Sensor box for in-situ plasma diagnostics in EUV sources

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Introduction

Next generation high volume manufacturing waferstepperss will use EUV light. The required EUV sources are using a tin (Sn) plasma to generate an emission at 13.5 nm. The development of these sources is not going as fast as the semiconductor industries would like.

We believe that the source suppliers would benefit from a better understanding of the plasma inside the source.

For this we have designed and built a small, versatile plasma characterization sensor box that can be placed inside the source. The sensor box operates stand-alone. Therefore it can be used without modification of the vacuum vessel since no feedthroughs are required.

Design of sensor box

The sensor box comprises of a sensor head and an electronics unit for sensor read out, data logging and power supply. Figure 1 shows the sensor head which incorporates five sensors: Langmuir probe (a), PT100 (b), photodiode (c), heat flux sensor (d) and Faraday cup (e). All five sensors are operated simultaneously.
The electronics unit is shown in figure 2. Sensor head and electronics unit are both placed inside the vacuum vessel.

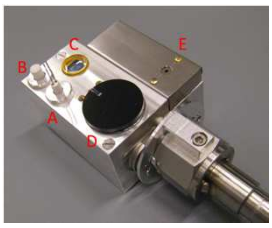

Figure 1: Sensor head with Langmuir probe (a), PT100 (b), photo diode (c), heat flux sensor (d) and Faraday cup (e).

Heat flux sensor:

The heat flux sensor is a sensor that is invented by TNO and is used to measure the amount of heat that is absorbed in a defined surface.

Langmuir probe

The Langmuir probe sensor is a sensor that is used to measure electron/ion temperature, electron/ion density and plasma potential.

Faraday cup

In the design of the sensor box we made it possible to put a negative, a positive or no bias on the Faraday cup. This makes it possible to measure either the electron or the ion flux generated by the plasma. The ion current can be used to predict the sputtering strength of the plasma.

Photo diode

The silicon photo diode is used to measure the intensity of the light emitted by the plasma between 200 nm and 1100 nm. It is possible to install additional band pass filters to narrow this wavelength band and look at a specific wavelength where a certain plasma emission line is expected.

PT100

The PT100 is installed to measure the temperature of the plasma/environment. This PT100 in captured inside a Al_2O_3 housing to protect it against the harsh conditions of the plasma.

Measurement protocol

The head of the sensor box was mounted inside one of the plasma setups available at TNO. All experiments where done with a microwave induced H_2 plasma at 0.3 mbar.

During the experiment we varied the microwave plasma input power between ~200 and 600 watt (CW). Besides power we also varied the distance of the sensor head to the microwave cavity in which the plasma was ignited.

Results

Figures 3 to 7 show a selection of the results of our measurements. The black curves in these figures are with the sensor head at 6 cm from the microwave cavity, the red curves with the sensor head at 12 cm from the microwave cavity.

As expected there is an increase of all sensor readings when the power of the microwave source is increased and when the sensor head is placed closer to the microwave cavity.

Figure 5 shows Langmuir probe data for a voltage sweep from -48 to +48V (blue curves). From the Langmuir probe data the plasma electron density and temperature can be calculated (see figures 6/7) .

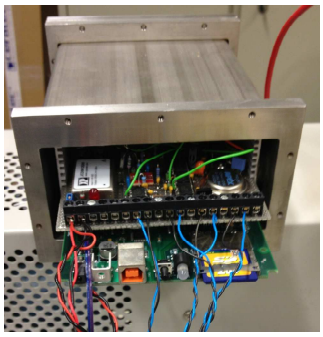

Figure 2: Opened sensor electronics unit for sensor read out, data logging and power supply.

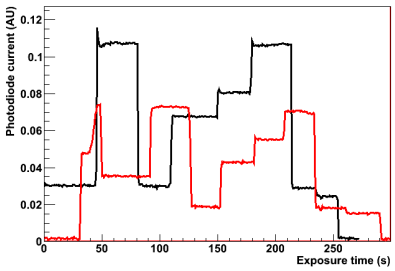

Figure 3: Photo diode signal, steps follow the varied microwave input power

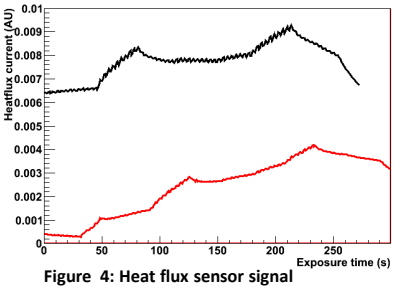

Figure 4: Heat flux sensor signal

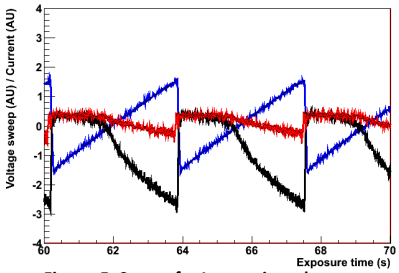

Figure 5: Sweep for Langmuir probe

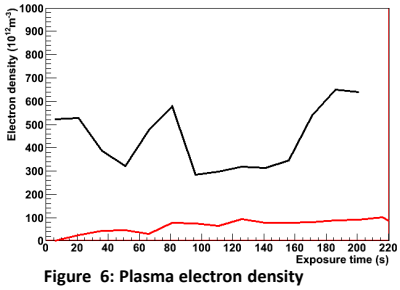

Figure 6: Plasma electron density

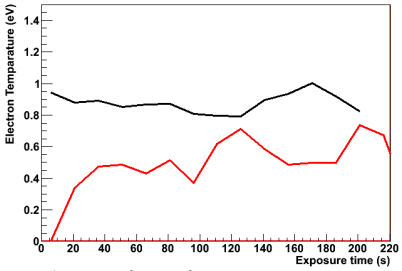

Figure 7: Plasma electron temperature

Conclusion:
A small, stand alone, sensor box for in situ plasma diagnostics has been realized successfully.