§21. Plasma Complexity Simulation Project

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Plasma Complexity Simulation Project is one of three major research projects which are promoted in the Department of Simulation Science. The main purposes are to clarify magnetic reconnection phenomena, which are controlled by various physics from micro to macro-scale, in solar and magnetosphere plasma and fusion plasma, and to clarify the physics of plasma-material interaction in compound physics system. This project is based on the collaborations with NINS, ES center, in JAMSTEC, and Kyusyu, Chiba, Shinsyu, Yokohama National, Saitama, Tokyo, Nagoya, and Konan universities. Innovative simulation methods called multi-hierarchy, multi-scale, and multi-physics models are now being developed in this project.

Preliminary model for multi-hierarchy simulation of magnetic reconnection phenomena is developed, which is designed to interlock three different simulation models based on domain decomposition method, i.e., (A) MHD model to describe global dynamics of reconnection phenomena, (B) PIC model to describe the microscopic processes in the vicinity of reconnection point, and (C) interface model to describe the interaction between micro and macro hierarchies, as shown in Fig. 1. This multi-hierarchy simulation method is confirmed to work well by applying the propagation of one-dimensional Alfven wave and the plasma inflow simulation. This multi-hierarchy model is now being improved to apply magnetic reconnection phenomena and its applicability will be checked.

Besides the development of multi-hierarchy simulation, both macroscopic and microscopic pictures of magnetic reconnection phenomena are analyzed by using MHD and EM particle simulations. Dynamic response of magnetosphere against solar wind is well reproduced in MHD simulation. Generation mechanism of anomalous resistivity due to instabilities is clarified by using EM particle simulation.

In order to clarify dynamical process of yielding hydrocarbon on the surface of material contacted with plasma by molecular dynamics (MD) simulation, an interaction potential function between carbon and hydrogen is developed based on the Brennar potential. Generation mechanism of C_2H_2 from the chemical spattering on a graphite surface is clarified by using developed MD simulation model. The C_2H_2 is mainly produced from graphite armchair (1 1 -2 0) surfaces, as shown in Fig. 2. The MD model of chemical sputtering will be expanded to large scale (100^3 nm^3) material in hierarchic graphite structures by comparison with Monte Carlo ACAT simulation.

Multi-hierarchy simulation scheme called a primal Equation-Free Projective Integration (EFPI) scheme is developed, which can perform macro-simulations while still taking the effects of micro-scale physics into account. Developed simulation model is applied to simulate the ion sound wave paradigm, which includes nonlinear wave steepening and kinetic effects in plasma.

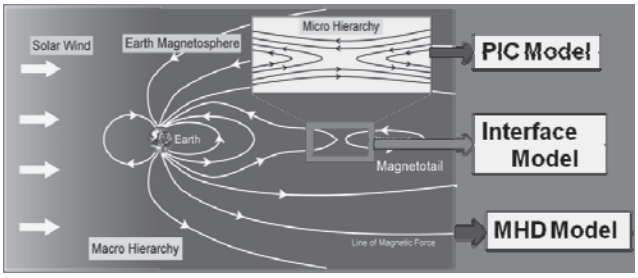

Fig. 1: Multi-hierarchy simulation model for the analysis of magnetic reconnection phenomena.

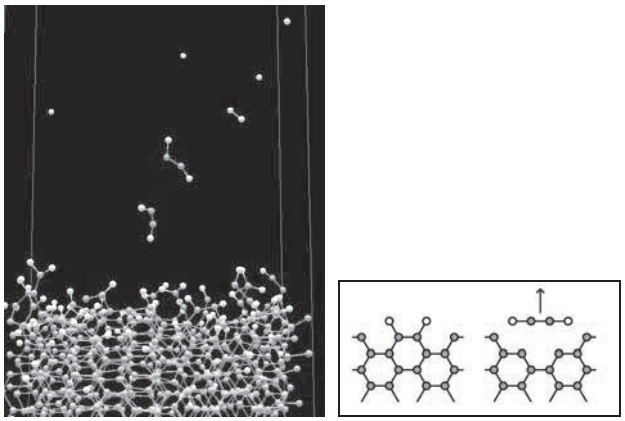

Fig. 2: MD simulation of generation process of C_2H_2 (left). The C_2H_2 is mainly produced from graphite armchair (11-20) surfaces (right).