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Extremely long life excimer laser technology for multi-patterning lithography

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ABSTRACT

Multi-patterning techniques with ArF immersion lithography is expected to continue as main solution for manufacturing IC chips. The reduction of laser downtime has great impact on the productivity of chipmakers. The laser downtime is closely related to the lifetime of consumable parts of the laser. Gigaphoton developed new laser modules, chamber and LNM (Line Narrowing Module) which have longer lifetime than current one. New chamber demonstrated 1.2 times longer lifetime than current chamber. New LNM demonstrated 1.8 times longer lifetime than current LNM. These new modules will help to reduce the downtime of the laser.

Keywords: DUV light source, ArF laser, Photo Lithography, long life modules

1. INTRODUCTION

ArF excimer lasers are widely used as light sources for the lithography process of semiconductor production and are expected to continue as the main solution for photolithography. The downtime of the laser is a key parameter which has a major impact on manufacturing IC chips. The main part of the laser downtime is periodic replacement time of the consumable modules. For the stable laser operation, consumable modules must be replaced periodically. Especially, replacement time of chamber and LNM occupy the large part of the laser downtime. Chamber and LNM must be replaced frequently because these two modules have relatively short lifetime. Therefore, lifetime extension of chamber and LNM are very important for the reduction of the laser downtime. In this proceeding, we report the development of new technologies to increase the lifetime of chamber and LNM.

2. CHAMBER LIFETIME EXTENSION

A schematic chamber structure is shown in Figure 1. The laser chamber is filled up with Argon, Fluorine and Neon buffer gases. One pair of electrodes, cathode and anode, is elongated in the chamber. High voltage is applied to the electrodes and electric discharge occurred. ArF excimer laser is generated by this discharge excitation. For efficient and stable discharge, laser gases between the electrodes must be ionized by corona preionizer. Laser gases are circulated by cross flow fan to blow off the discharge product made by the previous discharge. A heat exchanger exists to remove the heat generated by discharges and fan rotation.

Gigaphoton uses the Injection Lock system for twin chamber laser (Figure 2). Low energy but very spectrally narrow bandwidth seed light is generated by Oscillator chamber. Seed light is guided into

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amplifier chamber and amplified to high energy. Laser oscillation efficiency is low in oscillator side due to the large cavity loss by wavelength selection of LNM. On the other hand, the efficiency is high in amplifier side because the seed light is amplified several times due to the existence of cavity mirrors. Using these characteristics, the chamber lifetime can be extended. When output energy of the oscillator chamber decreased below the lower limit, the chamber is transferred to the amplifier side. We named this chamber operating system as GRYCOS (Gigaphoton Recycled Chamber Operation System) [1].

To develop the long lifetime laser chambers, electrode degradation must be suppressed. Laser performance becomes worse by electrodes degradation caused by large number of electric discharges. Degree of the degradation is in proportion to the laser shot number. As electrode degradation proceeds, electric discharges between two electrodes tend to be unstable. Then, laser output energy decreases and laser energy stability becomes worse. Finally, the chamber reaches its end of lifetime.

Gigaphoton developed new electrode for the longer lifetime chambers. We already introduced the specific technology, namely “G-electrode”, which is a metal electrode with specially treated surfaces, make discharge very stable and suppress the electrode degradation [2, 3]. We developed the new electrode which has improved durability compared to the conventional G-electrode. Using the new electrode, stable discharges are realized for longer period. Durability test was done for the “new type G-electrode” chamber. The test chamber was operated 33 Bpls on oscillator side and 40 Bpls on amplifier side. In GRYCOS operation, the lifetime of the chamber is mainly determined by energy stability deterioration when used on the amplifier side. Figure 4 shows the durability test result of new chamber. Vertical axis is figure of merit (FOM) of the chamber which relate to the stability of output energy. When FOM exceeds 1, the chamber reaches its end of lifetime. The lifetime of the test chamber was estimated to be around 70Bpls. From this result, we infer the lifetime of the new chamber is 70 Bpls in GRYCOS operation.

