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Basic research of Pt catalytic probe development
白金触媒プローブ開発の基礎研究

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Although radical density produced in plasma is usually monitored with the indirect optical emission spectroscopic (OES) method, some properties of atmospheric plasma such as radiation trapping, modification of electron energy distribution, and so on might make the OES data interpretation complicated and difficult. In order to obtain additional insight, the direct measurement with platinum probes with catalytic reaction with radicals is introduced. Calibration experiment of hot platinum wires resistance as the function of temperature is now under way.

1. Introduction

Non-equilibrium plasma has been used for material process for several decades, since it can generate chemically active species such as a hydroxyl radical. Recently, atmospheric pressure plasma draws attention to enhance the applicable field including wide material process, which are not resistant to the vacuum condition such as bio material or solution target. Radical density produced in plasma is usually monitored with the indirect optical emission spectroscopic (OES) method, since it does not disturb the plasma discharge. However some properties of atmospheric plasma such as radiation trapping, modification of electron energy distribution, and so on might make the OES data interpretation complicated and difficult. Additional insight can be obtained from the direct measurement with probes.

Plasma heat flux can be measured directly with various kinds of thermal probes and consists of contribution from ions, electrons, UV light, neutrals, radicals, and so on. In case of low pressure simple plasma, measured heat flux is analyzed successfully to obtain plasma parameters. In case of atmospheric pressure plasma, although heat flux has already reported[1, 2], analysis of its composition is still an open question. When the thermal probe tip surface is covered with catalytic metals such as platinum (Pt), probe temperature was found to become much higher than non-catalytic surface. This comes from the heat flux carried by active radicals. The catalytic probe to measure this excess heat flux might be a promising tool to monitor radical density.[3, 4]

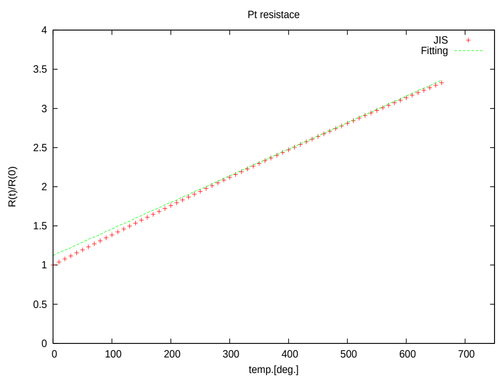

Fig.1: Temperature dependence of Pt resistance, which is normalized with those at 0 [deg.].

2. Concept of Pt catalytic probe

Although the probe tip temperature (T_p) is measured with optical fiber method in [3], our probe use the platinum (Pt) wire itself as a thermometer because of its simplicity. As shown in Fig. 1, electric resistance R_p of Pt wire is the smooth function of its temperature T_p. So if resistance of plasma irradiated wire is measured with the electric circuit, temperature can be deduced. There is already many commercial Pt resistance thermometer and analyzing system, although its Pt wire is covered with metal sheath and catalytic effect can not be available. So Pt catalytic probe head must be made by ourselves and the size of Pt wire (both length and diameter) is still an open question.

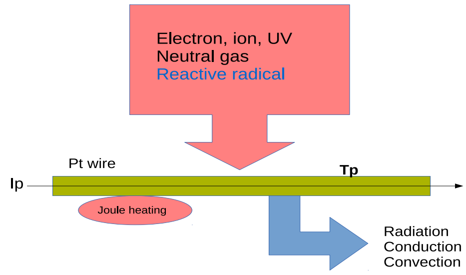

Fig.2: Schematic drawing of heat balance of Pt catalytic probe tip.

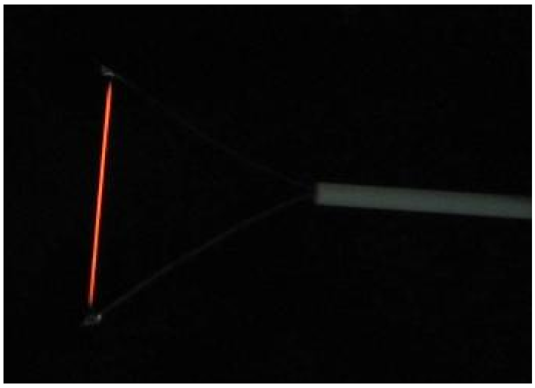

Fig.3: A photo of Pt wire. It is heated with Joule heating of the current of about 0.4 A.

Figure 2 shows the heat balance of Pt wire used as a catalytic probe. Pt temperature T_p is determined by the following equation.

$$c\rho V\frac{dT_p}{dt} = Q_{plasma} + Q_{Joule} - (Q_{rad} + Q_{conv} + Q_{cond}) \quad (1)$$

where Q_{plasma} is plasma heat flux which include the contribution not only from ions and electrons but also from radicals, and $Q_{Joule} = RI_p^2$ is the Juole heating of the current I_p which flows Pt wire to determine the resistance. c, ρ, V is specific heat, mass density, volume of Pt wire respectively. In case of steady state experiment, left hand side of eq.(1) is equal to 0.

Recently a new calibration method has been proposed. [5] If current I_p is large enough, Q_{Joule} balance all heat loss in steady state and T_p becomes high enough so that catalytic reaction is expected. Then plasma irradiation is overlapped and I_p is set to be smaller so that T_p is the same as in no plasma condition by monitoring of Pt resistance R_p. Then cooling powers Q_{rad}, Q_{conv}, and Q_{cond}, which are the function of T_p, are also kept the same value. So

$$Q_{Joule,0} = Q_{plasma} + Q_{Joule} \quad (2)$$

where $Q_{Joule,0} = R_p I_{p0}^2$ and $Q_{Joule} = R_p I_p^2$. If current I_{p0} and I_p is measured, plasma heat flux Q_{plasma} can be determined exactly.

3. Calibration experiment

In order to make Pt catalytic action effective, its temperature T_p must be high enough. We used two wires with diameter of 0.3 and 0.03 mm. Although the fat wire can not be heated up sufficiently with present current source, the narrow one shows red emission with about 0.4 A current. (Fig. 3) Relation between circuit current I_p and Pt resistance R_p (and also temperature) is very important information to determine plasma heat flux with eq.(2). Preliminary results will be presented at the conference.

Acknowledgements

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