§8. Study of Hydrogen Negative Ion Production Processes from Metal Surface

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[Introduction] Negative hydrogen isotope ions are used as sources in accelerator laboratories around the world and as heating sources in fusion reactions [1]. It is known that most of negative ions are produced on low work-function surface of metal electrodes, but details of production mechanism have not been clarified yet. Upon these backgrounds, this research is (1) aiming a more stable and efficient material surface design for negative ion production, and (2) theoretical understanding underlying its formation and interaction, starting from the first principle investigation and (3) its experimental validation.

[Work Function Variation in Alkali Metal – Metal Surface Systems] In the 2013 NIFS collaboration program, new results on theoretical analysis of the electronic structure changes and work function variation in alkali metal—metal surface systems were reported [2]. Here, analysis of the density of states profiles revealed that the position of the state corresponding to the interaction of adsorbed alkali metals on tungsten W(110) surface can provide insight on the work function variation of the system. At low coverage, the state resides in the unoccupied region of the density of states. Depolarization happens at high coverage when the state shifts to the occupied region. It was found that the corresponding coverage that will yield the minimum work function can be theoretically determined. The experimental observation that there exists an optimum alkali-metal coverage where the work function reaches the minimum value and the n/n_e ratio became maximum [3] was theoretically validated.

[Simulation of Surface Production of H− on a Cs Covered Mo Surface] A numerical simulation calculation, Atomic Collision in Amorphous Target (ACAT), has been carried out to clarify the effects due to the incident angle of hydrogen flux onto surface collision cascade in the subsurface region of a Cs covered Mo plasma grid[4]. The code has taken into account the threshold energy for negative hydrogen (H^-) ions to leave the surface. This modification has caused the shift of energy distribution functions of H^- from that of hydrogen atoms leaving the surface.

[Potential Energy Curves of Molecules] Theoretical investigation on the molecular orientation dependence and surface site dependence of the dissociative adsorption was performed for O_2/Al(111) system [5]. In this research, the dissociative adsorption, and enhancement of sticking probability of neutral molecules were studied. On production of H^- and vibrational molecules on a low work function surface, the activation barrier of the potential energy curve along the reaction path is important. The new theoretical investigation will provide insights to these problems.

[Experimental Validation] The apparatus at National Institute for Fusion Science for measuring the angle-resolved energy distribution function of positive/negative ions produced at metal surfaces, bombarded by H^+, H_2^+, H_3^+, in keV region has been improved. A new apparatus has been built to produce a sheet plasma and to control the plasma parameter in the peripheral region around the sheet by combination of a mesh grid and a magnetic field [6]. It was found that the electron temperature dependence upon the bias voltage of mesh behaves differently from that on a tandem type bucket source for the H^- volume production [7].

[1] K. Tsumori, et al., Review of Scientific Instruments 75, 1847 - 1850 (2004).
[2] A.A. B. Padama, K. Oka, W.A. Diño, H. Kasai, Journal of the Vacuum Society of Japan 57(:01) (2014) 27-31.
[3] M. Nishiura et al., Proceedings of 1998 International Conference on Ion Implantation Technology (Print ISBN 0-7803-4538-X) vol.1, 318 – 321.
[4] M. Wada, T. Kasuya, T. Kenmotsu and M. Sasao, Angular distributions of surface produced H- ions for reflection and desorption processes, the International Conference on Ion Sources (ICIS'13), Japan, September 9th - 13th, 2013.
[5] K. Shimizu, W.A. Diño, H. Kasai, Journal of the Physical Society of Japan, 82 , pp.113602 (2013).
[6] S. Kato, K. Doi, M.S. Fernandez, T. Kasuya, H.J. Ramos, M. Sasao, H. Yamaoka and M. Wada, presented at the International Conference on Ion Sources (ICIS'13), Japan, September 9th - 13th, 2013.
[7] Y. Jyobira et al., Review of Scientific Instruments 79, 02A508 (2008) .