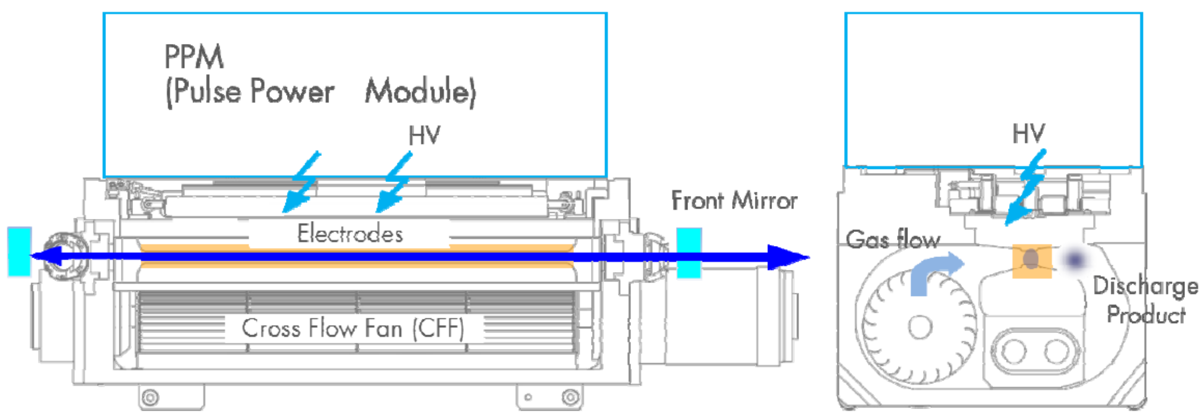

Figure 1. Schematic structure of the chamber

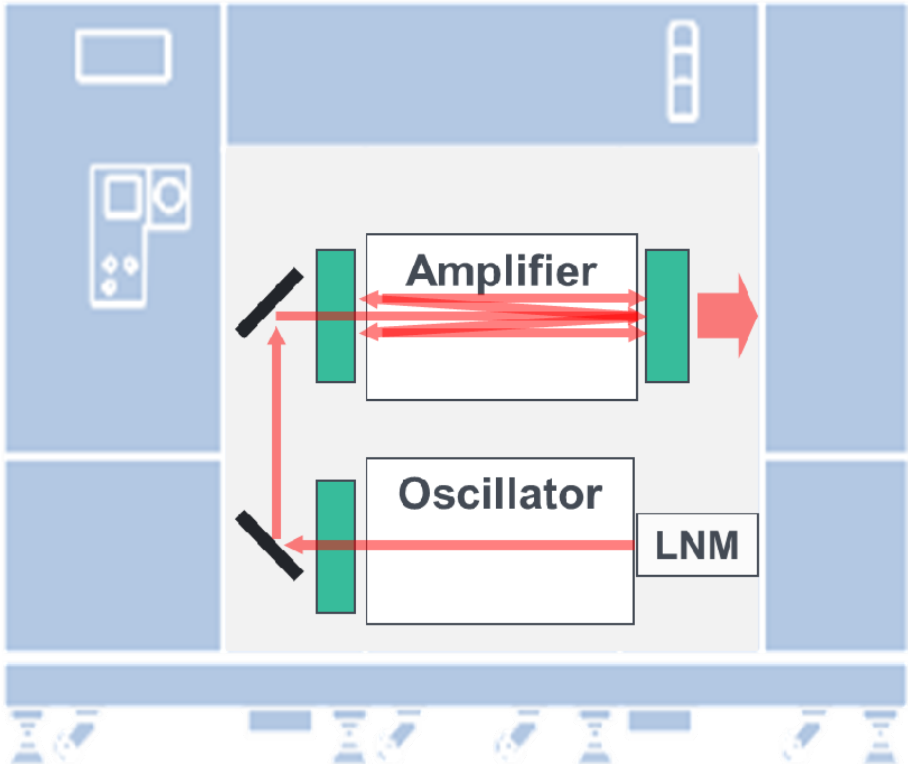

Figure 2. Schematic structure of injection locked laser system

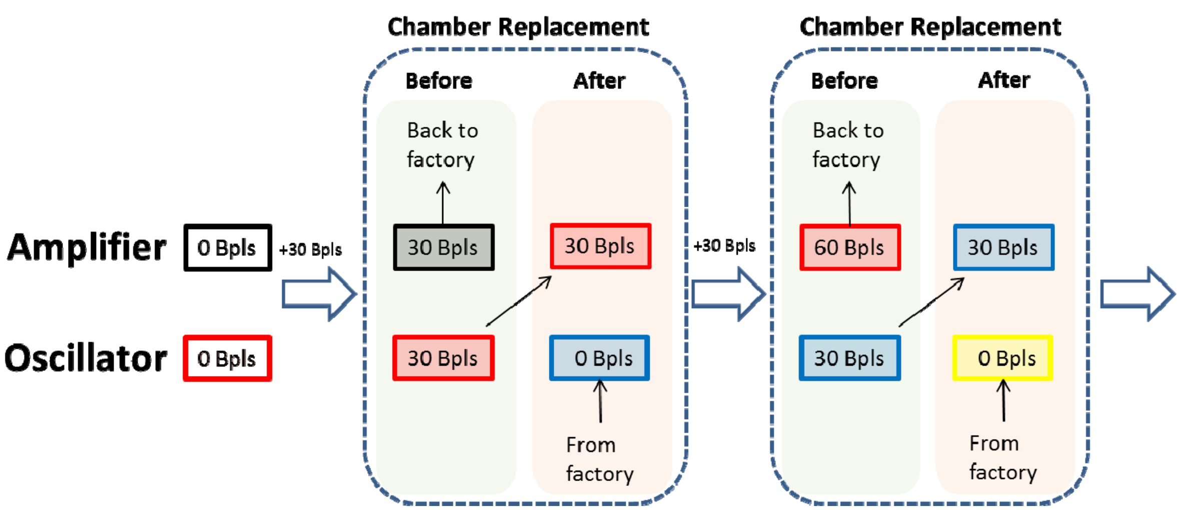

Figure 3. Diagram of chamber replacement by GRYCOS operation
(Lifetime 60 Bpls for example)

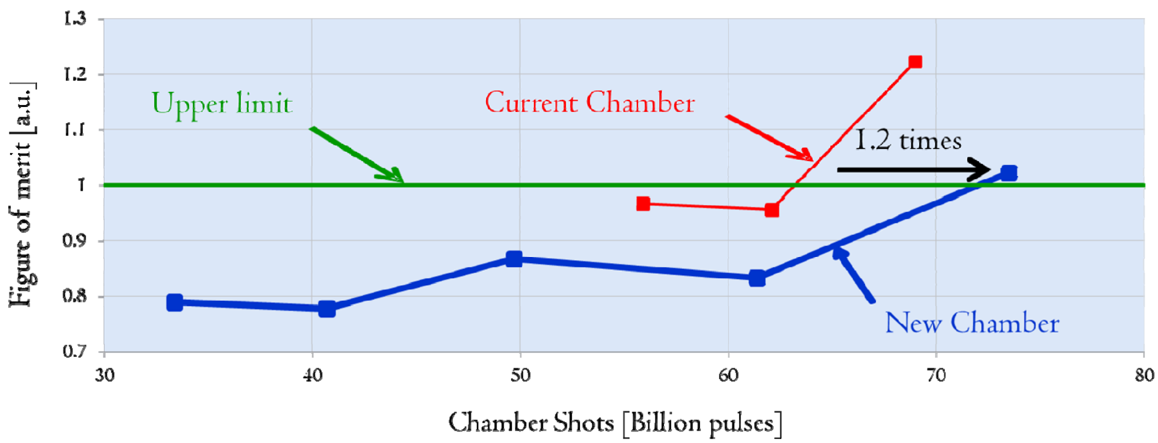

Figure 4. Durability test result of the new chamber

3. LNM LIFETIME EXTENSION

Figure 5 shows the schematic structure of LNM [4]. The functions of LNM are wavelength selection and bandwidth narrowing of the output laser light. LNM consists of optics such as a grating and prisms. The light beam generated by discharge chamber is expanded by prisms and irradiate to the grating. Specific wavelength light is reflected back into the chamber. In this way, only specific wavelength is amplified and then narrow bandwidth laser light is generated.

Gigaphoton developed new LNM which has 80% longer lifetime than that of current LNM. As laser shot number increased, diffraction efficiency of the grating decreased by degradation caused by high energy laser irradiation on the grating. Seed light energy decreases with decreasing the diffraction efficiency. LNM reaches its end of lifetime when seed light energy exceeds the lower limit of the acceptable range. To extend the lifetime of LNM, we reconsidered the optical configuration of the LNM. By implementing this new technology, degradation of the grating diffraction efficiency is suppressed. Figure 6 shows the durability test result of new LNM. The diffraction efficiency of new LNM decreases more slowly than current LNM. The lifetime of new LNM is confirmed to be 1.8 times longer than that of current one.

