6th Asia-Pacific Conference on Plasma Physics, 9-14 Oct, 2022, Remote e-conference

Microwave plasma source development and applications from low pressure to atmospheric pressure

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In these 50 years, low-pressure plasmas are used as one of important processing methods in semiconductor fabrication, innovative material synthesis and so on. In parallel to low pressure plasma research, non-thermal atmospheric pressure plasmas (non-thermal APPs) have attracted much attention in these 20 years, because of their compactness of the plasma equipment without vacuum system. This trend was very big impact for the plasma application research because the APP gave us new area of plasma applications such as liquid treatment, bio-application, agriculture, etc., where plasmas must be compatible with atmospheric pressure conditions.

To catch up with drastic expansion of the plasma application area, i.e., from low-pressure to atmospheric-pressure plasma and from solid-surface to liquid-surface treatment, plasma source must be also improved to fully-utilize benefit of the plasma treatments. One important point of the plasma application for materials processing is plasma-enhanced chemical reactions at low temperatures using non-thermal plasmas. In atmospheric pressure environment, however, plasma tends to be localized due to low plasma diffusivity and gas temperature tends to become very high, which is not appropriate for their application areas. To avoid this, pulsed power deposition to the plasma is common idea to sustain non-thermal APPs. Another issue of the APPs is control of plasma structure depending on their applications. To realize uniform APPs, power deposition technique, i.e., spatial control of power coupling, is very important. Furthermore, APPs often use air or air with water vapor, where electronegative oxygens drastically degrade plasma conditions and make plasma sustainment difficult. Especially, in the case of plasma liquid treatment, high water vapor concentration drastically influences the plasma sustainment. To give some solution to the above issues of APPs, we have proposed new concept plasma sources so far. One is a proposal to produce uniform plasma in atmospheric pressure condition. Another is a proposal of a plasma source which is compatible to liquid environment.

Atmospheric pressure microwave line plasma

As was mentioned above, uniform power deposition is important to realize uniform APP. We have developed a microwave APP source which can produce meter-length uniform plasma. Figure 1 shows concept of the plasma source, where pulsed microwave power propagates in a looped waveguide in one direction by using a microwave circulator and a tuner. This enables us uniform microwave power density along the waveguide. Placing a meter-length slot (gap width: 0.2 mm) along the waveguide, uniform plasma is produced along the slot (Fig. 2). Wide-area surface treatment such as wettability control and high-speed ashing will be presented.

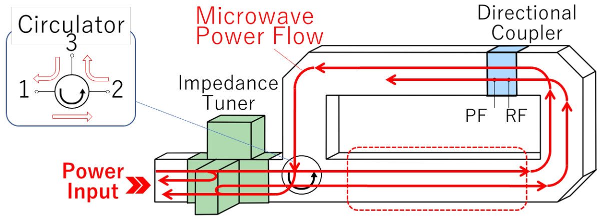

Fig. 1. Concept of microwave power flow control.

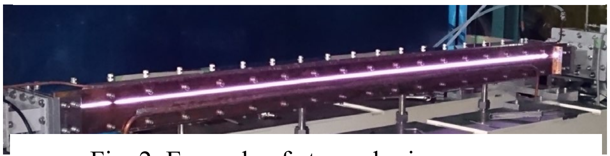

Fig. 2. Example of atmospheric pressure microwave line plasma.

Liquid treatment plasma source

APP production with water vapor environment can be much more eased when the pressure is slightly decreased from atmospheric pressure. We have developed a microwave plasma source for large volume liquid treatment. In this plasma source, pressure reduction is automatically realized in the microwave discharge gap utilizing Venturi effect with the liquid flow (~50L/min). This enables us stable plasma production in adjacent to the liquid flow. By this plasma system, effective decomposition of organic compound in the liquid is possible. Furthermore, nanomaterials (~ a few tens nm) can be effectively produced by the plasma treatment.

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