Seminar

Institute for Plasma Research

Title : Study of In Situ Measurement of Work Function and Caesium Dynamics

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Date : 15th July 2021 (Thursday)

Time : 10.00 AM

Venue : Online - Join the talk:
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Abstract :

Caesium seeded large negative hydrogen ion sources are the heart of neutral beam injection systems required in thermonuclear fusion devices for external heating and non-inductive current drive for steady-state operation. Caesium (Cs) is introduced in the negative hydrogen ion sources where Cs plays a role of catalyst in enhancing the negative ions yield by surface production to generate high power negative ion beams. The mechanism for surface production of negative ions is associated with the resonance electron capture (REC) by neutral hydrogen atoms and ions impinging on a low work function surface of the plasma grid (PG) usually Molybdenum or Tungsten. To achieve the desired low work function surface, optimum layers of Cs are deposited in situ primarily on the PG by introducing a precise amount of Cs vapour from the temperature-controlled Cs oven. The excess amount of Cs inside the source possesses a serious issue due to its leakage and deposition on the actively cooled surfaces, mainly in the extractor system which leads to high voltage breakdown among the grids kept at different voltage levels. Therefore, in situ monitoring of work function, Cs flux into the ion source and corresponding Cs coverage on the PG surface is needed to achieve an efficient negative ion source performance. It was found that there is no single probe available, which is suitable for ion source applications capable of measuring three key parameters like Cs flux, Cs coverage, and the work function to establish a correlation among all these three parameters. A vacuum-compatible novel probe "PRISM" (Probe for In Situ Measurement) is developed to measure all these three parameters in-situ.

The thesis work encompasses both theoretical and experimental understanding of work function in correlation with Cs dynamics in terms of Cs flux measurement and Cs coverage on the "PRISM" probe surface, highlighting its implications to the present-day negative ion sources. A phenomenological model is developed to fortify our understanding of the anomalous variation of work function induced by different layers of Cs deposition on a tungsten/molybdenum surface. The complete experimentally observed anomalous variation of work function in an ultra-pure condition, available in the literature, is explained by electric double layer formation on the caesiated tungsten surface. A Monte Carlo simulation is performed to optimize the nozzle diameter design for ensuring controlled Cs flux from a temperature-controlled Cs delivery system during the experiment. The observed work-function is around 3.06eV in an ion source type vacuum environment which contains hydrogen and atmospheric gases as impurities. Cs being highly reactive towards many elements and compounds, particularly with hydrogen and atmospheric gases, numerous Cs compounds are formed on the Cs coated surface and modifies the work function. As a result, reduced negative ion yield is expected than that of ideal work-function value normally considered during ion source design calculation.

References:

1. Pranjal Singh, M. Bandyopadhyay, K. Pandya, M. Bhuyan, and A. Chakraborty, "Characterization of *in situ* work function and caesium flux measurement setup suitable for caesium seeded negative ion source applications" Nuclear Fusion, 59, 106023 (2019), IOP Publishing.
2. Pranjal Singh, and M. Bandyopadhyay, "A model for real time, in situ estimation of caesium coverage on metal substrate using infrared imaging under vacuum", Review of Scientific Instruments, 90, 123505 (2019), AIP.
3. Pranjal Singh, C. Andhare, and M. Bandyopadhyay, "Monte Carlo simulations, analytical and experimental studies on the nozzle structure of a Cs vapour delivery system for negative ion sources", Fusion Engineering and Design, 159, 111802 (2020), Elsevier.