Topic number: 10

SPATIAL DISTRIBUTION OF SURFACE POTENTIAL AND DISCHARGE POWER IN PIEZOELECTRIC TRANSOMFORMER-BASED PLASMA REACTOR

Kenji Teranishi[(1,∗)], Shota Saitoh[(1)], Naoyuki Shimomura[(1)], Haruo Itoh[(2)]

[(1)] Institute of Technology and Science, The University of Tokushima
[(2)] Graduate School of Engineering, Chiba Institute of Technology
[(∗)] **teranishi@ee.tokushima-u.ac.jp**

Generation of discharge plasmas using piezoelectric transformers (PTs) is one of a unique method to produce various types of discharge plasma with compact configurations [1]. The plasma reactors are based on the excitation of discharge plasmas onto its device surface that generates high-voltage due to the piezoelectric effect. Some applications of the plasma reactors based on the dielectric barrier discharge (DBD) [2] have been demonstrated as compact ozone generators [1, 3] and excimer lamps [4]. In these reactors, the surface potential induced on the PT is distributed spatially as a standing wave in the long direction of the PT due to its electro-mechanical resonance. Hence, it is important to understand the behavior of surface potential and discharge power distribution on the PT surface [5]. This paper describes the measurement method of the surface potential and discharge power distributions in the DBD-type plasma reactor.

Figure 1(a) shows a schematic of the experimental arrangement for the surface potential and discharge power measurements. A Rosen-type PT is used and the dimensions are 60×13×2 mm. A DBD electrode configuration is constructed by the PT surface acting as a high-voltage electrode and a 1-mm-dielectric plate having copper contacts as back electrodes. The PT and the dielectric layer with the back electrode are supported at the PT center, inserting a spacer with 0.3-mm thickness to maintain the discharge gap. In order to detect the spatially distributed surface potential on the PT, the back electrode is segmented into 15 sections in the long direction of the PT. The planar dimension of each striped electrode is 1.5×13 mm and these are located at intervals of 2 mm. Each striped electrode connects to ground through a 1 nF capacitor C_n for detecting the surface potential and discharge power. The secondary voltage of the PT is measured by an oscilloscope using a commercial high-voltage probe and a potential divider developed in our laboratory [6]. The input resistance of the high-voltage probe and the potential divider is 50 and 1000 MΩ, respectively.

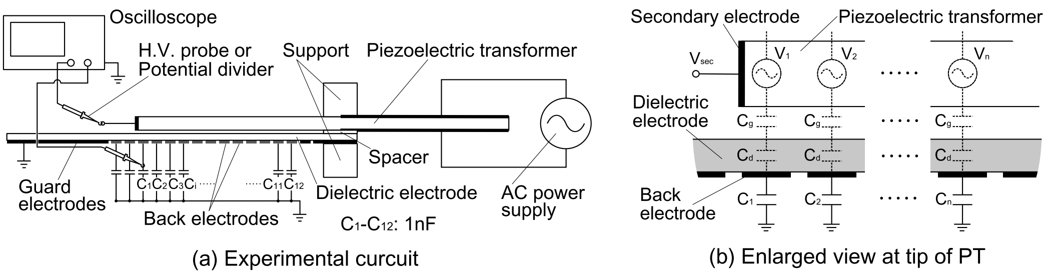

Fig. 1: A schematic diagram of experimental arrangement.

If the PT is driven at low applied voltages to not cause discharges, a surface potential V_n appears over each striped electrode, which is distributed in the long direction of the PT. Surface potential V_n can be regarded as an individual voltage source at each electrode and is divided into three effective capacitances connected in series: air gap C_g, dielectric layer C_d and the capacitor C_n, as shown in Fig. 1(b). Hence, V_n at each striped electrode can be written as

$$V_n = \frac{C_gC_d + C_dC_n + C_nC_g}{C_gC_d} V_{cn} = \frac{C_n}{C} V_{cn}, \qquad (1)$$

where V_{cn} is the voltage across the capacitor C_n, and $C = C_g C_d C_n/(C_g C_d + C_d C_n + C_g C_n)$ is the total capacitance of the equivalent circuit. Consequently, the relative surface potential distribution can be obtained by measuring the voltage V_{cn} across the capacitor C_n since the surface potential V_n is proportional to the voltage V_{cn}. Also, the absolute surface potential can be estimated if the total capacitance C at each stripped electrode is determined.

