Diode laser absorption spectroscopy for H(*n*=2) detection in a low-pressure hydrogen ECR plasma

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ASML's latest lithography machines use 13.5 nm EUV light, pushing the boundaries of semi-conductor chip feature sizes. Optimal scanner conditions are obtained by introducing a few Pa of hydrogen gas. Some of the EUV light is absorbed by this gas leading to an EUV-induced hydrogen plasma. The radicals and ions in the plasma, together with EUV photons, govern to a large extent the processes on the critical surfaces in the scanner. The density of atomic and molecular ions depends strongly on the density of the neutral plasma species present in the EUV-induced plasma through the very fast charge-exchange(CE) and dissociative-attachment(DA) reactions. Through a combined experimental and modelling effort we are gaining better insights in the densities and fluxes of the plasma produced species in EUV-induced hydrogen plasma. By using several optical diagnostic techniques we will measure in the near future the densities of atomic hydrogen in the ground state, H(*n*=1) (two-photon absorption laser induced fluorescence), in the H(*n*=2) state (diode laser absorption spectroscopy) and H(*n*>2) states (optical emission spectroscopy). In the present contribution we will show results on the detection of H(*n*=2) by means of diode laser absorption spectroscopy around 656.3 nm in an ECR plasma source. This source is used to mimic the EUV-induced hydrogen plasma conditions in terms of energy and flux of the hydrogen ions. We will show results on H(*n*=2) density measurements as function of distance from the source (1 to 35 mm) and hydrogen pressure (3 to 10 Pa). The minimal detectable absorption was around 5×10^{-4}, corresponding to a detection limit for H(*n*=2) of 1×10^{13} m^{-3}. To achieve this detection sensitivity the plasma was pulsed at a few Hz and a correction for the plasma emission had to be included.

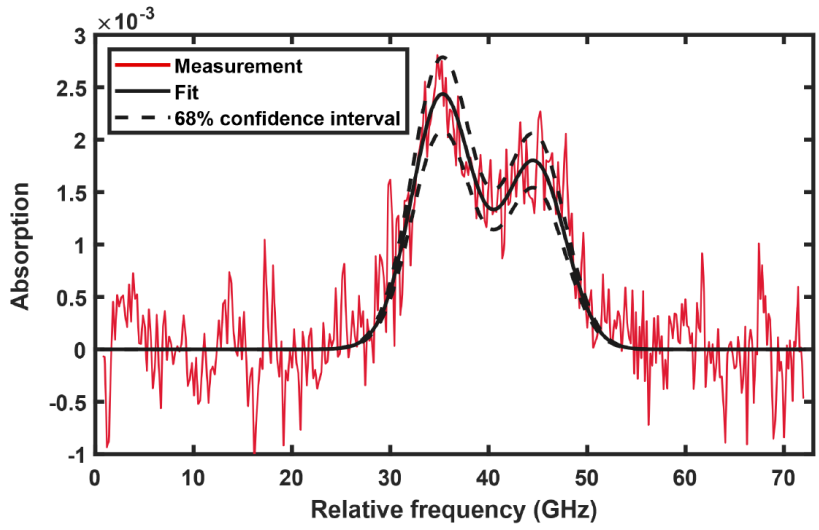

Figure 1. Absorption spectrum of H(*n*=2) measured at 5 mm from the ECR source and a pure hydrogen gas pressure of 8 Pa. The plasma power is (187 ± 5) W. Data is fitted with the theoretical absorption profile. Using an optical path length of 1 m, an H(*n*=2) density of $(1.9 \pm 0.3) \times 10^{13}$ m^{-3}.

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