A novel sensor for measuring hydrogen radical recombination rates

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In EUV lithography tool, EUV light is used to print structures on a wafer with nanometer precision. On the way to the wafer, this light passes through multiple optics, which is purged with H_2 gas. Due to the high energy of EUV photons, the H_2 gas gets highly ionized resulting in so-called EUV-induced plasma, composing predominantly of hydrogen ions and radicals. These plasma species are beneficial as they actively clean EUV optics from contaminants like C and Sn, and by that ensuring their high reflectivity and long life time. In order to predict their cleaning efficiency various models are used, which make use of the hydrogen ion and radical concentrations and fluxes at different positions in the scanner.

The biggest uncertainty in calculating the H radical fluxes in the lithography tool is caused by the unknown hydrogen recombination rates (γ) at different surfaces. It depends on multiple parameters like material type, surface roughness and temperature. Hydrogen atoms and radicals releases heat when recombining on the surface of a material. The recombination rate of a specific material can be indirectly measured from this heat released, which is proportional to γ[1].

We have developed a novel sensor, which can be used to measure the H recombination rates for realistic scanner materials of various types (metals, glasses, coatings) and thicknesses (nanometer-thick coatings to millimeter-thick foils) in a fast and inexpensive way. The device comprises of two active parts, each of them containing of a heat flux sensor (HFS). The gamma-sensor allows to measure either the absolute recombination rates if the H radical flux is known or gamma values relative to a reference material (ideally with γ close to 0) which will be used as one of the HFS. The feasibility tests allowed us to measure relative recombination rates for metal foils made of aluminum oxide, platinum, stainless steel and nickel. For Al_2O_3 and Pt, measurements were also done for coatings made of these materials and showed significant differences compared to foils.

[1] J.F.M. Velthuis, A. Storm, M. van Kampen, R. van der Horst and H. B. Profijt, 2019, Journal of Vacuum Science & Technology A 37, 061302