Figure 2(a) and (b) show the measured surface potential distributions, in which the commercial high-voltage probe and the developed potential divider is respectively used for the secondary voltage measurement. These results were obtained by applying a primary voltage of 2 V so as not to appears the DBD. The plots are the experimental results and the solid curves are the theoretical distributions fitted to the experimental values. It is seen that the surface potential distributions are affected by the secondary voltage measurement device. In the case of using the commercial high-voltage probe (Fig. 2(a)), the measured surface potential distribution gives close agreement with the theoretical curve in the x range from 11 to 23 mm, but it becomes lower than the theoretical curves near the tip of the PT. The decrease in the surface potential near the tip is due to the high-output impedance characteristics of the PT [5]. Although 50 MΩ in the input resistance for the high-voltage probe seems to be enough large, the PT has probably a large output impedance comparable to the probe impedance. In order to avoid the dropping characteristic, the potential divider with 1-GΩ input resistance was developed [6] and the surface potential distribution has been measured again. The result is shown in the figure (b). The decrease in the surface potential near the tip can be almost avoided and the measured distribution is well consistent with the theoretical curve. However, the surface potential only at the tip ($x = 1$ mm) is detected slightly lower than the theoretical curve. This is due to the electric field distortion near the tip of the PT owing to the edge effect. This result suggests that the total capacitance C cannot be regarded as the same value for all stripped electrode. Hence, if the absolute value of the surface potential is estimated according to Eq. (1), the capacitance C near the tip of the PT must be corrected taking into account the electric field distortion. The details of the absolute measurement of the surface potential including the discharge power distribution for the DBD will be presented in the conference.

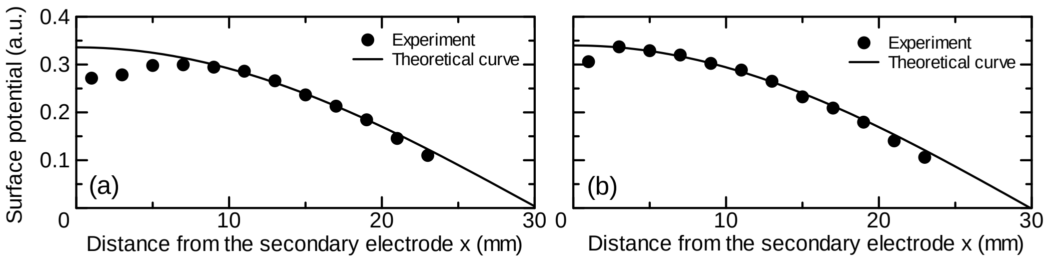

Fig. 2: Surface potential distributions obtained using (a) a commercial high voltage probe and (b) a developed potential divider for the secondary voltage measurement.

Reference

[1] H. Itoh, K. Teranishi and S. Suzuki, 2006 Plasma Sources, Sci. and Technol. 15 S51–S61

[2] K. H. Becker, U. Kogelschatz, K. H. Schoenbach and R. J. Barker 2005 Non-Equilibrium Air Plasma at Atmospheric Pressure (Bristol, UK: IOP Publishing)

[3] K. Teranishi, N. Shimomura, S. Suzuki and H. Itoh 2009 Plasma Sources, Sci. and Technol. 18 045011

[4] K. Teranishi, D. Inada, N. Shimomura, S. Suzuki and H. Itoh 2008 IEEE Trans. Plasma Sci. 36 1340–1341

[5] K. Teranishi and H. Itoh 2005 Japan. J. Appl. Phys. 44 7083–7088

[6] K. Teranishi, S. Saitoh, N. Shimomura, S. Suzuki and H. Itoh 2009 Proc. 29th Int. Conf. on Phenomena in Ionized Gases PB10-12