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

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In current large devices of the controlled thermonuclear fusion, it has been known that various types of impurity molecules are existed in edge and divertor plasmas, and these impurities should play as "poisons" for plasma hence degrading the plasma quality and properties.[1] In the LHD plasma, the evidence of the production of various hydrocarbon impurities is also 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 focused on two subjects, that is, to understand impurity molecule production at divertor, and their interactions with plasmas (electron, proton and other ions). In third year of this project, we have continued these studies with some new progressive subjects.

The experimental group for electron collisions has developed a new set-up for the ultra cold electron collision experiment utilizing the threshold photoelectrons. The aim of this study in the first step is to measure the total cross sections of cold electrons and investigate the quantum mechanical effects. In the preliminary experiment with an attenuation method, the total cross sections of cold electrons are successfully measured in collisions with N_2 and CO_2 molecules as well as Kr and Xe atoms in the collision energy range of 10 meV and 12 eV. The Feshbach resonance is firstly observed for the total cross sections of Kr and Xe atoms as well as the Ramsauer minimum. The shape resonance is also observed for the total cross sections of N_2 and CO_2 molecules.[2] This measurement will be continued for CH_4 molecules. The next step of this project will be planed to study of the temperature effect of target molecules and measure the differential cross sections.

The charge transfer processes of H^+ ions in collisions with impurity molecules below a few keV energies play a key role in low temperature edge plasmas. However, very little experimental and theoretical investigation had 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.[3] As a continuous study, the scaling properties have been examined for the double-charge transfer cross sections of slow He^{2+} ions colliding with some hydrocarbons.

One of the experimental groups for ion collisions has developed a production method of slow metallic ion beams, utilizing sputtering of metallic wires with MeV heavy ions. The single- and double-charge transfer cross sections for Be^{2+} ions colliding with C_3H_8 molecules have been measured at around 20 keV in collision energy.[4,5]

Another experimental group for ion collisions has studied the reaction processes by slow multiply charged ions colliding with the solid surface. This group has presented some new experimental results concerning the fragmentation and desorption processes induced by electron captures.[6,7]

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]

The simulation group for plasma science has prepared to construct the first version of simulation code for the LHD plasmas including with the various collision processes of methane molecules.

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

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