§5. Production Mechanism of Impurity Hydrocarbons and their Transportation in LHD Plasma

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In current controlled thermonuclear fusion devices, it has been known that various types of impurity molecules are produced near divertor edge, and these impurities should play as "poisons" for plasma hence degrading the plasma quality and other plasma properties.[1] In the LHD plasma, the evidence of the production of various hydrocarbon impurities is revealed also from the observation of CH-spectrum. Therefore, it is essential for production of high-quality plasma and excellent plasma control to better understand the production of these impurity molecules, interactions of these molecules with plasma and their transportation and behavior inside plasma. In addition, it has been widely utilized these molecular species as the probe of plasma analysis and diagnostics.

We have initiated this organized joint effort by gathering top-level scientists in the fields of the atomic, molecular, material, and simulation sciences to shed much light on these entire processes of impurities comprehensively. As the first and second years of this project, we have specifically focused on two subjects, that is, to understand (i) impurity molecule production at divertor, and (ii) their interactions with plasmas (electron, proton and other ions).

For (i), we employed primarily theoretical means to obtain some insights on molecular formation mechanisms and their yields near carbon-walls as well as formation rates. By ion impinging on adsorbed atoms and molecules, differences and similarities of mechanisms for ionization and charge transfer depending upon kinds of species of surface adsorbed particles as well as surface materials have been investigated systematically. For (ii), it has been known that charge transfer processes of H^+ ions in collisions with impurity molecular below a few-keV energies play a key role in low temperature edge plasmas. However, very little experimental and theoretical investigation has been carried out. Hence, we undertook a joint study with experimental and theoretical groups to look into various types hydrocarbon molecular targets and to extract some guidelines to derive a unified scaling rule for the cross sections of the charge transfer process.[2] Moreover, we measured the charge transfer cross sections by H^+ and O^+ ions colliding with C_2H_4 molecules and the detailed theoretical analysis in consideration of vibration of the target molecule before and after the charge transfer collision were performed.[3] The role of vibration of the target molecule in the charge transfer process was revealed to be important. Also, under the usual operational condition of fusion reactors, most of molecular species are in vibrationally excited states, or for some cases, even in electronically excited states. As a related subject, theoretical group has calculated the charge transfer cross sections of H^+ ions colliding with SiH_4 molecules.[4] These results were compared with the cross section values for CH_4 molecules.

The experimental group for electron collisions is now under preparations for two new subjects. This group has developed a new set-up for the ultra cold electron collision experiment utilizing the threshold photoelectrons. The aim of this study is to measure the total cross sections of cold electrons and investigate the quantum mechanical effects. This group has also developed the electron spectrometer system incorporating a toroidal analyzer. The aim of this study is to specify the direction of molecular axis, using a triply coincidence measurement among scattered electrons, secondary electrons released from target molecules, and fragment ions produced from target molecules via dissociative ionization process.

One of experimental groups for ion collisions has studied the reaction processes by slow multiply charged ions colliding with the hydrocarbon molecules adsorbed on the solid surface.[5-7]

The experimental group for plasma science has researched deeply on the gaseous phase molecular growth in the downstream region of Ar/CH_4 plasmas.[8] This group has also made a study of synthesis of gold nanoparticles in aqueous solutions using gas-liquid interface discharge at atmospheric pressure.[9]

We have observed several new insights in these projects and have reported.

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