Cleaning of tin layer on EUV multilayer mirrors by the EUV induced hydrogen plasma

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After tens of years of R&D activities, EUV lithography technology is now on operation in industry for semiconductor fabrication. For the industrial use, operational condition is required to be stable and sustainable. One of the issues to solve is the accumulation of the Sn debris from target plasma on the EUV collector. The excited states of hydrogen atoms, which are also called as “hydrogen radicals” would play an important role for the cleaning of this Sn contamination layer by a chemical reaction of $4H^* + Sn \rightarrow SnH_4$. However, for optimization of the operational parameters and understandings of the mechanism is not sufficient yet. The purpose of this research is to study the EUV induced H radicals, and Sn layer cleaning effects.

We have developed a EUV testbed that consists of a Nd:YAG drive laser, solid xenon cryo-target, and EUV focusing system, and a gas cell target. We have newly designed the gas cell target to contain hydrogen gas at a pressure. It is installed in the main vacuum chamber of the EUV source and H_2 gas was introduced and pumped down with its differential pumping system. The operational hydrogen gas pressure inside the gas cell was 0-23 Pa. The obtained in-band energy of EUV radiation from the Xe target was 48 mJ/sr. This corresponds to 8 mJ of EUV irradiation at the center of the gas cell after transferred by two EUV focusing mirrors. The EUV light was focused at the center of the gas cell to ablate the H_2 gas. We have successfully observed EUV-induced hydrogen plasma by optical emission spectroscopy confirming the existence of hydrogen radicals and determined the population density of each states.

Few hundreds of nanometers of Sn layer was deposited on ZrO capped Mo/Si multilayer substrates by an electron beam deposition device with substrate heating at a temperature of 230 degrees C. Sn layer cleaning was demonstrated by exposing the sample in the EUV induced hydrogen plasma. The cleaning rate was determined by particle analysis of the images obtained from secondary electron microscope (SEM) images. The hydrogen pressure and EUV intensity dependences on the cleaning effect will be discussed in the presentation.