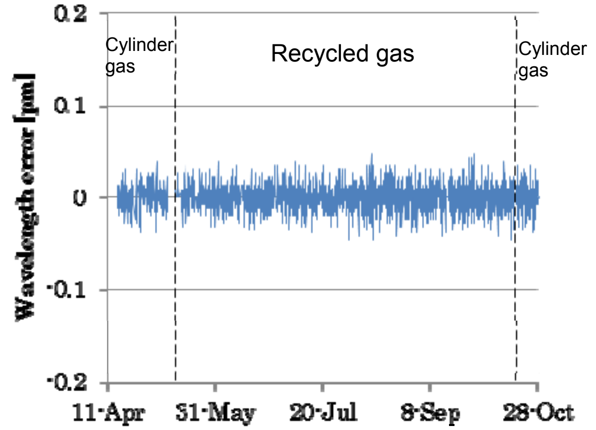

Fig.8 Wavelength error [pm]

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2.3 Laser performance with ArF hTGM system

Laser performance using recycled gas supplied from prototype ArF-hTGM system has been confirmed. One prototype ArF-hTGM system was connected to one laser and evaluated laser performance for two weeks. Fig.9 shows the usage of accumulated recycled gas, accumulated cylinder gas and the gas recycling rate. ArF-hTGM achieved 92% of the gas recycling ratio. Fig.10, 11 and 12 show laser key performance data, energy dose sigma (%), bandwidth (pm), and wavelength error (pm). Laser performance shows no significant difference before and after using recycled gas.

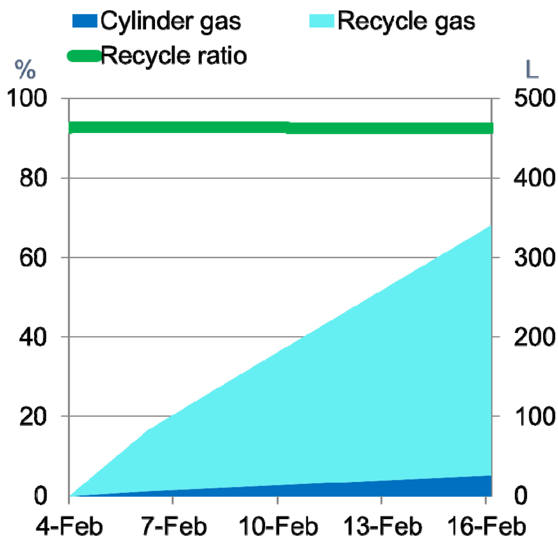

Fig.9 ArF-hTGM gas recycle ratio

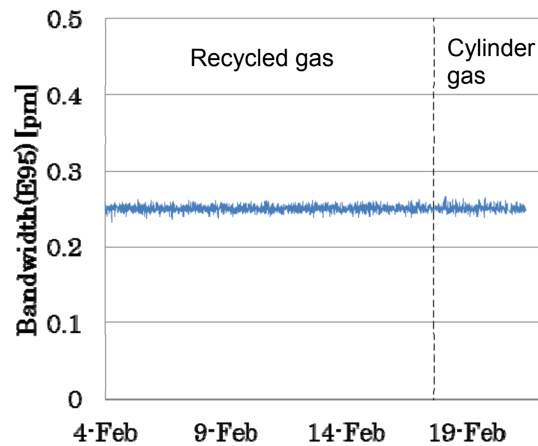

Fig.11 Bandwidth (E95) [pm]

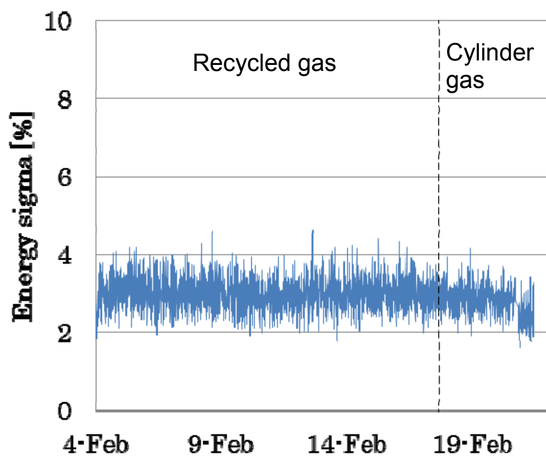

Fig.10 Energy dose sigma [%]

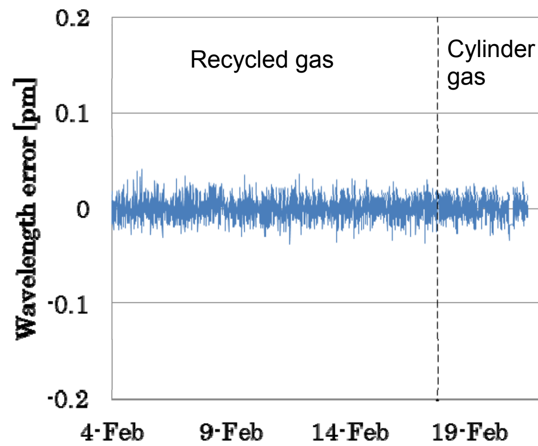

Fig.12 Wavelength error [pm]

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3. SUMMARY

Gigaphoton has been developing green technologies through the EcoPhoton™ program to support the sustainability of HVM environments. The hTGM system has been developed and confirmed long term performance. The hTGM system enables recycling of used laser gas and keeps the same performance level. KrF-hTGM achieved 85% of the gas recycling ratio and ArF-hTGM achieved 92% of the gas recycling ratio.

Gigaphoton's EcoPhoton™ program will continue to deliver innovative green technologies that help to sustain stable and efficient semiconductor manufacturing environment.

4. REFERENCES

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