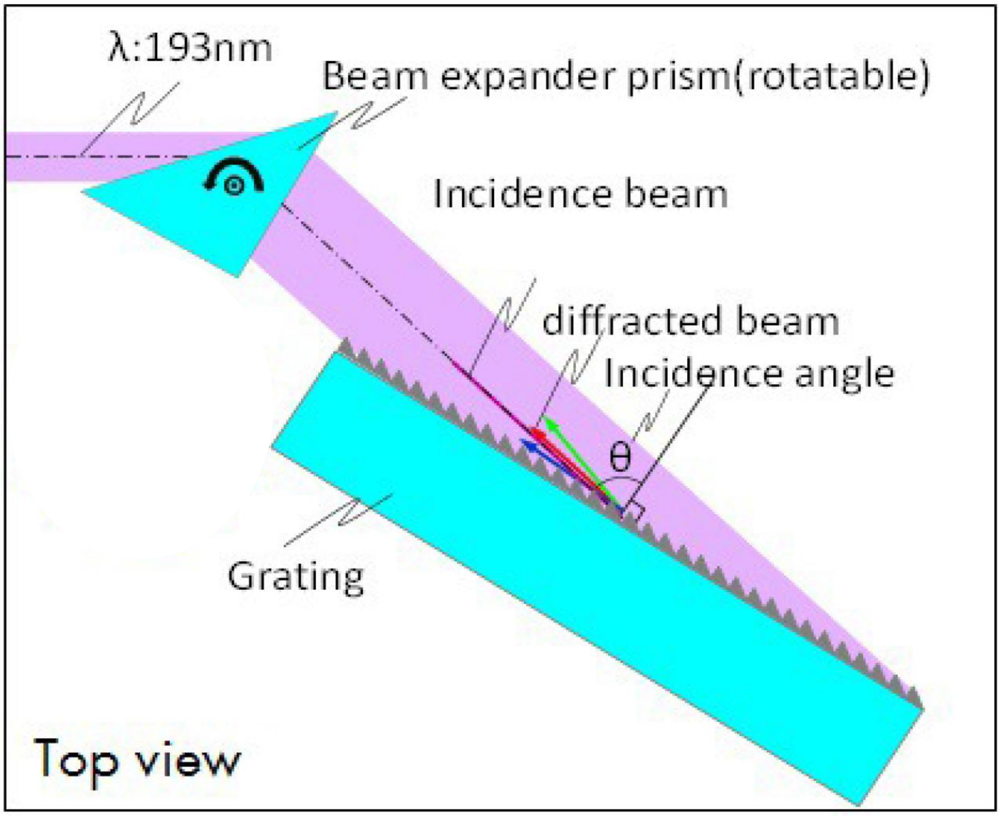

Figure 5. Schematic structure of LNM

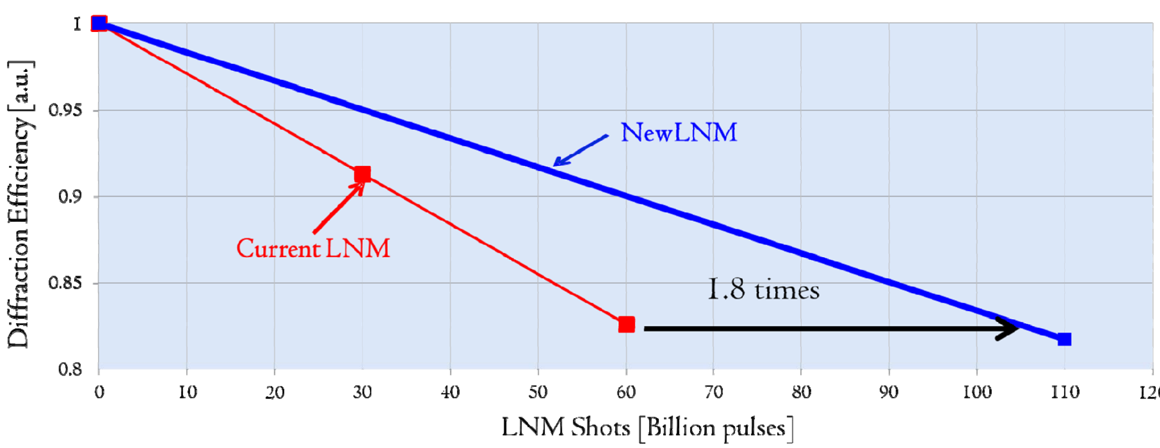

Figure 6. Durability test result of new LNM

4. SUMMARY

Gigaphoton developed the new chamber and new LNM those which have longer lifetime than before. The lifetime of new chamber is increased by 1.2 times longer than that of current chamber. The lifetime of new LNM is increased by 1.8 times longer than that of current LNM. These two modules will help to reduce the downtime of the laser and increase the productivity of chipmakers. Gigaphoton will continue to develop longer lifetime modules to reduce the laser downtime.

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