Permanent Magnet ECR Source for generation of EUV light*

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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 using **6.4 GHz** microwave frequency has been developed by the Plasma and Ion Source Technology Group at Lawrence Berkeley National Laboratory (LBNL). In this presentation, the **initial results** of the experiment are shown and **proposed improvements** for the plasma source and EUV measurement setup are presented.

Compact, permanent Magnet Microwave Plasma Source

To obtain reasonable intensities of Xe^{+10} ions, **C-band** (5.9 – 6.4 GHz) microwaves are used. **The ECR plasma heating** at 6.4 GHz requires ~2200 Gauss magnetic field in the source to couple the microwaves efficiently to the plasma. The magnetic field is produced using permanent magnets. By carefully designing the permanent magnet geometry, a uniform, large volume resonant magnetic field can be obtained. **Movable magnet yoke** provides a way to fine tune the B-field.

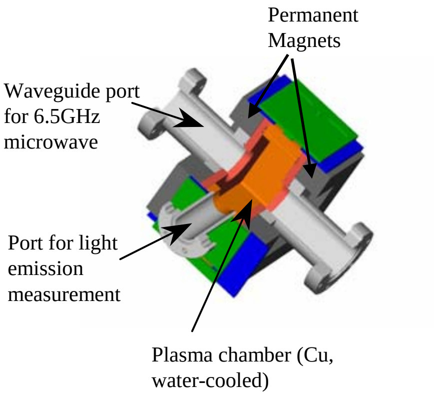

Figure 1. Compact Microwave Plasma Generator with its components

Figure 2. Opera3D simulation of the ECR resonance magnetic field

Waveguide
Movable Magnet Yoke
Gas Inlet
Microwave Input Port
Magnets
Source Pressure Measurement Port

Figure 3. Completed microwave plasma generator

Figure 4. Mass spectrum of the extracted Xenon ion beam

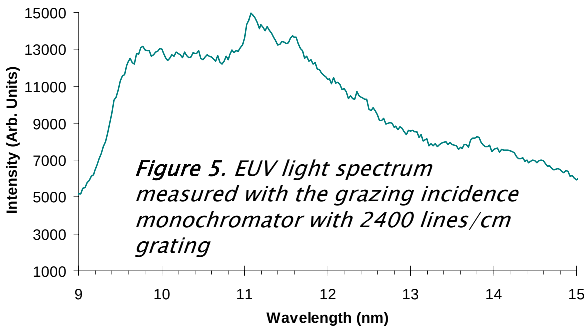

Figure 5. EUV light spectrum measured with the grazing incidence monochromator with 2400 lines/cm grating

Initial results and further development of the system

Initial results obtained from the permanent magnet ECR source are shown in Figures 4 and 5. **The analyzed mass spectrum** of the extracted **Xenon ion beam** shows charge states up to Xe^{+8}. Higher Xenon charge states overlap with impurities and are thus difficult to detect. **The EUV light spectrum** has visible lines around 11 and 13.5 nm, which are associated to Xe^{+10}.

To further improve the Xe^{+10} concentration in the plasma, a more closed magnetic field structure should be built to improve the confinement of the electrons and ions in the plasma, as shown in Figure 6. Further source developments and plasma pinching will be performed in the near future. To increase the accuracy of the EUV measurement, the Flying Circus EUV spectrograph is going to be employed.

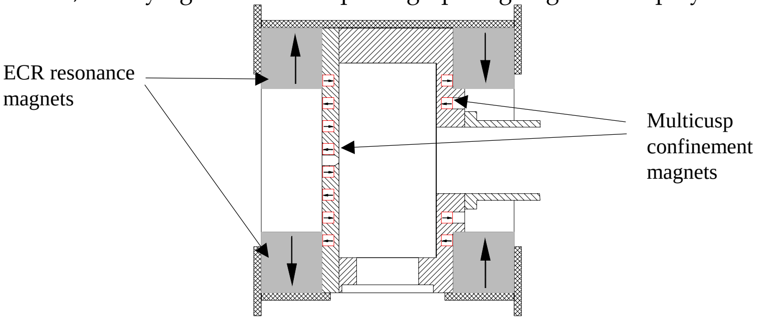

Figure 6. Proposed ECR plasma source update

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