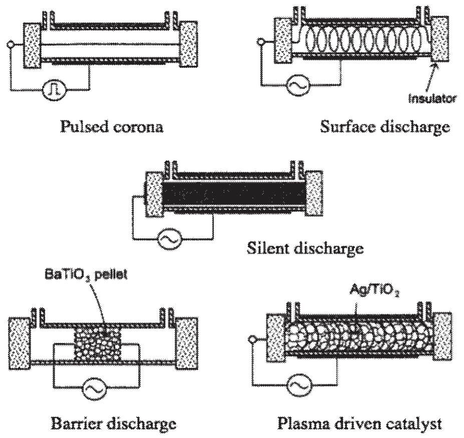
§3. Study of Removal of Volatile Organic Compound (VOC) and Related Atomic and Molecular Processes in Plasma Reactors

Sasaki, A. (Japan Atomic Energy Research Institute),
Kimura, M. (Kyushu Univ.),
Kato, T., Sakaue, H.A.,
Okuda, I., Kato, S., Takahashi, E. (National Institute of Advanced Industrial Science and Technology),
Sekine, M. (Nagoya Univ.),
Chang, J.-S. (Macmaster Univ., Canada)

We study atomic and molecular processes concerning to the removal of Volatile Organic Compound (VOC). VOCs such as toluene and benzene used in the printing industry may cause health hazards and recent regulations demand new removal technologies.

Decomposition of VOCs using non-thermal plasmas, is expected to be more efficient and more cost effective than present technologies. Fig.1 shows various kinds of plasma reactors, which are used in the study of decomposition of VOCs [1]. In the non-thermal plasmas, the electron temperature is high enough to excite and ionize VOCs molecules such as toluene and benzene, while the gas temperature remains room temperature. However, present experiments need input power density of more than 1kJ/*l*, which implies improvement of the efficiency is required, based on the better understanding of the chemical and physical processes in the plasma.



(Fig.1) Plasma reactors for the decomposition of VOCs[1].

Originally, we had planned a collaboration project between atomic and molecular physics and plasma engineering for the development of a simulation model of the decomposition VOCs based on the calculated atomic and molecular data to conduct experimental studies. Unfortunately, one of the principal collaborators of this project has passed away, we looked for different approach, for the modeling of the discharge, which is used for the removal of VOCs. We had a working group meeting on 19-May-2008 to discuss the present status of theoretical modeling of the discharge.

We also had discussions during a seminar held on 17 and 18-Dec-2008 at NIFS, titled "Looking for matching between needs and seeds of the A&M data", as a part of another collaboration project on the A&M data" at NIFS. We discussed results of comprehensive model of the Ar discharge to find an appropriate method to couple plasma hydrodynamics and atomic and molecular processes. Results of experimental studies with respect to the decomposition of PFCs using the electron beam irradiation have also been reported.

Atmospheric discharges, which used for the decomposition of VOCs, usually have essential spatial and temporal non-uniformity. Discharge current flows through narrow channels called streamers in which non-thermal plasma is created. The radius of the channel is defined by the mean free path of electron and photon, which ionize the gas. Therefore, discharge in the large gas volume sometimes consists of complex branched structure of streamers. Furthermore when a connection between positive and negative electrode is established through a channel, the current through the channel increases exponentially, which eventually leads to an arc discharge. In corona discharge or barrier discharge devices, although current growth is suppressed temporally and spatially and quasi-stable discharge can be obtained, the micro-structure of the plasma still should be taken into account.

For the analysis of the discharge, the standard model, based on coupled MHD, atomic and molecular kinetics and radiation transport simulation, has been investigated [2]. However, it is found that multi-scale nature of the discharge requires prohibitively large computer power. Otherwise, calculation is limited to only small part of breakdown, within the small volume near the streamer head.

During the project, we investigate possible new approach of the simulation of discharges to see the fractal model of discharges has been developed [3], however, it lacks physical interpretation of atomic and molecular processes for the development of the channel.

On the other hand, we note usefulness of theoretical and numerical methods used for the analysis of the physics of phase transition. Gas discharge can be understood as a phase transition from insulator to conductor. The phase transition model seems to be useful for reproducing spatial and temporal structure formation and their criticality. If this model is proven to reproduce characteristic feature of the discharge devices, it will be useful to design and optimize devices not only for decomposition of VOCs, but those used for a verity of industrial purposes including light sources.

[1] "Recent Development of Air Purification Technology; Effective Solution to VOCs control policy", edited by K. Takeuchi, CMC press, 2007 (in Japanese).
[2] S. Kato, E. Takahashi, A. Sasaki, and Y. Kishimoto, J. Plasma Fusion Res. 84, 477 (2008).
[3] H. Takayasu, Phys. Rev. Lett. 54, 1099 (1985).