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Role of liquid dielectric and its application for developing a dielectric barrier discharge configuration for cold plasma jet generation

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Cold atmospheric plasma is gaining interest and promising applications owing to its low-temperature plasma and ability to work in atmospheric conditions. Although working at low temperature, cold atmospheric plasma features atoms or molecules of gases (heavy species) at approximately room temperature but consists of energetic electrons, radicals, ions, excited gas molecules, and photons; consequently, it is a cocktail of reactive chemicals at low temperature. As a result, it can conduct surface modification or chemical reactions at low temperatures. However, the discharge zone of a cold atmospheric pressure plasma is small because it works at atmospheric pressure, requiring high breakdown voltage. Therefore, it is limited to placing treated objects inside the discharge zone, which is a disadvantage of cold atmospheric plasma. Fortunately, in some configurations with unique plasma gases, cold atmospheric plasma can be extended beyond the discharge zone, propagating plasma jet into the atmosphere; for instance, a gliding arc or dielectric barrier discharge (DBD) configuration with N_2, Ar, or He in the feed gas. Since the plasma jet propagates into the atmosphere, plasma jet facilitates interaction with the surface of liquid and solid materials, removing the size barrier of treated objects. Among reactor configurations for plasma jets, the DBD configuration is commonly used to create cold plasma jets, specifically, coaxial DBD with two electric rings placed outside a dielectric tube, which provides a parallel electrical field with the jet flow for a long plasma jet, reduces gas temperature, and includes a dielectric layer between the high voltage electrode and treated object, preventing a high increase in current when the plasma jet interacts with materials, which is potential for bio applications. However, two electrodes are not isolated, resulting in a longer distance between them, or sometimes a spark between two electrodes. We found that if two electrodes were immersed inside liquid dielectric materials such as transformer oil, due to the flexible liquid phase, two electrodes were in absolute isolation from ambient air and completely filled with high dielectric materials. Interestingly, this configuration features several advantages for plasma jet generation, such as a long plasma jet, low-temperature plasma, and an effective plasma source.

Here, we summarize our recent development in a cold plasma jet using a DBD configuration with a liquid dielectric to isolate electrodes from ambient air. The DBD plasma jet is a coaxial DBD with two electric rings placed outside a quartz tube; a chamber of transformer oil covers the two electrodes to isolate them from ambient air and completely fill the surroundings with high dielectric materials. This method achieved a short electrode distance, a long plasma jet with low temperature [1], and enabled comfortable electrical analysis [2]. Regarding saving inert plasma gas and controlling plasma chemistry, the coaxial double DBD [3] or multi-bore DBD [4] configuration is suitable for these purposes. Moreover, DBD plasma jet challenges are discussed and suggested for future development.

References

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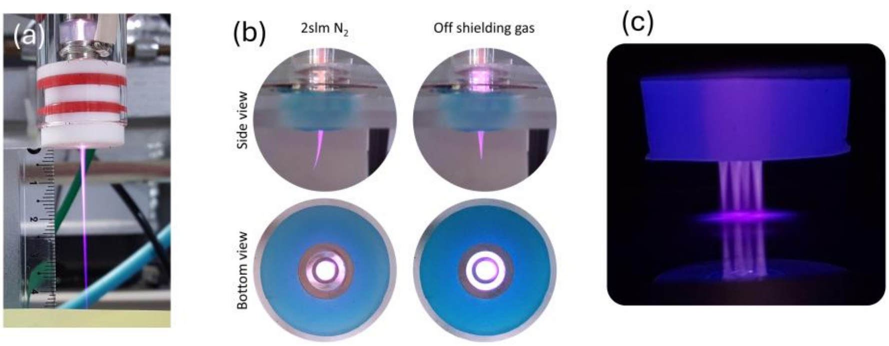

Figure. Photos of plasma discharge by DBD with liquid dielectric to isolation electrodes from ambient air