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Initial Ignition Dynamics of Radio Frequency Induction Thermal Plasma in Atmospheric Pressure

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Thermal plasmas generated by inductively coupled plasma (ICP) technique have been drawn a considerable attention in a diversity of researches over the last few decades due to its wide range of operating conditions, and various industrial and commercial applications [1-3]. So far, however, attention has been drawn on heating, and stabilization of induction plasmas. But, when operated at high-pressures (around 1 atm or more), initial start-up is one of the important issues to ignite the discharge of induction plasmas, as the starting of high-pressure rf plasma torches are hard, and a high-voltage initiation is usually required. So far several techniques, such as, dc arc jet [1] and dc-rf hybrid plasma torch [2] are used to initiate the high-pressure rf inductive discharges. But, these hybrid plasma torches characteristically operate at power levels of 50 to 100 kW or even more, where the dimensions of the second-stage, high-power unit make it difficult to initiate and operate in a stable manner [3]. But to promote induction plasmas into industrial and commercial fields, it is mandatory to make it cost effective with as low power as possible. Therefore, it is necessary to understand the physical mechanisms of the formation of high-pressure induction plasmas, which is quite different with that of the low-pressure plasma dynamics. With those in mind, we have studied the dynamics of atmospheric pressure argon induction thermal plasma (ITP) at the ignition stage experimentally to find a simple and easy ingnition method of atmospheric pressure ITP. High-speed imaging (13500 f/s) is performed to investigate the dynamics of physical processes and initial formation of rf discharge. A very interesting result is observed from the experiment, which clarify the dynamics of high-pressure inductive discharges. The experimental observations reveal that (1) firstly, multiple streamer-like discharge paths, which is called the electrostatic discharge or *E* discharge [Fig. 1(a) & (b)], are developed due to strong electrostatic field (100-200 kV/m), (2) secondly, the discharge paths connect among the streamers due to the induced azimuthal electric field thereby forming the electrically conducting ring-shaped azimuthal discharge, which is called the electromagnetic discharge or *H* discharge [Fig. 1(c) & (d)], and (3) finally, volumetric induction plasmas [Fig. 1(e)] are formed due to the Joule heating with the azimuthal current flowing through the electrically conducting ring. The transition between electrostatic and electromagnetic discharge is called the *E-H* mode transition. The *E-H* mode transition time, which corresponds to the duration of H-discharge, is estimated from high-speed imaging as well as by observing the time behavior of high-frequency plasma loading impedance at the *E-H* mode transition stage.

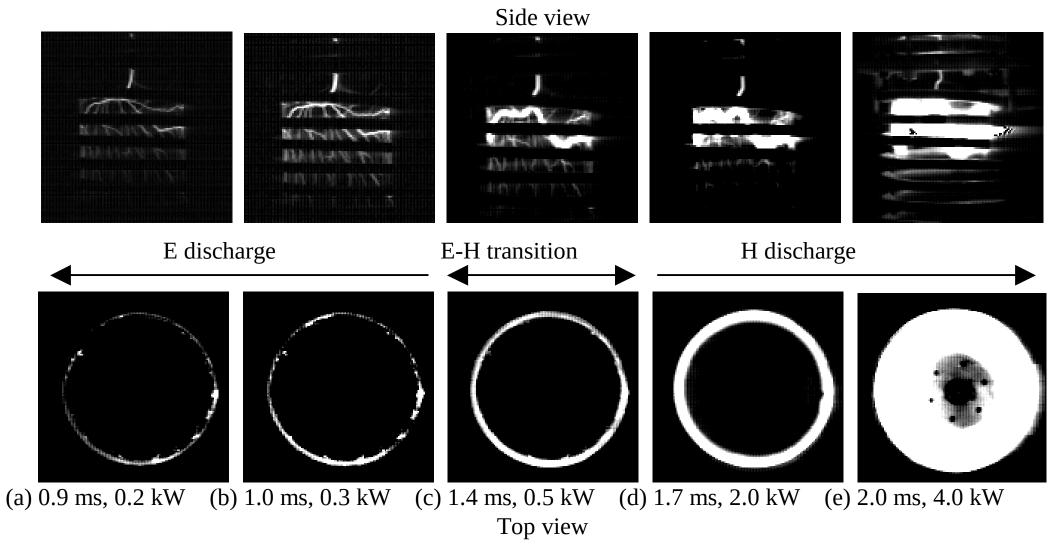

Fig.1 High-speed imaging to understand the initial formation of high-pressure induction thermal plasma

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