High Repetition Rate Ultra-Narrow Bandwidth 193 nm Excimer Lasers for DUV Lithography

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ABSTRACT

Results on the feasibility of highest repetition rate ArF lithography excimer lasers with narrow spectral bandwidth of less than 0.4 pm are presented. The current 193 nm lithography laser product NovaLine A2010 delivers output power of 10 W at 2 kHz repetition rate with energy dose stability of ± 0.5 %. A novel 193 nm absolute wavelength calibration technique has been incorporated in the laser which gives absolute wavelength accuracy better than 0.5 pm. Long-term test results of optical materials, coatings and laser components give insight into estimated cost of ownership developments for the laser operation over the next years. Progress in pulse stretching approaches to achieve lower stress of the wafer scanner illumination optics and lens allow optimistic estimates of total system CoO. Initial results on the laser operation at 4 kHz in order to reach 20 W output power are discussed.

Keywords: excimer laser, microlithography, 193 nm

1. INTRODUCTION

The feasibility of ArF excimer lasers with ultra-narrow bandwidth at high output power is one of the important prerequisites for the economic implementation of 193 nm lithography in production. Cost of ownership comparable to current 248 nm lithography wafer scanner is required. First ArF excimer lasers have been installed for the process development of 193 nm lithography since 1999. These units are utilizing lens systems with numerical aperture (NA) of about 0.7. Refractive lens systems are employing CaF₂ as a second material in the fused silica lens system in order to achieve some degree of achromatization. The laser bandwidth for these generation of 193 nm tools is about 0.6 pm, FWHM 1.2. For this generation of ArF scanners the 1 kHz laser with 5 W average power is employed.

The second generation of ArF scanners is aiming at improved throughput. For this application we have developed the NovaLine A2010 line narrowed 193nm excimer laser which operates at 2 kHz repetition rate with 10 W output power and a bandwidth of less than 0.5 pm FWHM. For the production tools used for 193 nm lithography an output power of 20 W is targeted in order to maximize the throughput of the scanner. The throughput of the system together with the lifetime of the components in the beam delivery and the excimer laser determine the overall operating cost. These costs must get reduced in order to support the introduction of the 193 nm technology in the semiconductor fab. Also for the 193 nm the trend is towards higher NA; depending on the lens design and the amount of CaF₂ used in the lens system, the bandwidth requirement may get as small as 0.25 pm FWHM 3. The development roadmap for the excimer laser light source is determined by this rapid progress in scanner technology.

2. PERFORMANCE CHARACTERISTICS AT 2 KHZ

The main target of our development has been the stable laser operation at 2 kHz with improved spectral performance and an overall increase of the laser efficiency. The gas flow system and the electrode configuration of the laser tube have been redesigned and a new solid state switch has been adapted to the laser. As a result the efficiency of the laser for the line narrowed operation could get significantly improved. The high efficiency of the laser has a direct impact on the durability of the laser modules, less input energy is used to reach the output pulse. Another improvement of the laser efficiency is caused by the laser resonator optics. The resonator design of the 2 kHz laser has lower losses compared to the resonator of the 1