Understanding the nature of near-anode plasma conditions in DC 1 Atm pressure glows and the role that it may play in plasma self-organization

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DC atmospheric glows have attracted much interest in recent years. The origin of plasma self-organization on both metal and liquid electrodes is not well understood. These discharges with liquid electrodes can also be used to produce nanoparticles efficiently in solution. In this work, we describe electrical and spectroscopic characteristics of DC atmospheric pressure glows. A spatially resolved spectroscopic survey near the plasma-electrode interface is presented. This detailed information on gas temperature and plasma density yields insight into physical processes taking place there and provides a basis for speculation on the origin of the self-organization. The vapor cloud, which often appears around the main plasma column, is postulated to play a role in mass transport and discharge maintenance. Here, we present spectroscopic measurements of this region and comment on its composition and overall origin. Work supported by DOE DE-SC0001939.

1. Introduction

Self-organization occurs in a variety of biological, physical, chemical, and cognitive systems. In plasma physics, self-organization is observed in phenomena ranging from plasmoid formation in low pressure, RF plasmas to large-scale, and magnetized structures observed on the surface of the sun. Of recent interest is the puzzling formation of self-organization patterns on the surface of liquid anodes in 1 ATM DC glows. Shirai [1] documented an array of such patterns over a broad parameter spaced including the variation of gap spacing, current, and sensitivity to feed gas trace oxygen concentration. While these patterns are of academic interest in regards to understanding collective phenomena, the appearance of the patterns may play an important role in the sub-surface liquid phase chemistry, driving convection and inducing thermal gradients.

In many studies to date, salt water is typically used as the electrolyte in these discharges. In this current work, the effect of a different electrolyte—copper sulfate—was investigated. At similar solution conductivities and applied voltages reported previously with salt water, it was found that the self-organization patterns are markedly different. As can be seen in figure 1 which shows a side-by-side comparison between the salt-water pattern and the copper sulfate pattern. A new, complex, was also observed with $CuSO_4$. What role does the electrolyte play in determining the pattern shape? This observation suggests that electrolyte ion mass or perhaps ionization state of solution ions may play a key role in determining overall pattern shape. This dependence has not previously been explored.

Figure 1 depicts another interesting comparison between the salt-water solution and a copper sulfate solution for a DC glow. The transport of ions and electrons as well as the role of electrolytic species to discharge maintenance is not well understood. What is quite apparent however both cases is the appearance of a prominent halo that surrounds the main plasma column. Spectroscopic analysis of the halo suggests that it consists of sodium in the case of the salt electrolyte and copper in the case of the copper sulfate solution. In this case, clearly the solution ions play a role not only in electrolytic processes in solution but also apparently in the gas phase. How does the introduction of these low ionization potential species into the plasma column affect ionization there? Is penning ionization therefore an important process in discharge maintenance? The relationship between this ionic mass transport into the gas phase requires further elucidation.

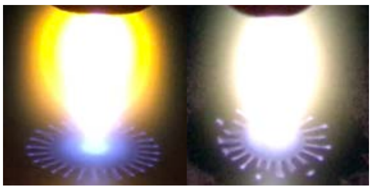

Fig. 1 – Plasma emission clouds image with patterns at 2.2kV, 8mm gap length with 200 sccm He flow. *Note: (L) NaCl solution. (R) $CuSO_4$ solution.*

2. References

[1] N. Shirai, S.Uchida and F. Tochikubo, Plasma Sources Sci. Technol. 23(2014).