The Generation of EUV Light with a Compact ECR Plasma Source

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Extreme ultraviolet (EUV) lithography is considered to be the most favored technique for manufacturing integrated circuits at 65 nm node and beyond. Producing high power of **13.5 nm EUV light** is needed in order to meet the throughput requirement for mass production. In particular, Xenon ions with charge state of ten are found to be responsible for the production of the 13.5 nm line in electromagnetic spectrum. To obtain reasonable concentration of **Xe^{10+}** ions in the plasma, an **Electron Cyclotron Resonance (ECR)** based plasma generator has been developed in the Plasma and Ion Source Technology Group at Lawrence Berkeley National Laboratory (LBNL) for EUV generation. The photon flux from the plasma-source can be measured with open microchannel plate detectors or photo diodes, with scintillator converters. The concept of using **ECR plasma source to produce EUV** light will be introduced in this presentation as well as the methods of measuring the EUV light.

Plasma Source Concept

The plasma source concept is based on ECR ion source. In the ECR ion source the electrons are gaining energy from the rf-electromagnetic field which frequency is in resonance with the internal magnetic field of the plasma source. In Figure1. the basic operational principle of the ECR ion source is described.

Xe^{10+} excitation is well known to produce 13.5 nm line is the electromagnetic spectrum. This charge state is easily produced using an ECR ion source. In Figure 2 is an example of Xenon spaectrum measured from a conventional ECR ion source is shown.

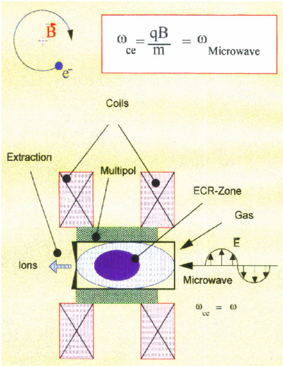

Figure 1. The principle of the ECR ion source.

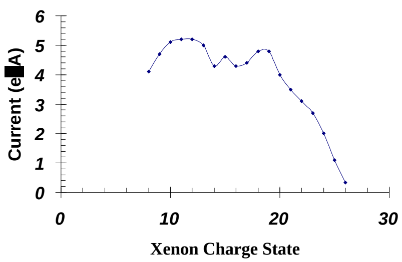

Figure 2. LBNL 6.4 Ghz ECR ion soruce Xe spectra

The proposed plasma generator would use simple permanent magnet dipole magnetic field and 6.4 GHz microwave frequency. The first experimental plasma source would have extraction opening so that the ion species can be analyzed. It will also have a port for the actual light wavelength measurement. The microwave plasma source is shown in Figure 3.

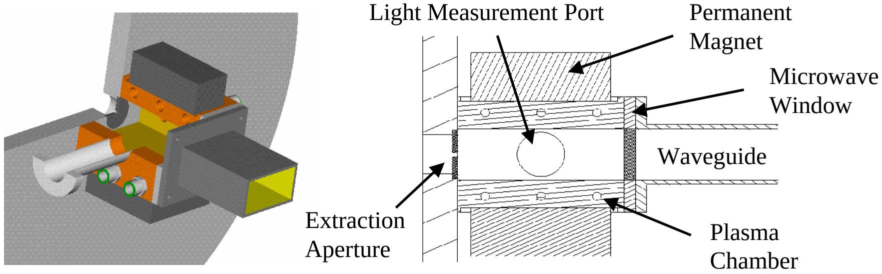

Figure 3. The proposed plasma generator for 13.5 nm light

EUV Measurement Concept

Light is emitted from radiative recombination processes in the ECR plasma. Recombination results in production of excited states of the Xe ions. Light emission from the ions is isotropic, but the plasma density distribution in the ECR might produce global light emission structure.

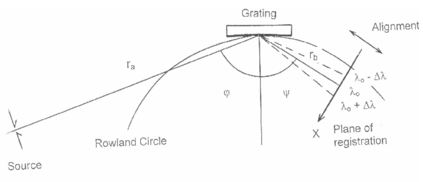

Figure 4. Diffraction of light.

Wavelength of emitted light can be selected with a grading spectrometer. GS can be fabricated so that light in the desired wavelength regime can be diffracted. The diffraction condition is (See Figure 4.):

$$d\,(\sin\varphi - \sin\psi) = n\lambda$$

The achievable dispersion is given by:

$$D = \Delta\lambda / \Delta x = \Delta\lambda / r_b \Delta\psi = d \cos\psi / r_b$$

Once a spectrum has been recorded and 13.5 nm emission has been identified, and optimized, the grading can be replaced with a Mo-Si mirror with high efficiency of 13.5 nm reflection. One can now place a piece of EUV resist in front of the detector, with a little mask pattern on the resist. Exposure of this resist with EUV for series of time intervals, followed by resist development allows a fairly accurate determination of the effective flux at 13.5 nm into this piece of solid angle.